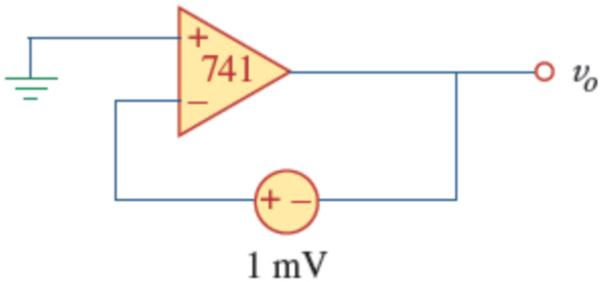
1. value:
10.00 points

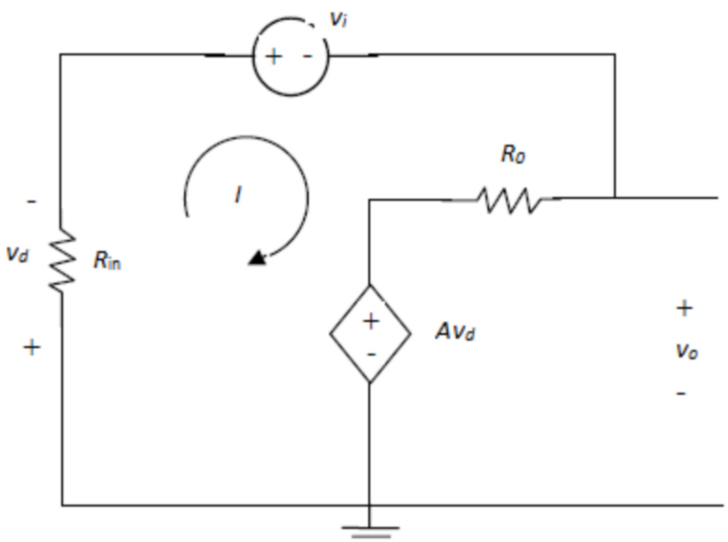
A 741 op amp shown in the circuit given below has an open-loop voltage gain of 70000, an input resistance of 2 MΩ, and an output resistance of 150 Ω. Calculate the output voltage $v_0$ in the op amp circuit.




The output voltage of the op amp is *-0.999986 ± 2%* mV.

**Explanation:**

The formula to find the output voltage is derived as follows:




$(R_0 + R_i)I + v_i + Av_d = 0$

But $v_d = R_iI$

$v_i + (R_o + R_i + R_iA)I = 0$

$$I = \frac{-v_i}{R_o + (1 + A)R_i} \qquad \text{\_\_\_\_\_\_\_\_\_\_(1)}$$

$-Av_d - R_0I + v_o = 0$

$v_o = Av_d + R_oI = (R_o + R_iA)I$

Substituting for $I$ in equation(1),

$$v_o = -\left(\frac{R_o + R_iA}{R_o + (1 + A)R_i}\right)v_i$$

Then, the output voltage is calculated as follows:

$$v_o = -\left(\frac{R_o + R_iA}{R_o + (1 + A)R_i}\right)v_i$$

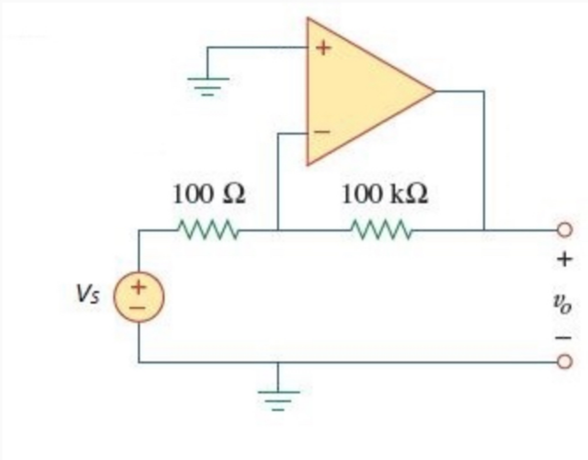
$$v_o = -\left(\frac{150\,\Omega + (2\,\text{M}\Omega \times 70000)}{150\,\Omega + (1 + 70000) \times 2\,\text{M}\Omega}\right) \times 1 \text{ mV}$$

$v_o$ = - 0.999986 mV

The output voltage is - 0.999986 mV.

2. value: **10.00 points**

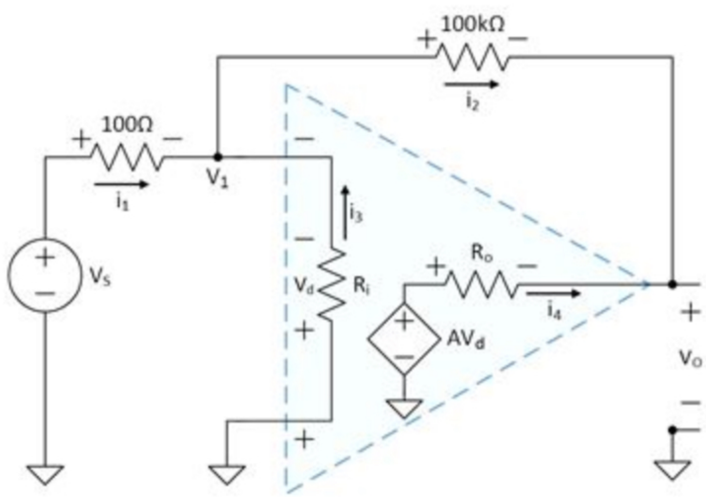
The op amp in the circuit given below has $R_i = 100\ k\Omega$, $R_O = 100\ \Omega$, $v_S = 1\ mV$, and $A = 100{,}000$.




Calculate the output voltage $v_o$ for the given op amp circuit.

The output voltage $v_o$ for the given op amp circuit is -0.99 ± 2% mV.

**Explanation:**




At node V1, $i_1 - i_2 + i_3 = 0A$

$$\frac{V_S - V_1}{100\Omega} - \frac{V_1 - V_O}{100k\Omega} + \frac{-V_1}{R_i} = 0A$$

which leads to $V_1 = \frac{1000V_S + V_O}{1002}$

At node Vo, $i_2 + i_4 = 0A$

$$\frac{V_1 - V_O}{100k\Omega} + \frac{AV_d - V_O}{R_o} = 0A$$

But, $V_d = -V_1$ and $A = 100{,}000$ so

$$V_1 - V_O + 1000(-100{,}000V_1 - V_O) = 0$$

$$V_O = \frac{-99{,}999{,}999}{1001}V_1 = \frac{-99{,}999{,}999}{1001}\left[\frac{1000V_S + V_O}{1002}\right]$$

This gives us $\frac{V_O}{V_S} = -990.07$

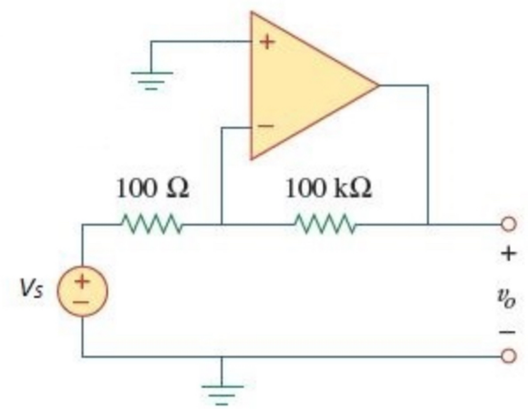
If $V_s = 1$ mV, then $V_o = -0.9901$ mV

The output voltage $v_o$ for the given op amp circuit is -0.9901 mV.

# 3.

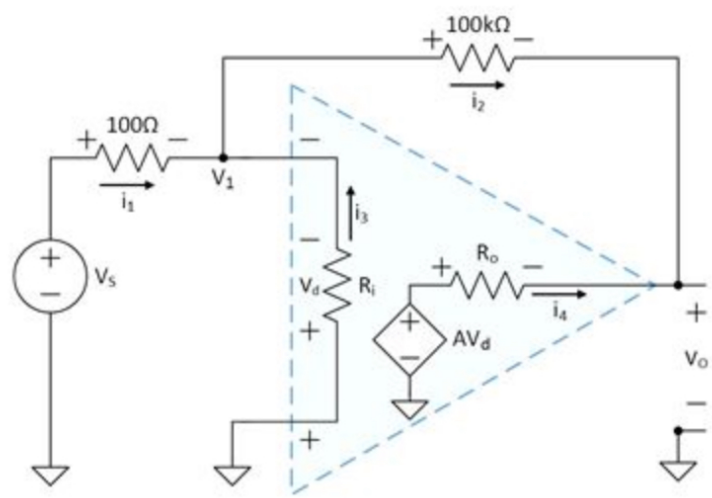
value:
**10.00 points**

The op amp in the circuit given below has $R_i = 100\ \text{k}\Omega$, $R_o = 100\ \Omega$, $v_S = 1$ mV, and $A = 100{,}000$.




Calculate the differential voltage $v_d$.

The differential voltage $v_d$ is 9.90 ± 2% nV.




**Explanation:**

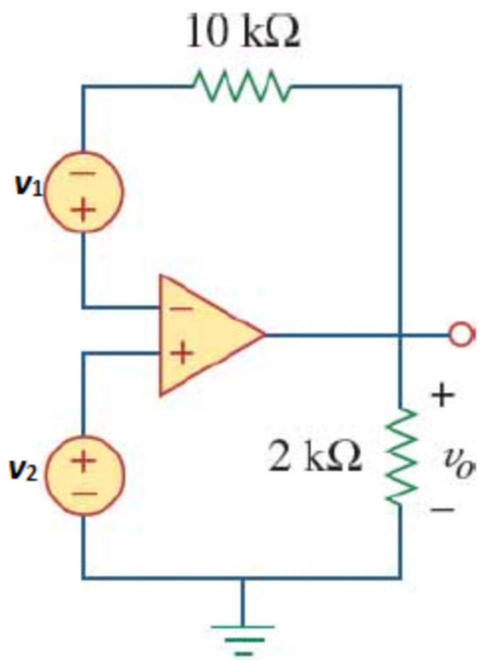
The differential voltage is calculated as follows:
$v_O = Av_d = 100{,}000\ v_d$
Then, $v_d = -\frac{v_o}{10^5} = -\frac{-0.99\ \text{mV}}{10^5} = --9.90\ \text{nV}$.

The differential voltage $v_d$ is — 9.90 nV.

# 4.

value:
10.00 points

Calculate the output voltage of the op amp circuit given below, where $v_1$ = 2.0 V and $v_2$ = 1.4 V.




The output voltage of the op amp circuit is -0.6 ± 2% V.

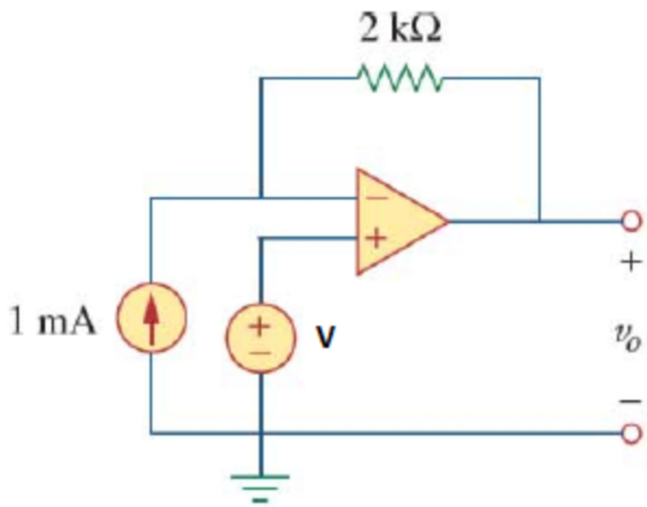
**Explanation:**

The output voltage is calculated as follows:
Since $v_a = v_b$ = 1.4 V and $i_a$ = 0, no current flows through the 10-kΩ resistance.
Using the compensatory circuit concept,
from the given figure we get, $-v_a + 2.0 + v_o = 0$.
$v_o = v_a - 2.0 = 1.4\text{ V} - 2.0\text{ V} = -0.6\text{ V}$

The output voltage of the op amp circuit is - 0.6 V.

5. value:
10.00 points

Find the output voltage $v_o$ for the op amp circuit given below, where $V$ = 12 V.




The output voltage $v_o$ for the given op amp circuit is 10 ± 2% V.

**Explanation:**

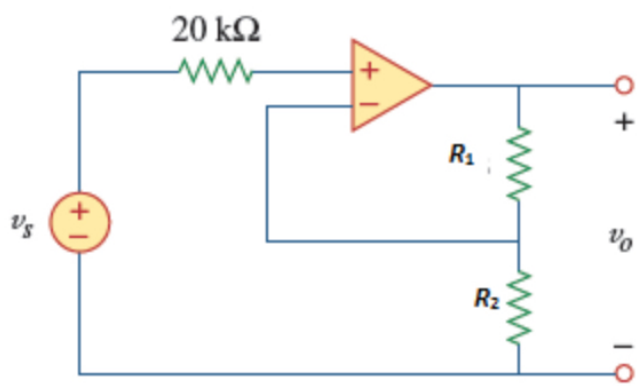
Let $v_a$ and $v_b$ be respectively the voltages at the inverting and the noninverting terminals of the op amp.
$v_a = v_b = 12$ V
At the inverting terminal,
$$1 \text{ mA} = \frac{12 \text{ V} - v_o}{2 \text{ k}\Omega}$$

$v_o = 10$ V

The output voltage $v_o$ for the given op amp circuit is 10 V.

6. value:
10.00 points

Find the voltage gain $v_0/v_s$ of the circuit given below, where $R_1$ = 19 kΩ and $R_2$ = 19 kΩ.




The voltage gain $v_0/v_s$ of the circuit is 2.00 ± 2% .

**Explanation:**

Since no current enters the op amp, the voltage at the input of the op amp is $v_s$.
Hence,

$$v_s = v_o\left(\frac{19\,\mathrm{k\Omega}}{19\,\mathrm{k\Omega}+19\,\mathrm{k\Omega}}\right)$$

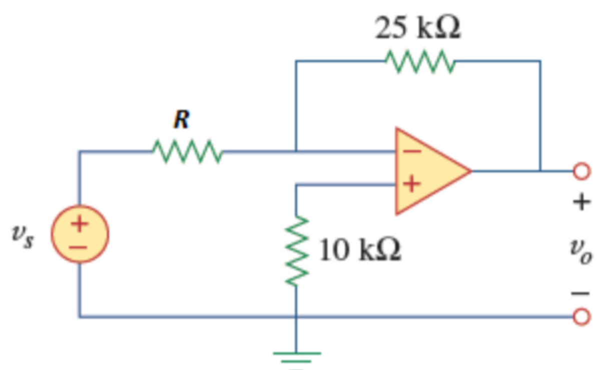
$$\frac{v_o}{v_s} = 2.00$$

The gain $v_0/v_s$ of the circuit is 2.00.

# 7.

value:
10.00 points

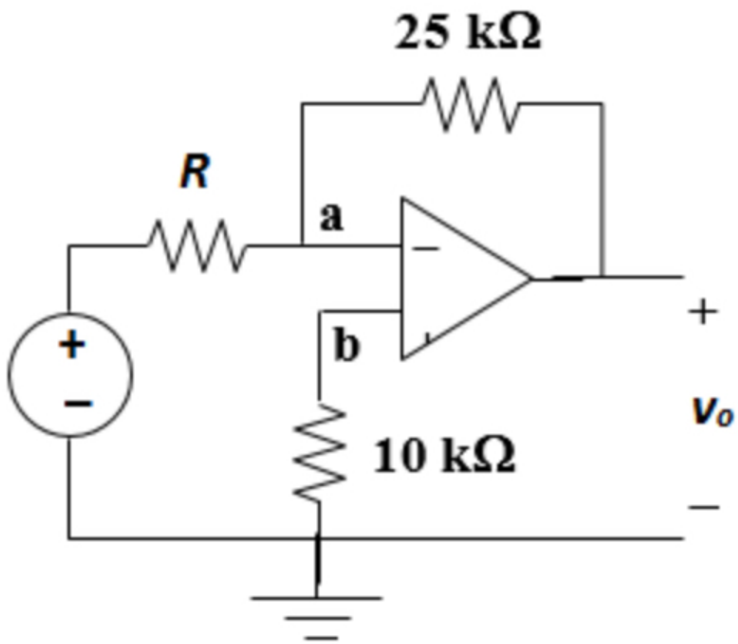
Calculate the voltage ratio $v_0/v_s$ for the op amp circuit given below, where $R$ = 6 kΩ. Assume that the op amp is ideal.




The voltage ratio $v_0/v_s$ for the op amp circuit is *-4.17 ± 2%*.

**Explanation:**

Step 1: Label the unknown nodes in the op amp circuit. Next we write the node equations and then apply the constraint $v_a = v_b$. Finally, solve for $v_o$ in terms of $v_s$.




Step 2:

$\frac{v_a - v_s}{6\,k\Omega} + \frac{v_a - v_0}{25\,k\Omega} + 0 = 0$ and $\frac{v_b - 0}{10\,k\Omega} + 0 = 0$ or $v_b = 0 = v_a$

Thus,

$\frac{-v_s}{6\,k\Omega} + \frac{-v_0}{25\,k\Omega} = 0$

or

$v_o = \frac{-25\,k\Omega}{6\,k\Omega} v_s$

or

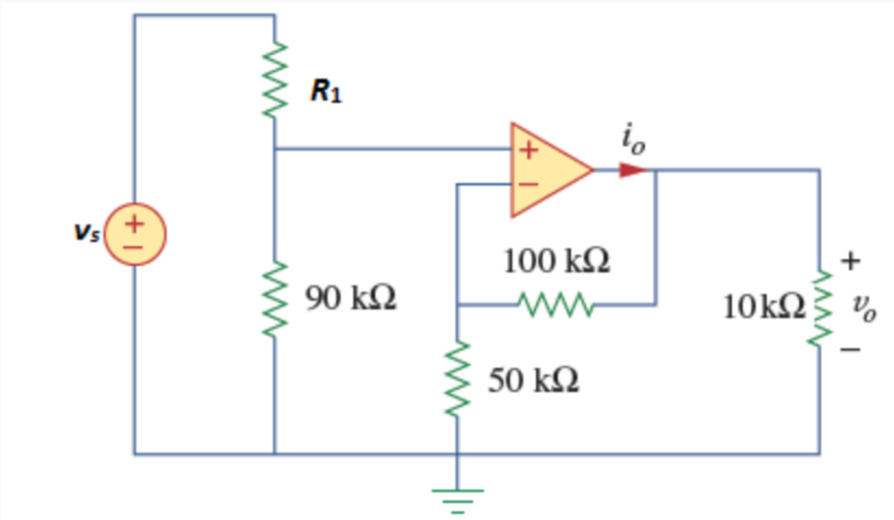
$v_0/v_s$ = - 4.17

The voltage ratio $v_0/v_s$ is - 4.17.

# 8.

value:
10.00 points

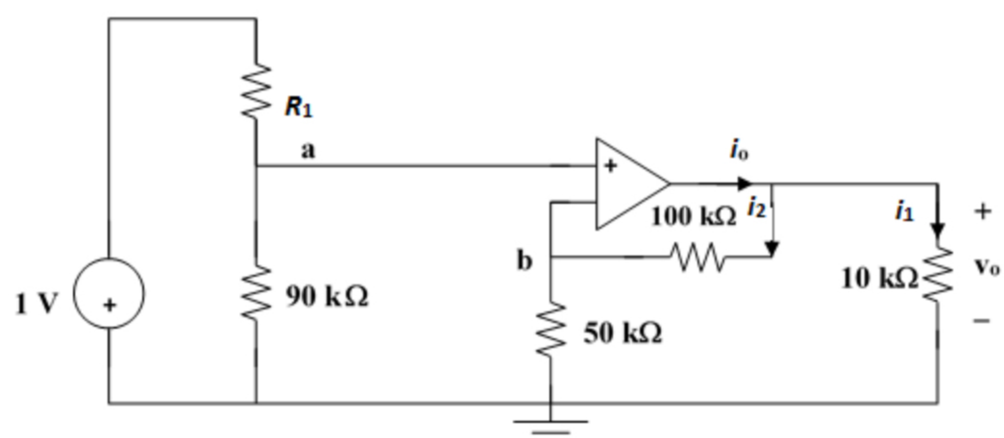
Consider the op amp circuit given below, where $R_1$ = 12 kΩ and $v_s$ = 1 V.




Calculate the output voltage $v_0$ for the given circuit.

The output voltage $v_o$ is 2.65 ± 2% V.

**Explanation:**




By voltage division,

$$v_a = \frac{90\ \text{k}\Omega}{90\ \text{k}\Omega + 12\ \text{k}\Omega} \times 1\ \text{V} = 0.88\ \text{V}$$

$$v_b = \frac{50\ \text{k}\Omega}{50\ \text{k}\Omega + 100\ \text{k}\Omega} = \frac{v_o}{3}$$

But $v_a = v_b \rightarrow \frac{v_o}{3} = 0.88\ \text{V}$

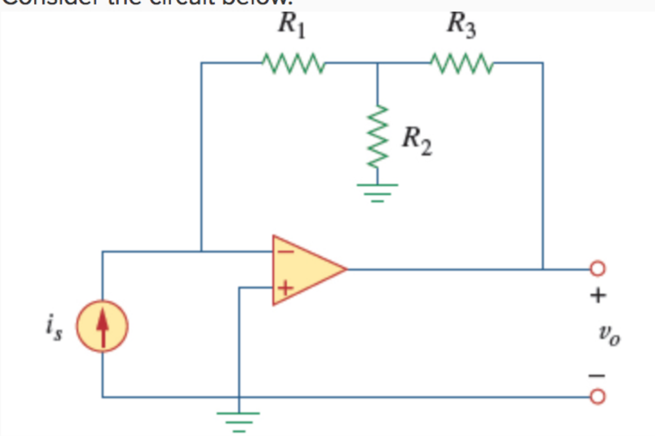
$v_o$ = 2.65 V

The output voltage $v_o$ is 2.65 V.

# 9.

value:
**10.00 points**

Consider the circuit below.




Identify the ratio $\frac{v_0}{i_s}$ in the given op amp circuit.

→ ○ $\frac{v_0}{i_s} = -\left(R_1 + R_3 + \frac{R_1 R_3}{R_2}\right)$

○ $\frac{v_0}{i_s} = -\left(R_1 + R_2 + \frac{R_1}{R_2}\right)$

○ $\frac{v_0}{i_s} = -\left(R_1 + \frac{R_3}{R_1}\right)$

○ $\frac{v_0}{i_s} = -\left(R_2 + R_3 + \frac{R_2 R_3}{R_1}\right)$

**Explanation:**

Let $v_1$ be the voltage at the node where the three resistors meet. Applying KCL at this node gives

$i_s = \frac{v_1}{R_2} + \frac{v_1 - v_o}{R_3} = v_1\left(\frac{1}{R_2} + \frac{1}{R_3}\right) - \frac{v_o}{R_3}$ --------------(1)

At the inverting terminal,

$i_s = \frac{0 - v_1}{R_1}$

$v_1 = -i_s R_1$ ---------------(2)

Combining (1) and (2) leads to

$i_s\left(1 + \frac{R_1}{R_2} + \frac{R_1}{R_3}\right) = -\frac{v_o}{R_3}$

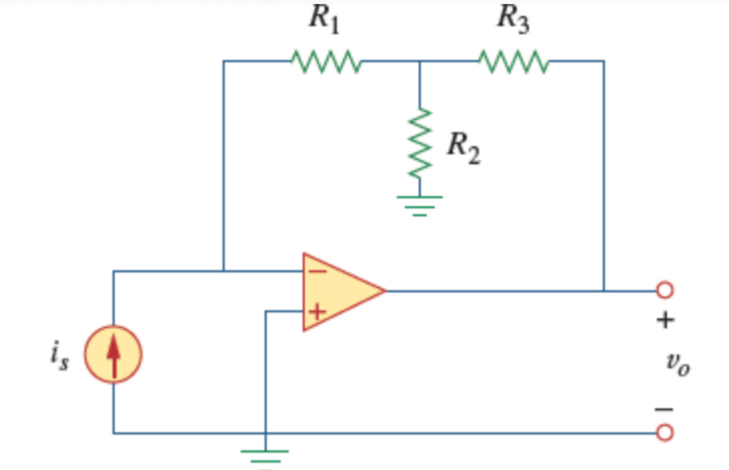
$\frac{v_o}{i_s} = -\left(R_1 + R_3 + \frac{R_1 R_3}{R_2}\right)$

The ratio $\frac{v_o}{i_s} = -\left(R_1 + R_3 + \frac{R_1 R_3}{R_2}\right)$.

# 10.

value:
10.00 points

Consider the circuit below.




Find the value of the ratio $\frac{v_o}{i_s}$ for $R_1$ = 18 kΩ, $R_2$ = 26 kΩ, and $R_3$ = 34 kΩ.

The value of the ratio $\frac{v_o}{i_s}$ = *-75.54 ± 2%* kΩ.

**Explanation:**

The ratio is calculated as follows:

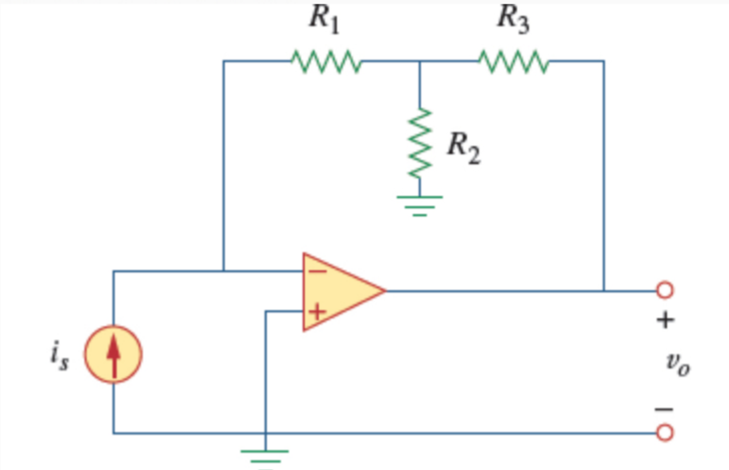
$$\frac{v_0}{i_s} = -\left(\left(18\text{ k}\Omega + 34\text{ k}\Omega\right) + \left(\frac{18\text{ k}\Omega \times 34\text{ k}\Omega}{26\text{ k}\Omega}\right)\right) = -75.54\text{ k}\Omega$$

The value of the ratio $\frac{v_0}{i_s} = -75.54\text{ k}\Omega$.

11.

value:
**10.00 points**

Consider the circuit below.




Identify the ratio $\frac{v_0}{i_s}$ in the given op amp circuit.

→ ◯ $\frac{v_0}{i_s} = -\left(R_1 + R_3 + \frac{R_1 R_3}{R_2}\right)$

◯ $\frac{v_0}{i_s} = -\left(R_1 + R_2 + \frac{R_1}{R_2}\right)$

◯ $\frac{v_0}{i_s} = -\left(R_1 + \frac{R_3}{R_1}\right)$

◯ $\frac{v_0}{i_s} = -\left(R_2 + R_3 + \frac{R_2 R_3}{R_1}\right)$

**Explanation:**

Let $v_1$ be the voltage at the node where the three resistors meet. Applying KCL at this node gives

$i_s = \frac{v_1}{R_2} + \frac{v_1 - v_o}{R_3} = v_1\left(\frac{1}{R_2} + \frac{1}{R_3}\right) - \frac{v_o}{R_3}$ ---------------(1)

At the inverting terminal,

$i_s = \frac{0 - v_1}{R_1}$

$v_1 = -i_s R_1$ ---------------(2)

Combining (1) and (2) leads to

$i_s\left(1 + \frac{R_1}{R_2} + \frac{R_1}{R_3}\right) = -\frac{v_o}{R_3}$

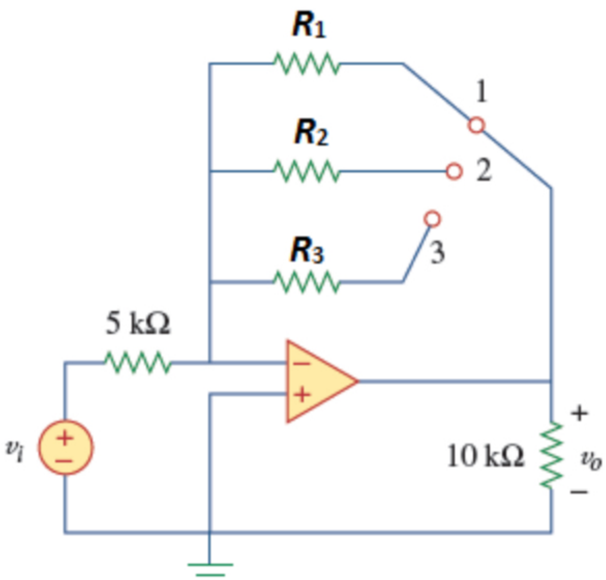
$\frac{v_o}{i_s} = -\left(R_1 + R_3 + \frac{R_1 R_3}{R_2}\right)$

The ratio $\frac{v_o}{i_s} = -\left(R_1 + R_3 + \frac{R_1 R_3}{R_2}\right)$.

# 12.

value:
10.00 points

In the circuit given below, $R_1$ = 18 kΩ, $R_2$ = 80 kΩ, and $R_3$ = 2 MΩ. Calculate the gain $\frac{v_0}{v_i}$ when the switch is in position 1, position 2, and position 3.




The gain $\frac{v_0}{v_i}$ at the position 1 is -3.6 ± 2%.
The gain $\frac{v_0}{v_i}$ at the position 2 is -16.0 ± 2%.
The gain $\frac{v_0}{v_i}$ at the position 3 is -400 ± 2%.

**Explanation:**

The gain is calculated as follows:
Position 1:

$$G = \frac{v_0}{v_i} = -\frac{R_f}{R_i} = -\frac{18\text{ k}\Omega}{5\text{k}\Omega} = \text{-3.6}$$

Position 2:

$$G = \frac{v_0}{v_i} = -\frac{80\text{ k}\Omega}{5\text{k}\Omega} = \text{- 16.0}$$

Position 3:

$$G = \frac{v_o}{v_i} = -\frac{2\text{ M}\Omega}{5\text{ k}\Omega} = \text{- 400}$$

The gain $\frac{v_0}{v_i}$ at the position 1 is - 3.6.
The gain $\frac{v_0}{v_i}$ at the position 2 is - 16.0.
The gain $\frac{v_0}{v_i}$ at the position 3 is - 400.