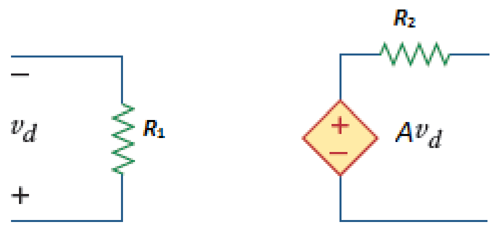
The equivalent model of a certain op amp is shown in the figure given below, where R_1 = 2.8 MΩ, R_2 = 39 Ω, and A = 10 × 10^4.



References

Section Break Difficulty: Easy Learning Objective: Understand how real operational amplifiers (op amps) function.

1. Award: **10.00 points**

Calculate the input resistance of the given circuit.

The input resistance of the circuit is *2.8 ± 2%* MΩ.

Explanation:

The input resistance is the Thevenin equivalent resistance seen at the input terminals, that is R_{in} = 2.8 MΩ.

The input resistance of the circuit is 2.8 MΩ.

Hints

Hint #1

References

Worksheet Difficulty: Easy Learning Objective: Understand how real operational amplifiers (op amps) function.

2. Award: **10.00 points**

Calculate the output resistance of the given circuit.

The output resistance of the given circuit is *39 ± 2%* Ω.

Explanation:

The output resistance is the Thevenin equivalent resistance seen at the output terminals, that is R_{out} = 39 Ω.

The output resistance of the given circuit is 39 Ω.

Hints

Hint #1

References

Worksheet Difficulty: Easy Learning Objective: Understand how real operational amplifiers (op amps) function.

3. Award: **10.00 points**

The open-loop gain of an op amp is 75000. Calculate the output voltage when there are inputs of +10 μV on the inverting terminal and +20 μV on the noninverting terminal.

The output voltage is *750 ± 2%* mV.

Explanation:

The output voltage is calculated as follows:
$v_o = Av_d = A(v_2 - v_1) = 75000 \times (20\ \mu V - 10\ \mu V) = 750$ mV

The output voltage is 750 mV.

Hints

Hint #1

References

Worksheet Difficulty: Medium Learning Objective: Understand how real operational amplifiers (op amps) function.

4. Award: **10.00 points**

The output voltage of an op amp is -1 V when the noninverting input is 1 mV. If the open-loop gain of the op amp is 2 × 10^6, what is the inverting input?

The inverting input of the op amp is *1.000 ± 2%* mV.

Explanation:

The inverting input of the op amp is calculated as follows:
$v_0 = Av_d = A(v_2 – v_1)$
$v_2 - v_1 = \frac{v_0}{A} = \frac{-1}{2 \times 10^6} = -\ 0.50 \mu V$

$v_2 – v_1$ = - 0.50 μV = - 0.000 mV
1 mV – v_1 = - 0.000 mV
v_1 = 1 mV – (- 0.000) = 1.000 mV

The inverting input of the op amp is 1.000 mV.

Hints

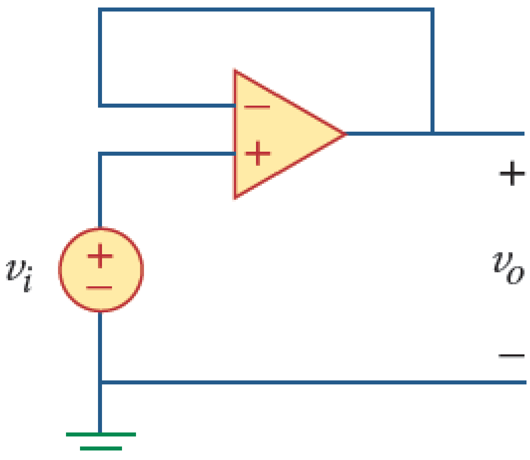
Hint #1

References

Worksheet Difficulty: Medium Learning Objective: Understand how real operational amplifiers (op amps) function.

5. Award: **10.00 points**

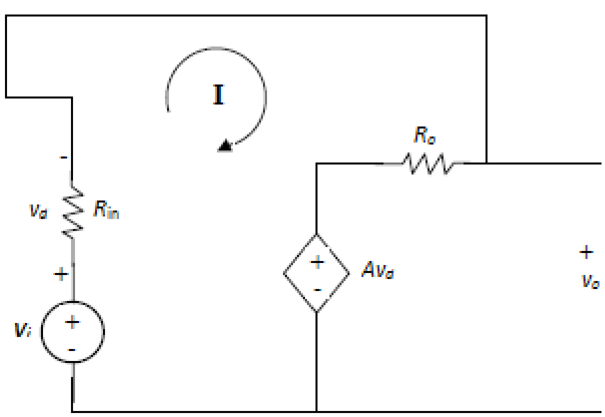
For the op amp circuit given below, the op amp has an open-loop gain of 90000, an input resistance of 14 kΩ, and an output resistance of 115 Ω. Find the voltage gain v_0/v_i using the nonideal model of the op amp.



The voltage gain v_0/v_i of the op amp is *0.999989 ± 2%*.

Explanation:

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



$-v_i + Av_d + (R_i + R_0)I = 0$
But $v_d = R_iI$
$-v_i + (R_i + R_o + R_iA)\ I = 0$
$I = \frac{v_I}{R_o + (1 + A)R_i}$

$-Av_d - R_0I + v_0 = 0$
$v_o = Av_d + R_oI = (R_o + R_iA)\ I = \frac{(R_o + R_iA)v_i}{R_o + (1 + A)R_i}$

The voltage gain is calculated as follows:
$\frac{v_o}{v_i} = \frac{R_o + R_iA}{R_o + (1 + A)R_i} = \frac{115\Omega + (14\ \text{k}\Omega \times 90000)}{115\ \Omega + ((1 + 90000) \times 14\ \text{k}\Omega)} = \mathbf{0.999989}$

The voltage gain is 0.999989.

Hints

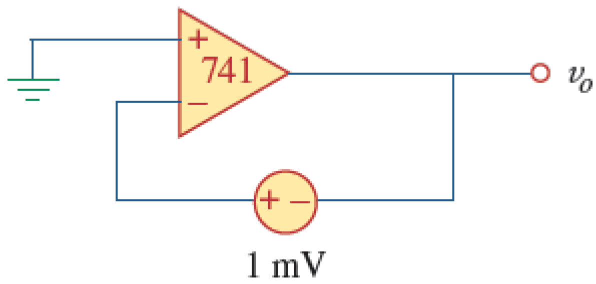
Hint #1

References

Worksheet	Difficulty: Medium	Learning Objective: Understand how real operational amplifiers (op amps) function.

6. Award: **10.00 points**

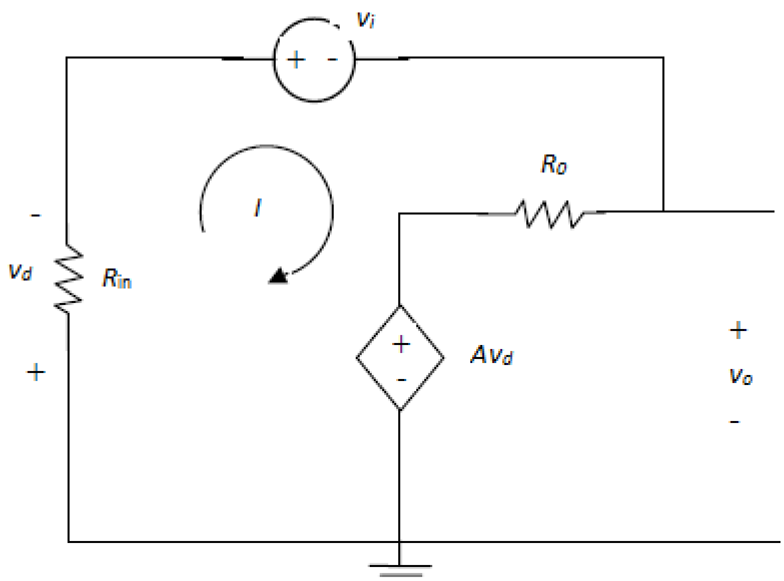
A 741 op amp shown in the circuit given below has an open-loop voltage gain of 80000, an input resistance of 2 MΩ, and an output resistance of 110 Ω. Calculate the output voltage v_0 in the op amp circuit.



The output voltage of the op amp is *-0.999988 ± 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 $v_d = R_iI$

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

$I = \frac{-v_i}{R_o + (1 + A)R_i}$ ____________(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:

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

$$v_o = -\left(\frac{110\,\Omega + (2\,\text{M}\Omega \times 80000)}{110\,\Omega + (1+80000)\times 2\,\text{M}\Omega}\right)\times 1\ \text{mV}$$

v_o = - 0.999988 mV

The output voltage is - 0.999988 mV.

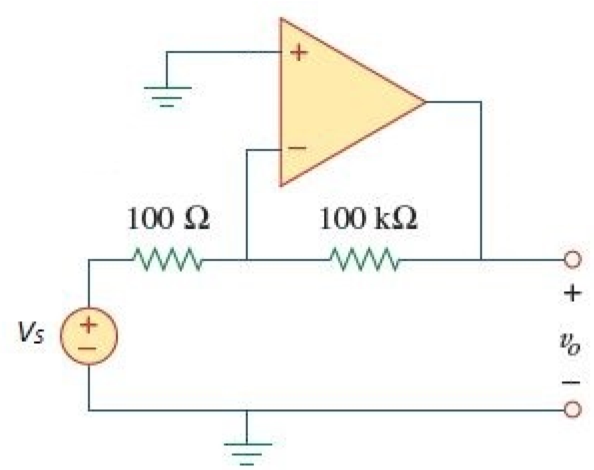
Hints

Hint #1

References

Worksheet Difficulty: Medium Learning Objective: Understand how real operational amplifiers (op amps) function.

The op amp in the circuit given below has R_i = 100 kΩ, R_0 = 100 Ω, v_S = 1 mV, and A = 100,000.



References

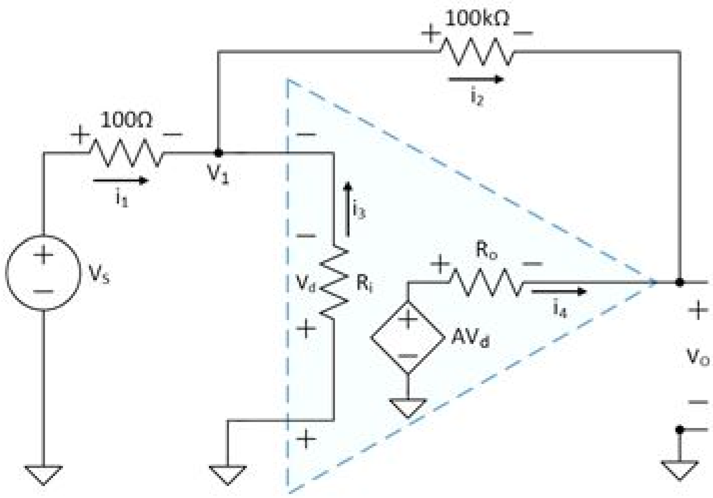
Section Break Difficulty: Medium Learning Objective: Understand how real operational amplifiers (op amps) function.

7. Award: **10.00 points**

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 V$_1$, $i_1 - i_2 + i_3 = 0\text{A}$

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

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

At node V$_o$, $i_2 + i_4 = 0\text{A}$

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

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.

Hints

Hint #1

References

Worksheet Difficulty: Medium Learning Objective: Understand how real operational amplifiers (op amps) function.

8.

Award: **10.00 points**

Calculate the differential voltage v_d.

The differential voltage v_d is 9.90 ± 2% nV.

Explanation:

The differential voltage is calculated as follows:
$v_0 = Av_d = 100{,}000\ v_d$
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.

Hints

Hint #1

References

Worksheet Difficulty: Medium Learning Objective: Understand how real operational amplifiers (op amps) function.

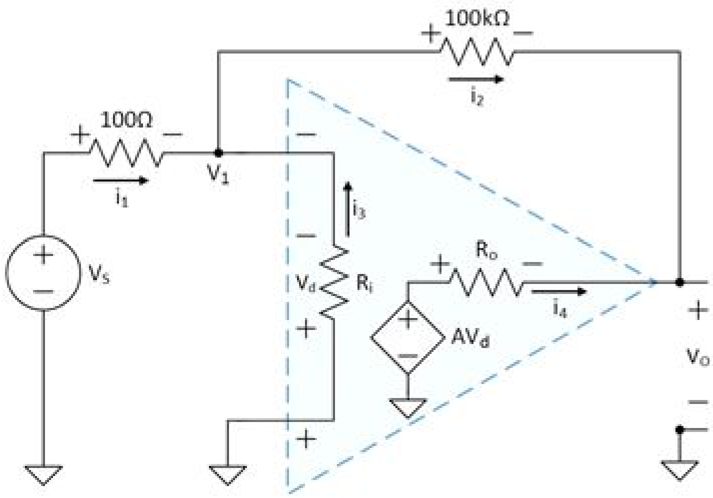
9.

Award: **10.00 points**

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 V_1, $i_1 - i_2 + i_3 = 0\text{A}$

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

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

At node V_o, $i_2 + i_4 = 0\text{A}$

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

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.

Hints

Hint #1

References

Worksheet Difficulty: Medium Learning Objective: Understand how real operational amplifiers (op amps) function.

10. Award: **10.00 points**

Calculate the differential voltage v_d.

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

Explanation:

The differential voltage is calculated as follows:
$v_0 = Av_d = 100{,}000\, v_d$
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.

Hints

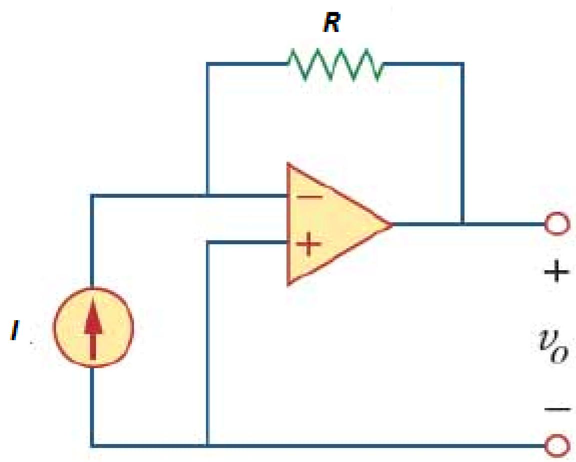
Hint #1

References

Worksheet Difficulty: Medium Learning Objective: Understand how real operational amplifiers (op amps) function.

11. Award: **10.00 points**

Calculate the output voltage v_o for the op amp circuit given below, where I = 1 mA and R = 3 kΩ. (Assume ideal op amp)



The output voltage v_o for the given op amp circuit is *-3.0 ± 2%* V.

Explanation:

If v_a and v_b are the voltages at the inverting terminal and noninverting terminals of the op amp,
$v_a = v_b = 0$
$1 \text{ mA} = \frac{0 - v_o}{3 \text{ k}\Omega}$

v_0 = - 3.00 V

The output voltage v_o for the given op amp circuit is - 3.00 V.

Hints

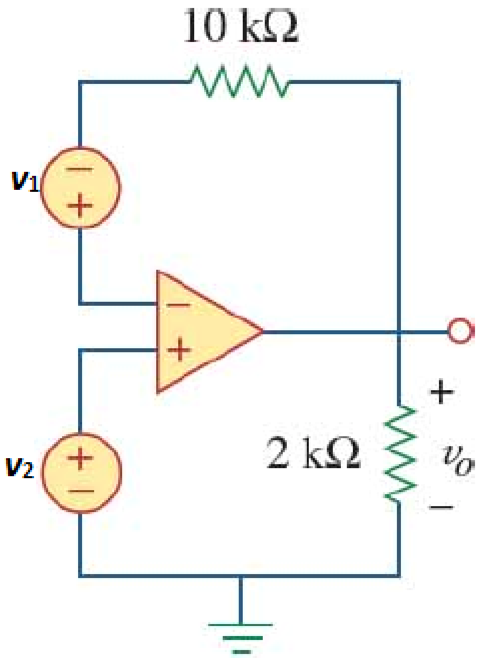
Hint #1

References

Worksheet Difficulty: Easy Learning Objective: Understand that ideal op amps function nearly identical to real ones and that they can be used to effectively model them in a variety of circuit applications.

12. Award: **10.00 points**

Calculate the output voltage of the op amp circuit given below, where v_1 = 2.3 V and v_2 = 1.5 V.



The output voltage of the op amp circuit is -0.8 ± 2% V.

Explanation:

The output voltage is calculated as follows:
Since $v_a = v_b$ = 1.5 V and i_a = 0, no current flows through the 10-kΩ resistance.
Using the compensatory circuit concept,
from the given figure we get, $-v_a + 2.3 + v_o = 0$.
$v_o = v_a - 2.3$ = 1.5 V – 2.3 V = - 0.8 V

The output voltage of the op amp circuit is - 0.8 V.

Hints

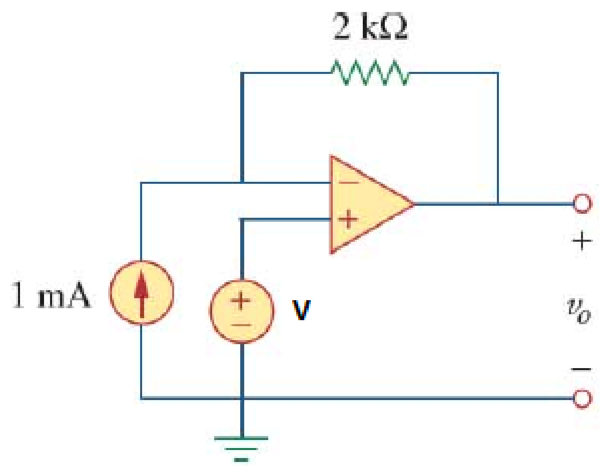
Hint #1

References

Worksheet Difficulty: Easy Learning Objective: Understand that ideal op amps function nearly identical to real ones and that they can be used to effectively model them in a variety of circuit applications.

13. Award: **10.00 points**

Find the output voltage v_o for the op amp circuit given below, where $V = 11$ V.



The output voltage v_o for the given op amp circuit is *9 ± 2%* V.

Explanation:

Let v_a and v_b be respectively the voltages at the inverting and the noninverting terminals of the op amp.

$v_a = v_b = 11$ V

At the inverting terminal,

$$1 \text{ mA} = \frac{11 \text{ V} - v_o}{2 \text{ k}\Omega}$$

$v_o = 9$ V

The output voltage v_o for the given op amp circuit is 9 V.

Hints

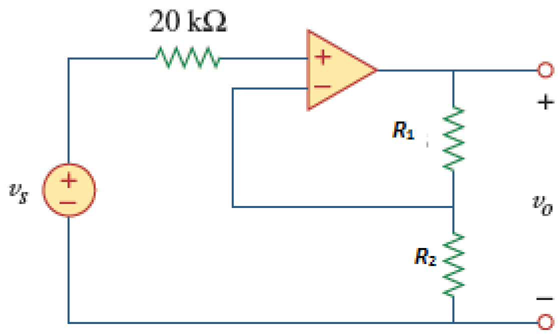
Hint #1

References

Worksheet | Difficulty: Easy | Learning Objective: Understand that ideal op amps function nearly identical to real ones and that they can be used to effectively model them in a variety of circuit applications.

14. Award: **10.00 points**

Find the voltage gain v_0/v_s of the circuit given below, where R_1 = 17 kΩ and R_2 = 14 kΩ.



The voltage gain v_0/v_s of the circuit is *2.21 ± 2%*.

Explanation:

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

$$v_s = v_o\left(\frac{14\,\text{k}\Omega}{17\,\text{k}\Omega + 14\,\text{k}\Omega}\right)$$

$$\frac{v_o}{v_s} = 2.21$$

The gain v_0/v_s of the circuit is 2.21.

Hints

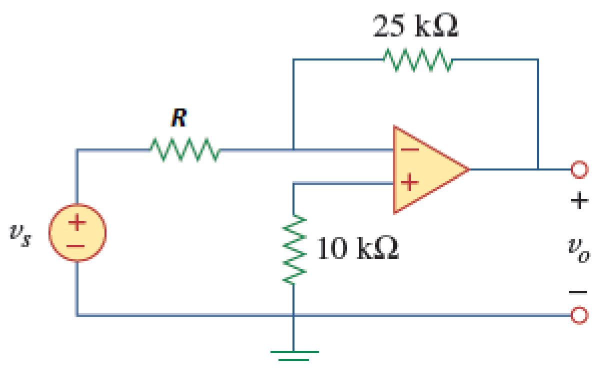
Hint #1

References

Worksheet Difficulty: Medium Learning Objective: Understand that ideal op amps function nearly identical to real ones and that they can be used to effectively model them in a variety of circuit applications.

15. Award: **10.00 points**

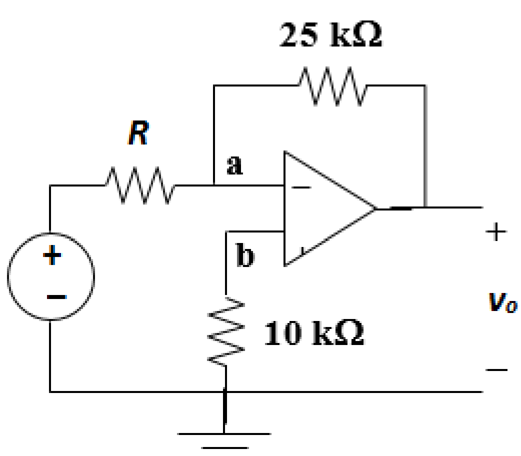
Calculate the voltage ratio v_0/v_s for the op amp circuit given below, where R = 11 kΩ. Assume that the op amp is ideal.



The voltage ratio v_0/v_s for the op amp circuit is -2.27 ± 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:
$\frac{v_a - v_s}{11\,\text{k}\Omega} + \frac{v_a - v_0}{25\,\text{k}\Omega} + 0 = 0$ and $\frac{v_b - 0}{10\text{k}\Omega} + 0 = 0$ or $v_b = 0 = v_a$

Thus,
$$\frac{-v_s}{11\,\text{k}\Omega} + \frac{-v_0}{25\text{k}\Omega} = 0$$

or
$$v_o = \frac{-25\,\text{k}\Omega}{11\,\text{k}\Omega} v_s$$

or
v_0/v_s = - 2.27

The voltage ratio v_0/v_s is - 2.27.

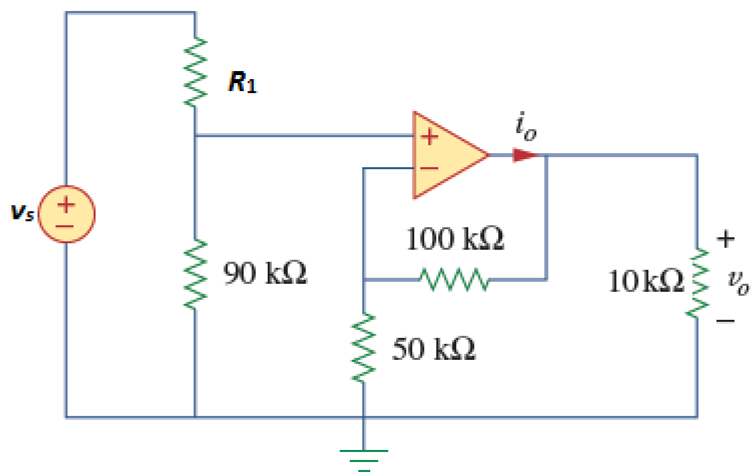
Hints

Hint #1

References

Worksheet Difficulty: Medium Learning Objective: Understand that ideal op amps function nearly identical to real ones and that they can be used to effectively model them in a variety of circuit applications.

Consider the op amp circuit given below, where R_1 = 19 kΩ and v_s = 1 V.



References

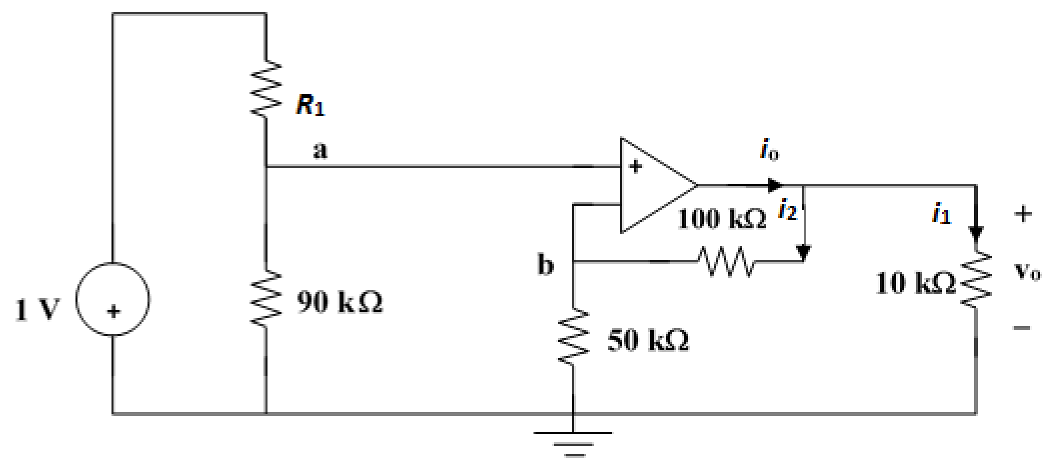
Section Break Difficulty: Medium Learning Objective: Understand that ideal op amps function nearly identical to real ones and that they can be used to effectively model them in a variety of circuit applications.

16. Award: **10.00 points**

Calculate the output voltage v_0 for the given circuit.

The output voltage v_o is *2.48 ± 2%* V.

Explanation:



By voltage division,

$$v_a = \frac{90\ \text{k}\Omega}{90\ \text{k}\Omega + 19\ \text{k}\Omega} \times 1\ \text{V} = 0.83\ \text{V}$$

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

But $v_a = v_b \rightarrow \frac{v_o}{3} = 0.83\ \text{V}$

v_o = 2.48 V

The output voltage v_o is 2.48 V.

Hints

Hint #1

References

Worksheet Difficulty: Medium Learning Objective: Understand that ideal op amps function nearly identical to real ones and that they can be used to effectively model them in a variety of circuit applications.

17. Award: **10.00 points**

Calculate the output current in the circuit.

The output current in the circuit is *264.22 ± 2%* μA.

Explanation:

The output current is calculated as follows:

$$i_o = i_1 + i_2 = \frac{v_0}{10\ \text{k}\Omega} + \frac{v_0}{50\ \text{k}\Omega + 100\ \text{k}\Omega} = \frac{2.48\ \text{V}}{10\ \text{k}\Omega} + \frac{2.48\ \text{V}}{50\ \text{k}\Omega + 100\ \text{k}\Omega} = \mathbf{264.22}\ \mu\mathbf{A}$$

The output current in the circuit is 264.22 μA.

Hints

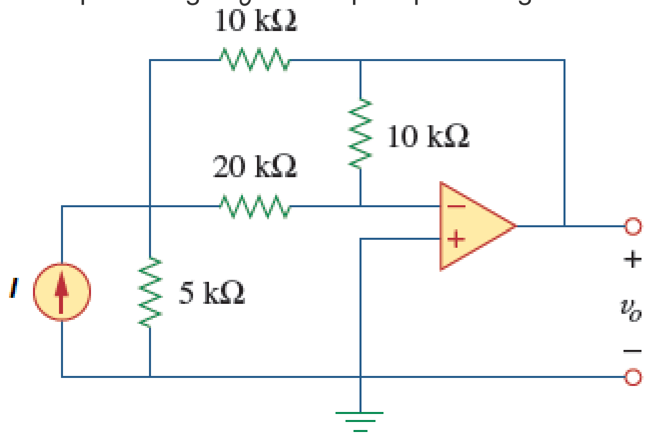
Hint #1

References

Worksheet	Difficulty: Medium	Learning Objective: Understand that ideal op amps function nearly identical to real ones and that they can be used to effectively model them in a variety of circuit applications.

18. Award: **10.00 points**

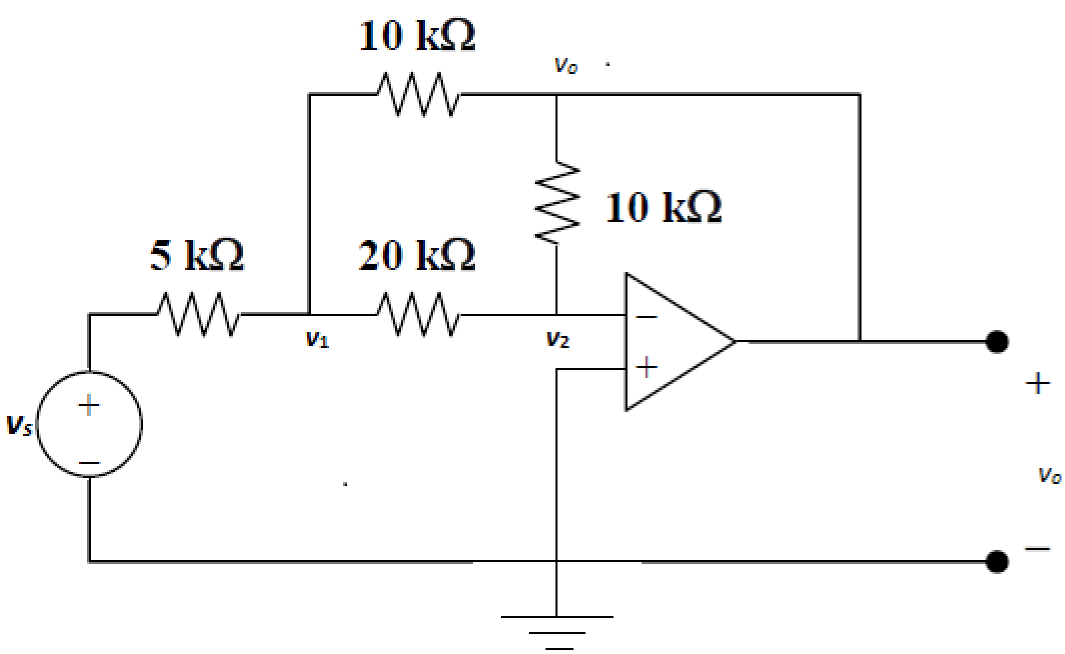
Determine the output voltage v_o in the op amp circuit given below, where I = 7 mA.



The output voltage v_o is *-8.75 ± 2%* V.

Explanation:

The transformation of a current source to a voltage source is shown below, where v_S = 35 V.



At node 1,
$$\frac{35\text{ V} - v_1}{5\text{ k}\Omega} = \frac{v_1 - v_2}{20\text{ k}\Omega} + \frac{v_1 - v_o}{10\text{ k}\Omega}$$

But v_2 = 0. Hence, 140 V – $4v_1$ = v_1 + $2v_1$ – $2v_o$

140 V = $7v_1$ – $2v_o$ --------- (1)

At node 2, $\frac{v_1 - v_2}{20\text{ k}\Omega} = \frac{v_2 - v_o}{10\text{ k}\Omega}$, v_2 = 0 or v_1 = $-2v_o$ ------(2)

From (1) and (2), 140 = $-14v_o$ – $2v_o$

v_o = - 8.75 V

The output voltage is - 8.75 V.

Hints

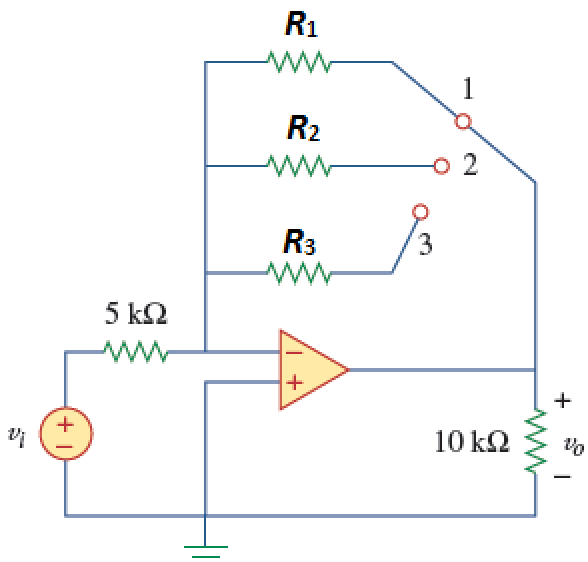
Hint #1

References

Worksheet	Difficulty: Medium	Learning Objective: Understand that ideal op amps function nearly identical to real ones and that they can be used to effectively model them in a variety of circuit applications.

19. Award: **10.00 points**

In the circuit given below, R_1 = 20 kΩ, R_2 = 66 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 *-4.0 ± 2%*.
The gain $\frac{v_0}{v_i}$ at the position 2 is *-13.2 ± 2%*.
The gain $\frac{v_0}{v_i}$ at the position 3 is *-400 ± 2%*.

Explanation:

The gain is calculated as follows:
Position 1:
$$G = \frac{v_0}{v_i} = -\frac{R_f}{R_i} = -\frac{20\,\text{k}\Omega}{5\text{k}\Omega} = \text{-4.0}$$

Position 2:
$$G = \frac{v_0}{v_i} = -\frac{66\,\text{k}\Omega}{5\,\text{k}\Omega} = \text{- 13.2}$$

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 - 4.0.
The gain $\frac{v_0}{v_i}$ at the position 2 is - 13.2.
The gain $\frac{v_0}{v_i}$ at the position 3 is - 400.

Hints

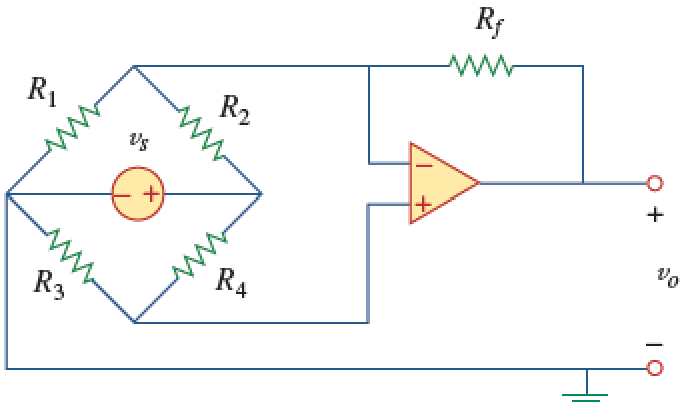
Hint #1

References

Worksheet	Difficulty: Medium	Learning Objective: Understand how the basic inverting op amp is the workhorse of the op amp family.

20. Award: **10.00 points**

In the circuit given below, find k in the voltage transfer function $v_O = kv_S$.



- $k = \left[\left(\frac{1}{R_1} - \frac{1}{R_2} - \frac{1}{R_F}\right)\left(\frac{R_3}{R_3+R_4}\right) + \frac{1}{R_2}\right]$
- $k = R_f\left(\left(\frac{R_3}{R_1} + \frac{R_3}{R_f} + \frac{R_4}{R_2}\right)\left(\frac{R_3}{R_3+R_4}\right) - \frac{1}{R_1}\right)$
- $k = R_f\left(\left(\frac{R_3}{R_1} - \frac{R_3}{R_f} + \frac{R_4}{R_2}\right)\left(\frac{R_3+R_4}{R_3}\right) + \frac{1}{R_2}\right)$
- → $k = R_F\left[\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_F}\right)\left(\frac{R_3}{R_3+R_4}\right) - \frac{1}{R_2}\right]$

From the figure, $v_1 = v_2$.
Node 1 is the inverting input and node 2 is the non-inverting input.
Applying KCL at node 1 gives
$\frac{v_o - v_1}{R_F} = \frac{v_1 - v_s}{R_2} + \frac{v_1}{R_1}$ ------------(1)

Applying KCL at node 2 gives
$\frac{0 - v_2}{R_3} + \frac{v_s - v_2}{R_4} = 0 \rightarrow v_1 = \frac{R_3}{R_3 + R_4} v_s$ --------------(2)

Substituting (2) into (1) yields
$\frac{v_o}{R_F} = v_1\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_F}\right) - \frac{v_s}{R_2}$

Therefore,
$\frac{v_0}{v_s} =$
$k = R_F\left[\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_F}\right)\left(\frac{R_3}{R_3+R_4}\right) - \frac{1}{R_2}\right]$

The expression for $k = R_F\left[\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_F}\right)\left(\frac{R_3}{R_3+R_4}\right) - \frac{1}{R_2}\right]$
.

Hints

Hint #1

Hint #2

References

Multiple Choice	Difficulty: Medium	Learning Objective: Understand how the basic noninverting op amp works and how they can be analyzed in electrical circuit applications.