Kirchoff's Circuit Laws

Classroom Problems & Solutions

KIRCHOFF'S LAW for Current Intensity (I): *(1st Law)*

In **Series** Circuits: the current is the same at every point in the circuit.

$$I_{S\ \text{SERIES}} = I_1 = I_2 = I_3 = I_4 = \ldots$$

In **Parallel** Circuits: the current from the battery/source equals the sum of the current intensities through each of the branch.

$$I_{S\ \text{PARALLEL}} = I_1 + I_2 + I_3 + I_4 + \ldots$$

KIRCHOFF'S LAW for Potential Difference (V): *(2nd Law)*

In **Series** Circuits: The Potential Difference across the battery/source is equal to the sum of individual Potential Differences across the individual resistors.

$$V_{s_{SERIES}} = V_1 + V_2 + V_3 + V_4 + \cdots$$

In **Parallel** Circuits: The Potential Difference across the battery/source is the same as the potential difference across each branch.

$$V_{s_{PARALLEL}} = V_1 = V_2 = V_3 = V_4 = \cdots$$

USING KIRCHOFF'S LAWS AND OHM'S LAW WE CAN NOW SOLVE VARIOUS CIRCUIT PROBLEMS

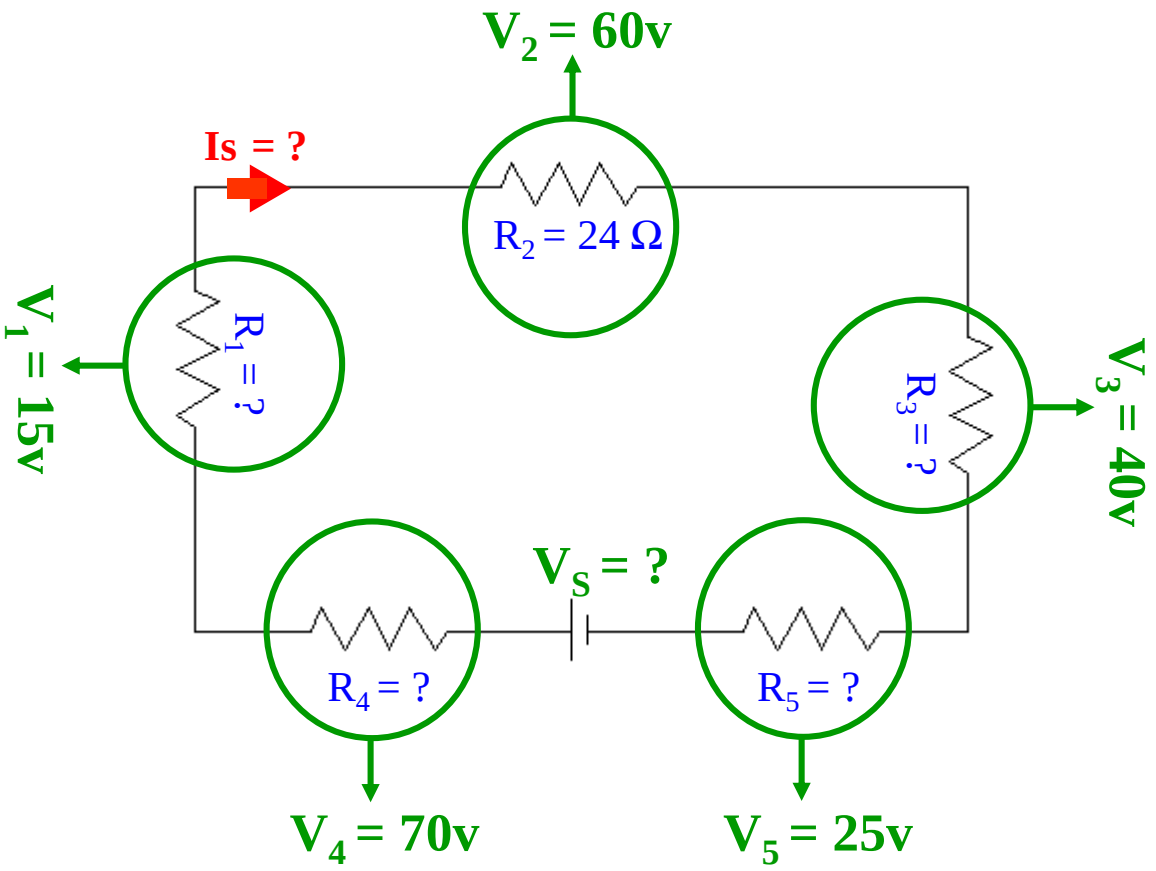
Recall:

$$R = \frac{V}{I} \rightarrow IR = V \rightarrow I = \frac{V}{R}$$

Kirchoff's Laws Problems:

Ex:1

The following series circuit contains 5 resistors. The voltages across each resistor is given and the value of one resistor is shown. Using the information provided on the diagram determine the Potential Difference (Vs) and the Total Current (Is) from the power supply.



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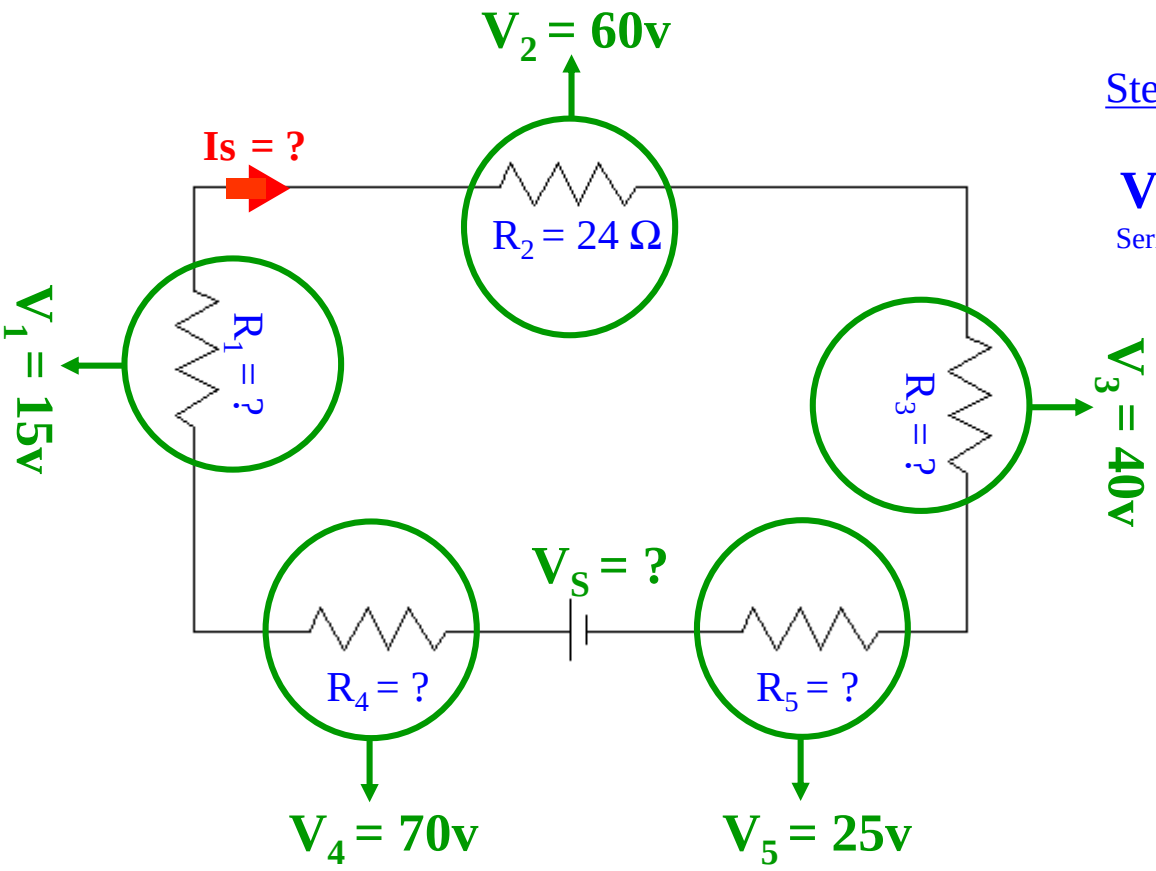

Step:1

$$V_S = V_1 + V_2 + V_3 + V_4 + V_5 \quad \text{(Series)}$$

$$V_S = 15 + 60 + 40 + 70 + 25$$

$$\boxed{V_S = 210\ V}$$

(In series voltages are added for total)

Kirchoff's Laws Problems:

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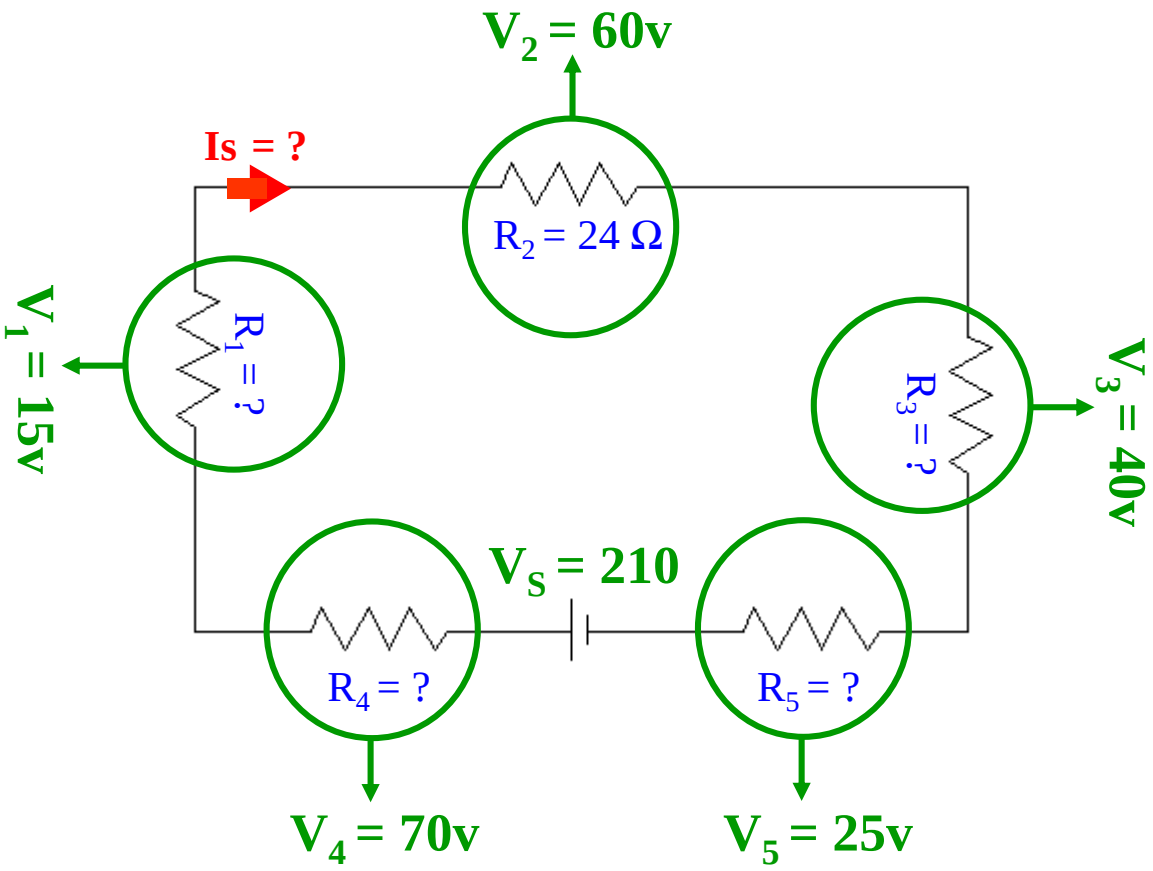


Step:2 $I_2 = \frac{V_2}{R_2}$

$I_2 = \frac{60}{24}$

$I_2 = 2.5A$

Step:3

$I_S = I_1 = I_2 = I_3 = I_4 = I_5$

Series

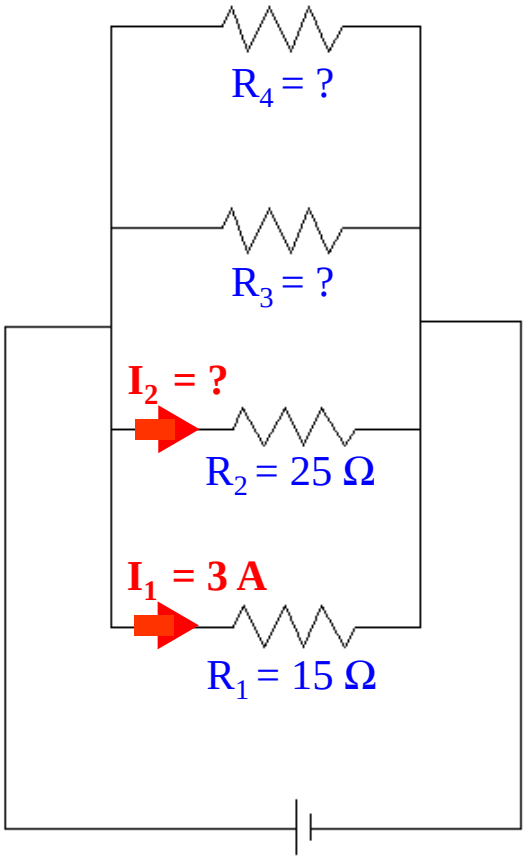
$I_S = 2.5A$

(same current everywhere in series)

Kirchoff's Laws Problems:

Ex:2

The following parallel circuit contains 4 resistors. Using the information provided on the diagram determine the Potential Difference across R_4 and the Current flowing through R_2.



Kirchoff's Laws Problems:

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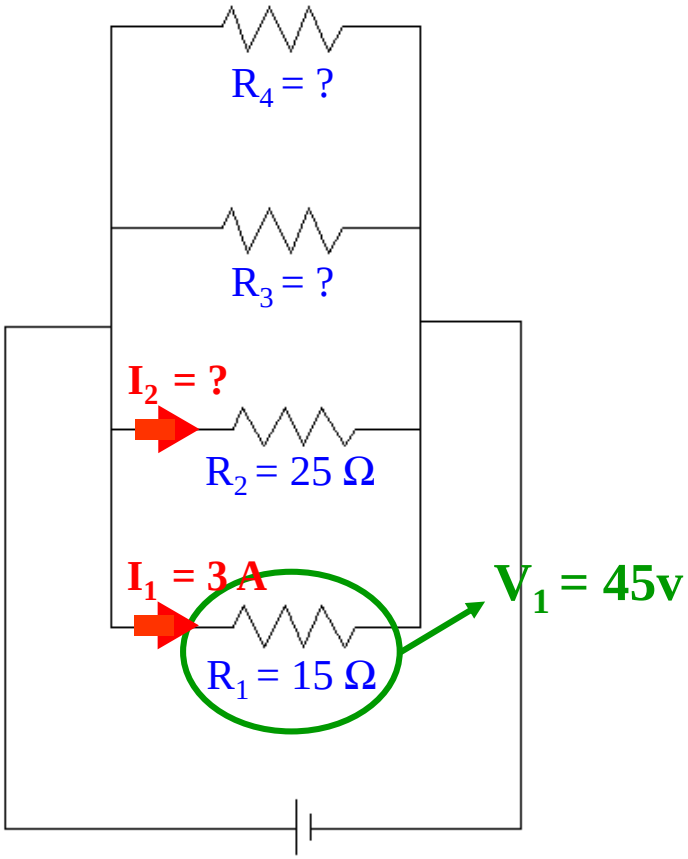


Step:1

$$V_1 = I_1R_1$$

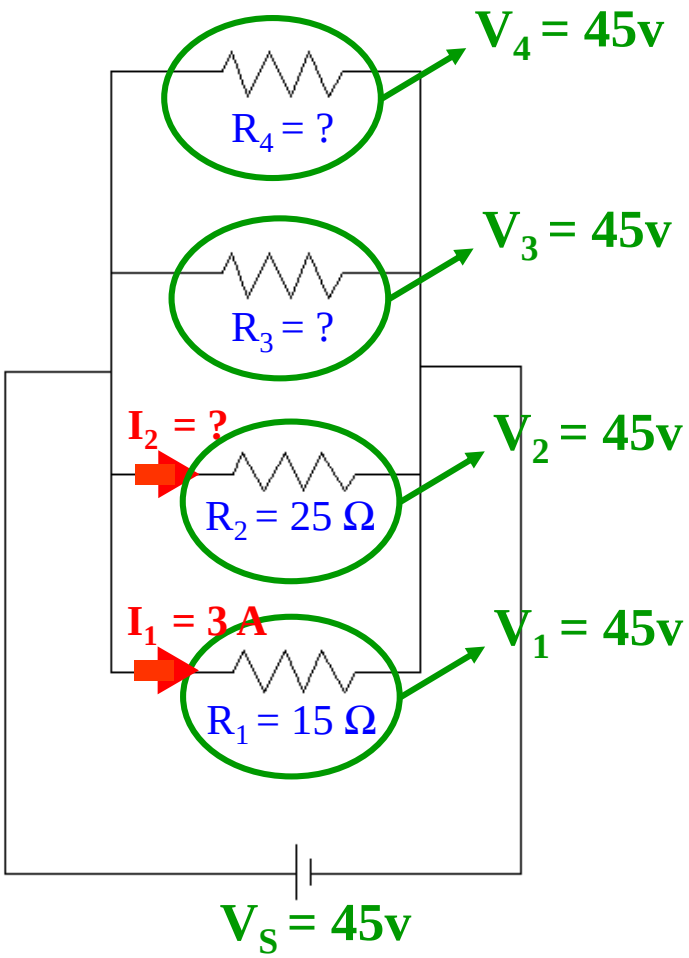
$$V_1 = 3\ (15)$$

$$V_1 = 45\ V$$

Kirchoff's Laws Problems:

Ex:2

The following parallel circuit contains 4 resistors. Using the information provided on the diagram determine the Potential Difference across R_4 and the Current flowing through R_2.



Step:2

$V_S = V_1 = V_2 = V_3 = V_4$
Parallel

$V_4 = 45\ V$

(Voltage is same in every branch)

Kirchoff's Laws Problems:

Ex:2

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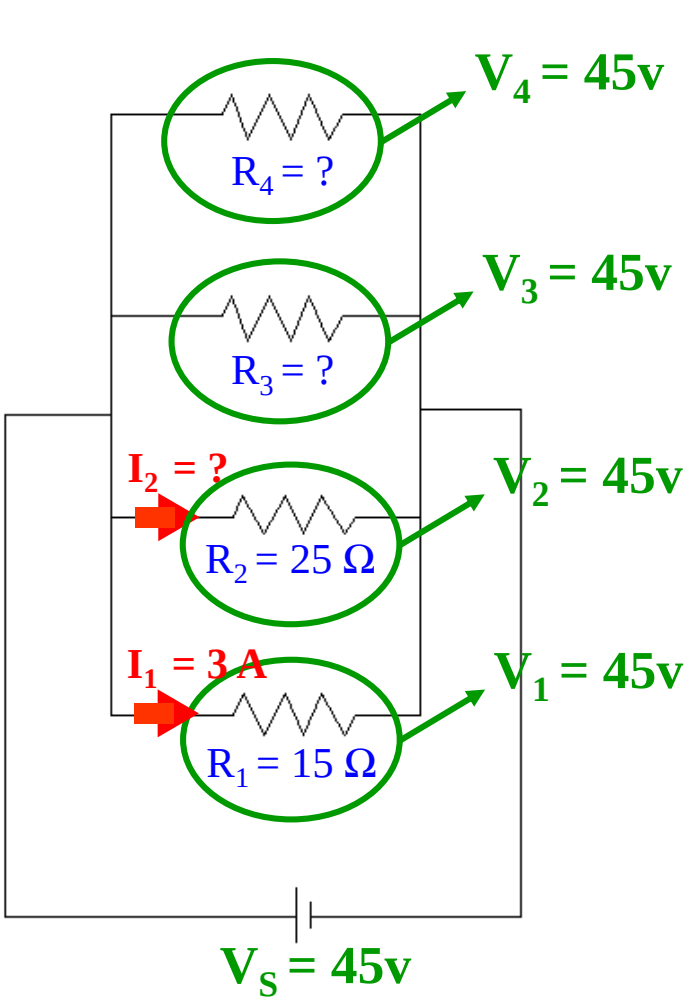


(I_2)

Step:3 $I_2 = \frac{V_2}{R_2}$

$I_2 = \frac{45}{25}$

$I_2 = 1.8A$

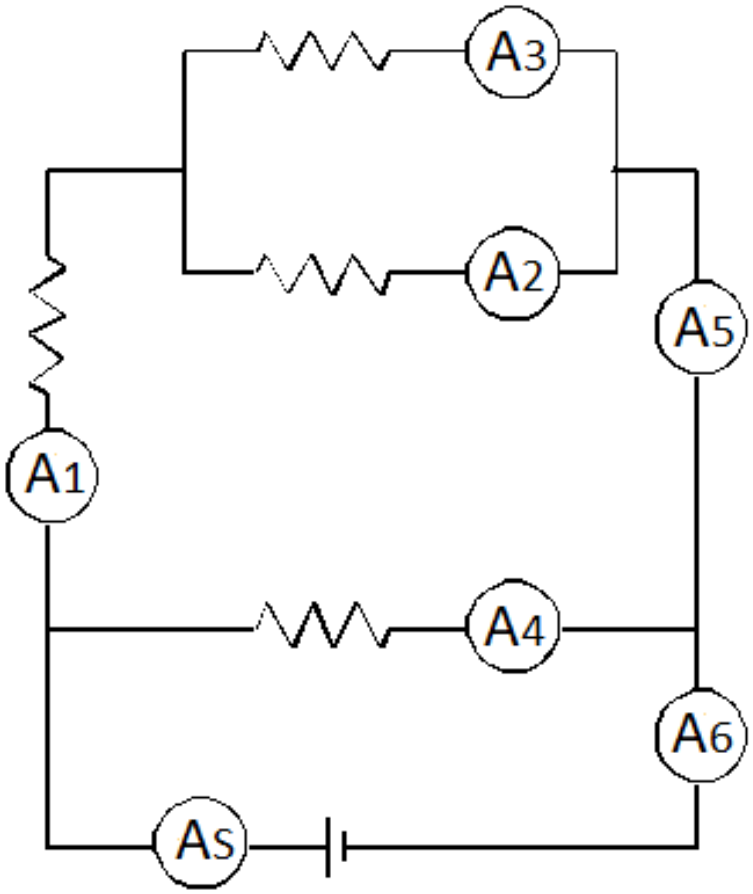
Kirchoff's Laws Problems:

Ex:3

Given the following circuit diagram
in which several ammeters have been installed:

- Ammeter A_3 reads 2 A.
- Ammeter A_4 reads 3 A.
- Ammeter A_S reads 8 A.

What is the reading on Ammeters A_1 A_2 A_5 A_6?



Kirchoff's Laws Problems:

Fill in your circuit diagram with any known information

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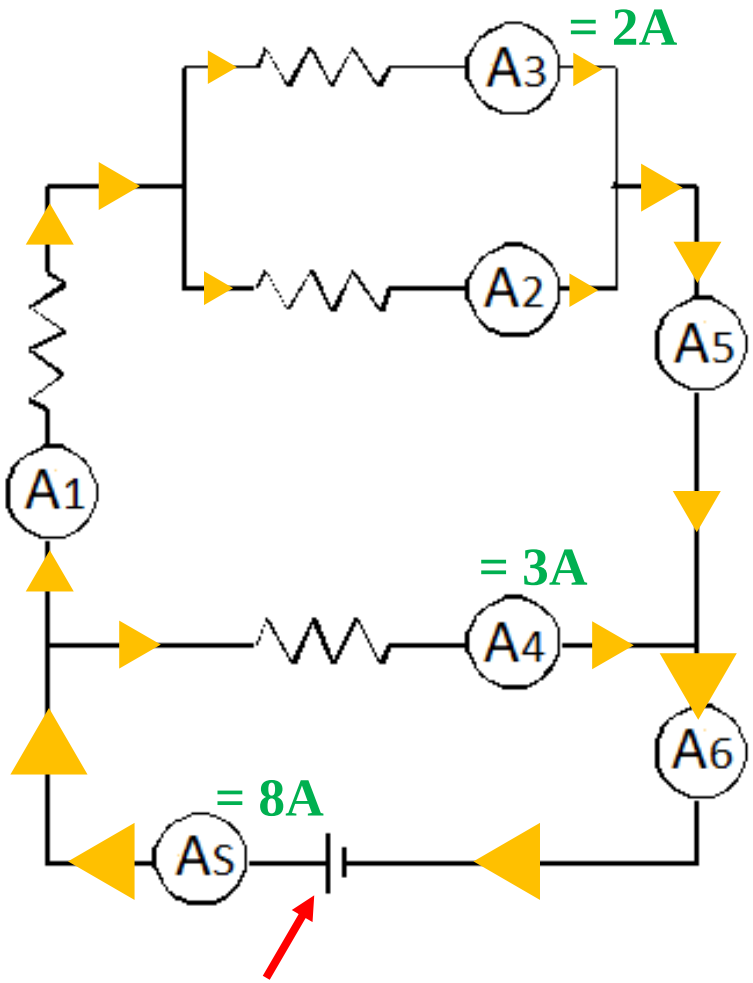


Current (electrons) starts at positive end of the Source

Recall that when current (electrons) reach branches, it will split apart. Some of the current will go through one branch and some of the current will go through another branch

Kirchoff's Laws Problems:

Step:1

$A_S = A_4 + A_1$

$8 = 3 + A_1$

$\boxed{A_1 = 5A}$

Step:2

$A_1 = A_2 + A_3$

$5 = A_2 + 2$

$\boxed{A_2 = 3A}$

Step:3

$A_5 = A_2 + A_3$

$A_5 = 3 + 2$

$\boxed{A_5 = 5A}$

also ($A_1 = A_5$)

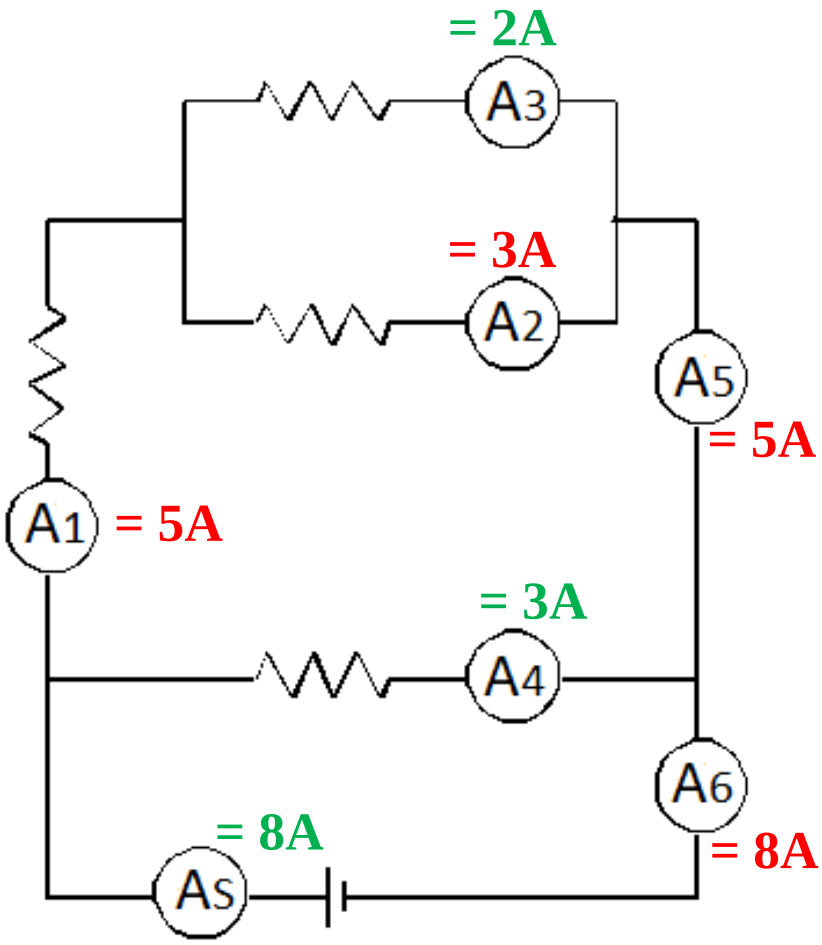
Step:4

$A_6 = A_4 + A_5$

$A_6 = 3 + 5$

$\boxed{A_6 = 8A}$

also ($A_S = A_5$)

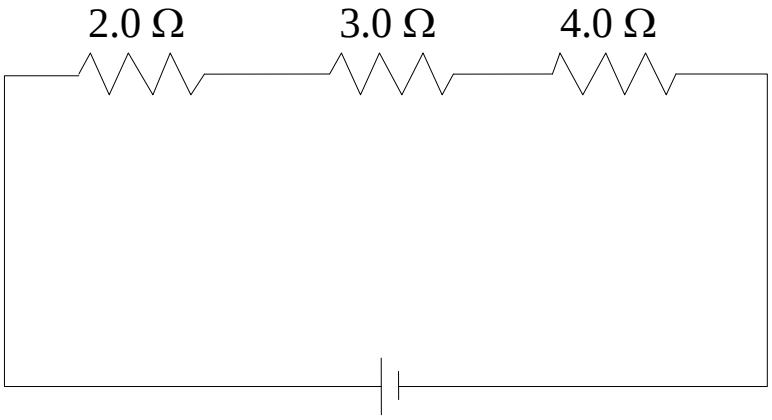


Follow where current splits apart and where it recombines

Kirchoff's Laws Problems:

Ex:4 Three known resistances are connected in series to the terminals of a power source. The potential difference at the terminals of the 3.0 Ω resistance is 12 V.

What is the potential difference of the power source (Vs)?



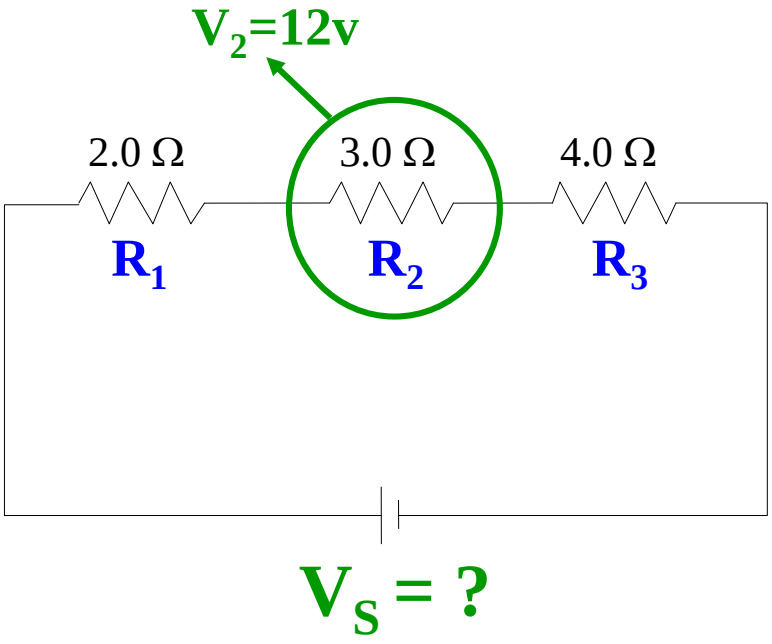
Kirchoff's Laws Problems:

2 METHODS CAN BE USED TO SOLVE THIS PROBLEM

Fill in your circuit diagram with any known information

Ex:4 Three known resistances are connected in series to the terminals of a power source. The potential difference at the terminals of the 3.0 Ω resistance is 12 V.

What is the potential difference of the power source (Vs) ?



METHOD 1

Kirchoff's Laws Problems:

2 METHODS CAN BE USED TO SOLVE THIS PROBLEM

Fill in your circuit diagram with any known information

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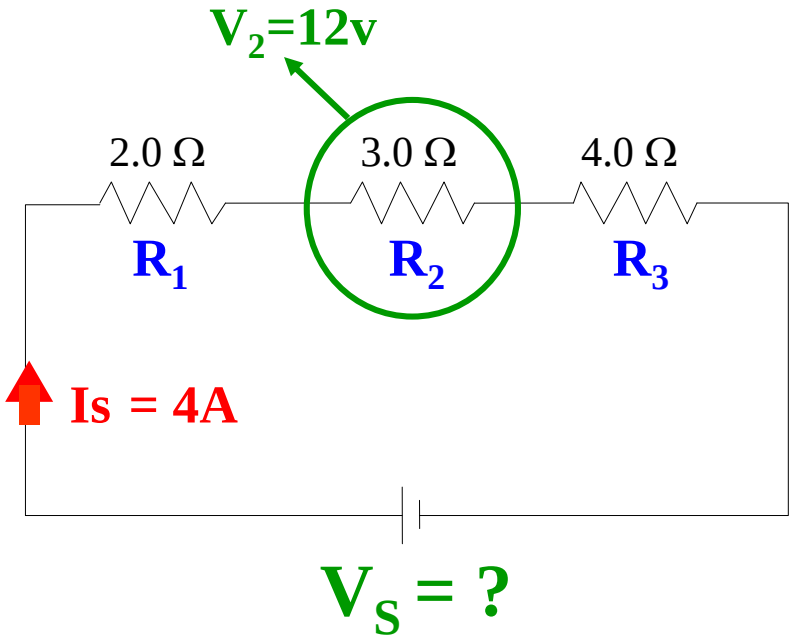

METHOD 1

Step:1 $I_2 = \frac{V_2}{R_2}$

$I_2 = \frac{12}{3}$

$I_2 = 4A$

Step:2

$I_S = I_1 = I_2 = I_3$

Series

$I_S = 4A$

(same current everywhere in series)

Kirchoff's Laws Problems:

2 METHODS CAN BE USED TO SOLVE THIS PROBLEM

Fill in your circuit diagram with any known information

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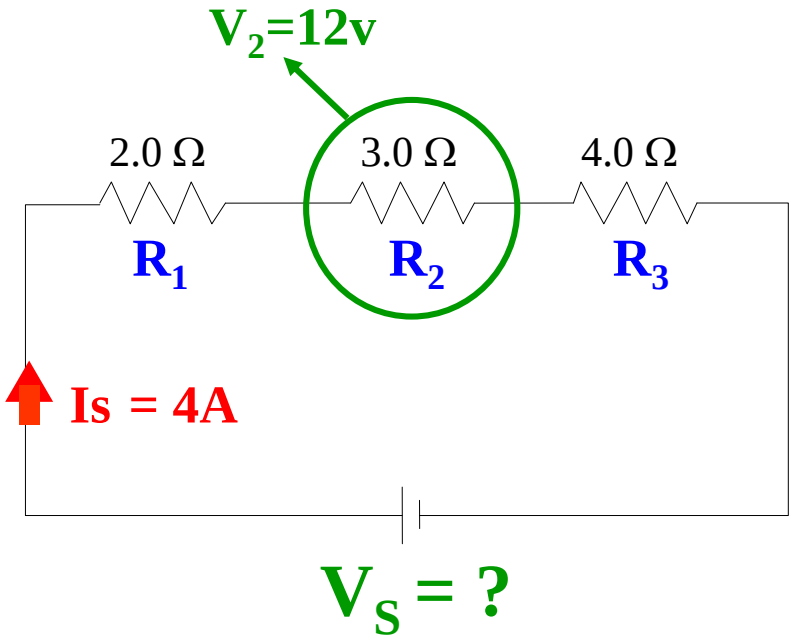

METHOD 1

Step:3

$R_T = R_1 + R_2 + R_3$ (Series)

$R_T = 2 + 3 + 4$

$R_T = 9\ \Omega$

Step:4

$V_S = I_S R_T$

$V_S = 4\ (9)$

$V_S = 36\ V$

Kirchoff's Laws Problems:

2 METHODS CAN BE USED TO SOLVE THIS PROBLEM

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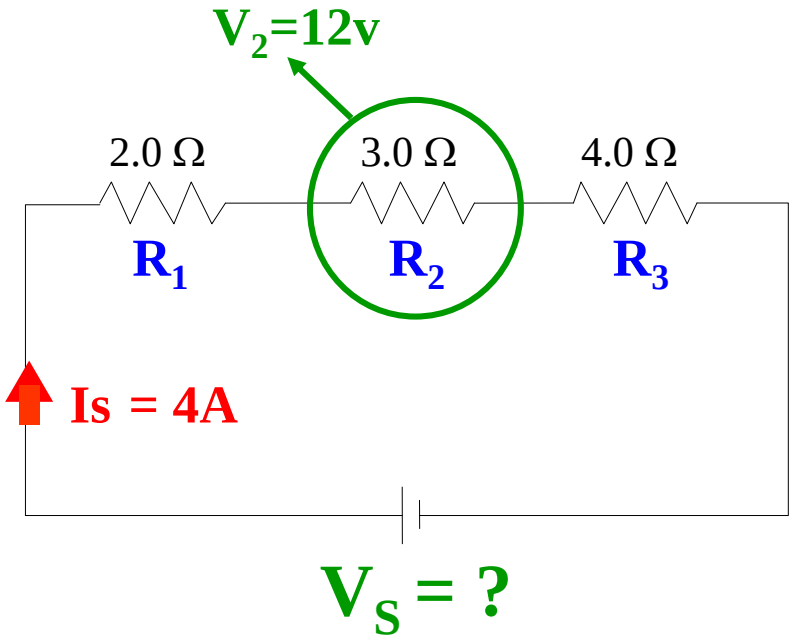

METHOD 2

Step:1 $I_2 = \frac{V_2}{R_2}$

$I_2 = \frac{12}{3}$

$I_2 = 4A$

Step:2

$I_S = I_1 = I_2 = I_3$ (Series)

$I_S = 4A$

(same current everywhere in series)

Kirchoff's Laws Problems:

2 METHODS CAN BE USED TO SOLVE THIS PROBLEM

Fill in your circuit diagram with any known information

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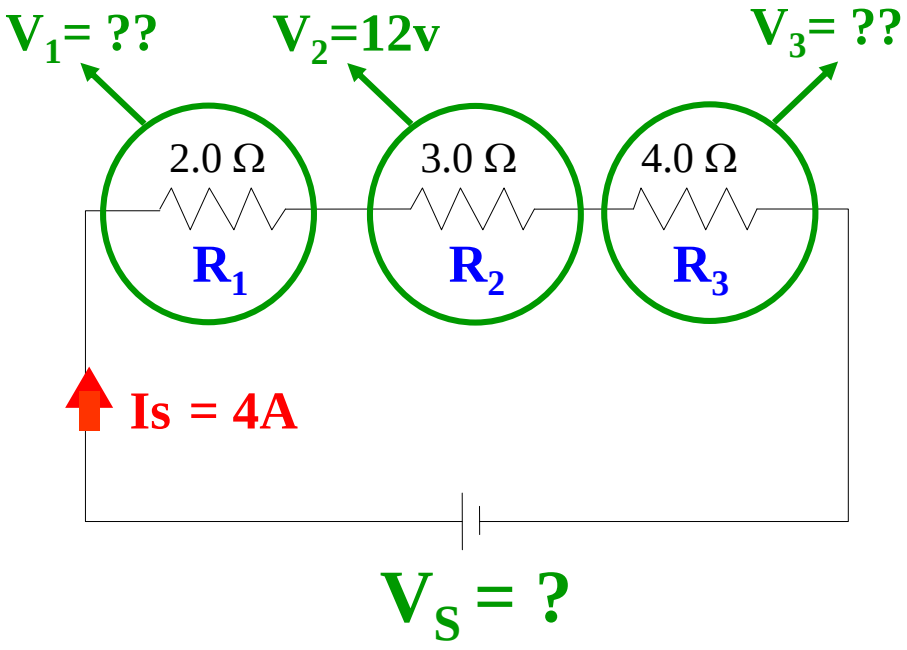

METHOD 2

Step:3

$$V_1 = I_1R_1$$

$$V_1 = 4\ (2)$$

$$V_1 = 8\ V$$

Step:4

$$V_3 = I_3R_3$$

$$V_3 = 4\ (4)$$

$$V_3 = 16\ V$$

Kirchoff's Laws Problems:

2 METHODS CAN BE USED TO SOLVE THIS PROBLEM

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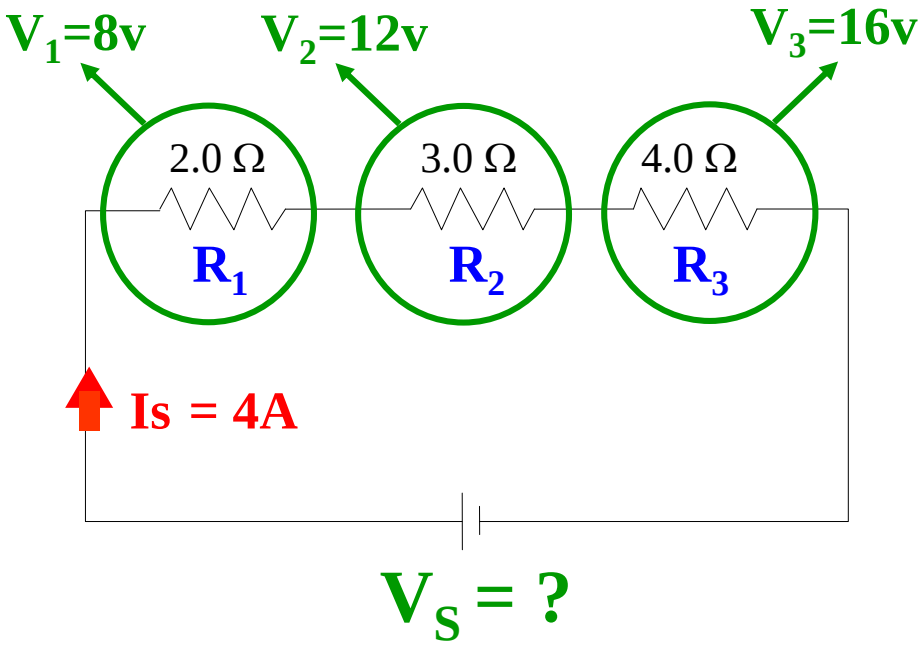


METHOD 2

Step:5

$V_S = V_1 + V_2 + V_3$
Series

$V_S = 8 + 12 + 16$

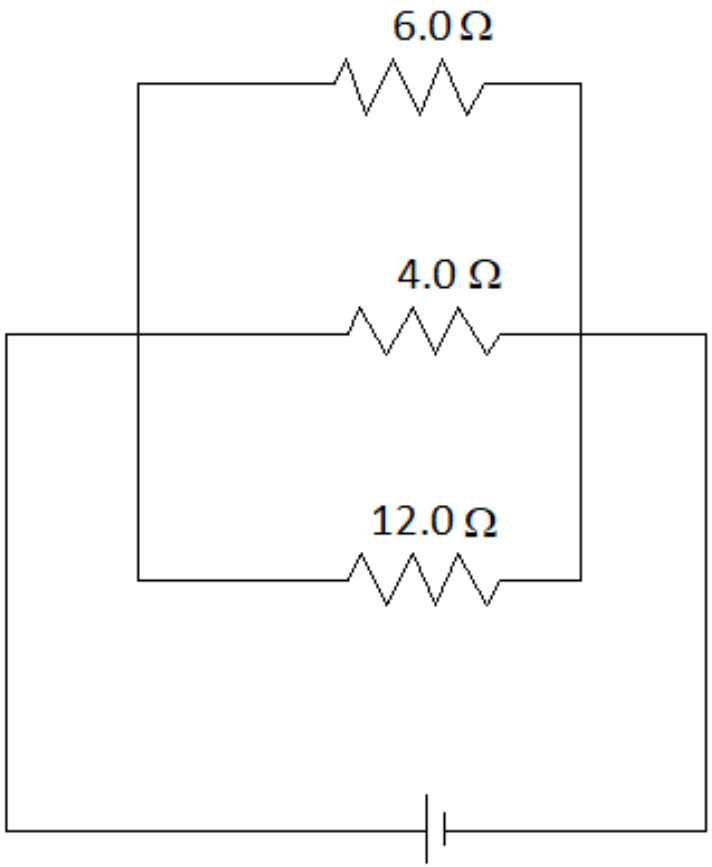
$V_S = 36\ V$

(In series voltages are added for total)

Kirchoff's Laws Problems:

Ex:5 Three known resistances are connected in parallel to the terminals of a power source. The current passing through the 4.0 Ω resistance is 2.0 A.

What is the intensity of the current coming from the power source (I_S) ?



Kirchoff's Laws Problems:

2 METHODS CAN BE USED TO SOLVE THIS PROBLEM

Fill in your circuit diagram with any known information

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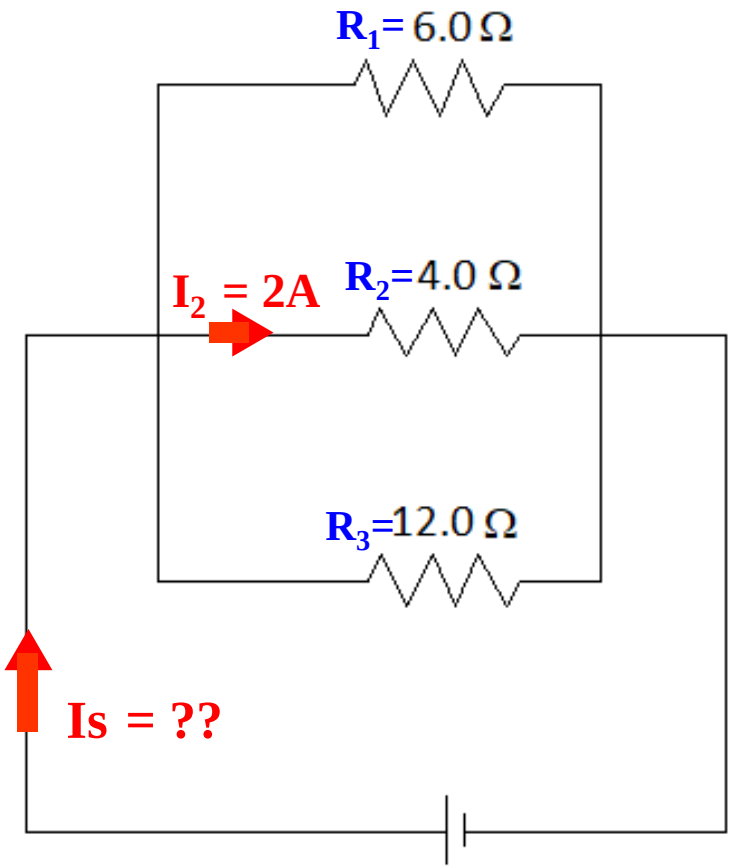

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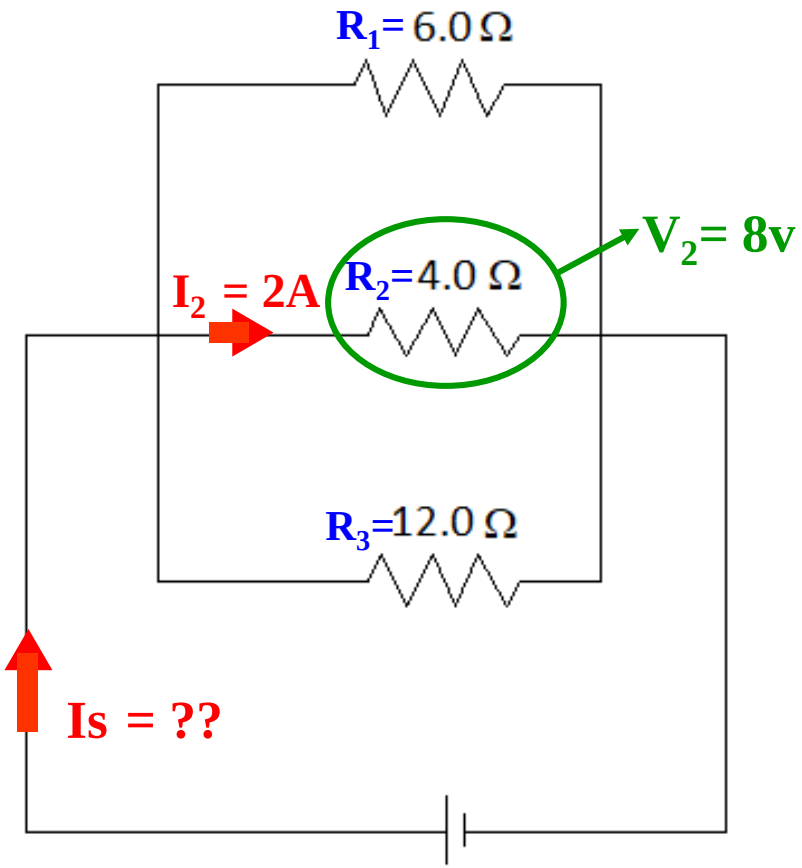

METHOD 1

Step:1

$$V_2 = I_2R_2$$

$$V_2 = 2\ (4)$$

$$V_2 = 8\ V$$

Step:2

$$V_S = V_1 = V_2 = V_3$$

Parallel

$$V_S = 8\ V$$

(Voltage is same in every branch)

Kirchoff's Laws Problems:

2 METHODS CAN BE USED TO SOLVE THIS PROBLEM

Fill in your circuit diagram with any known information

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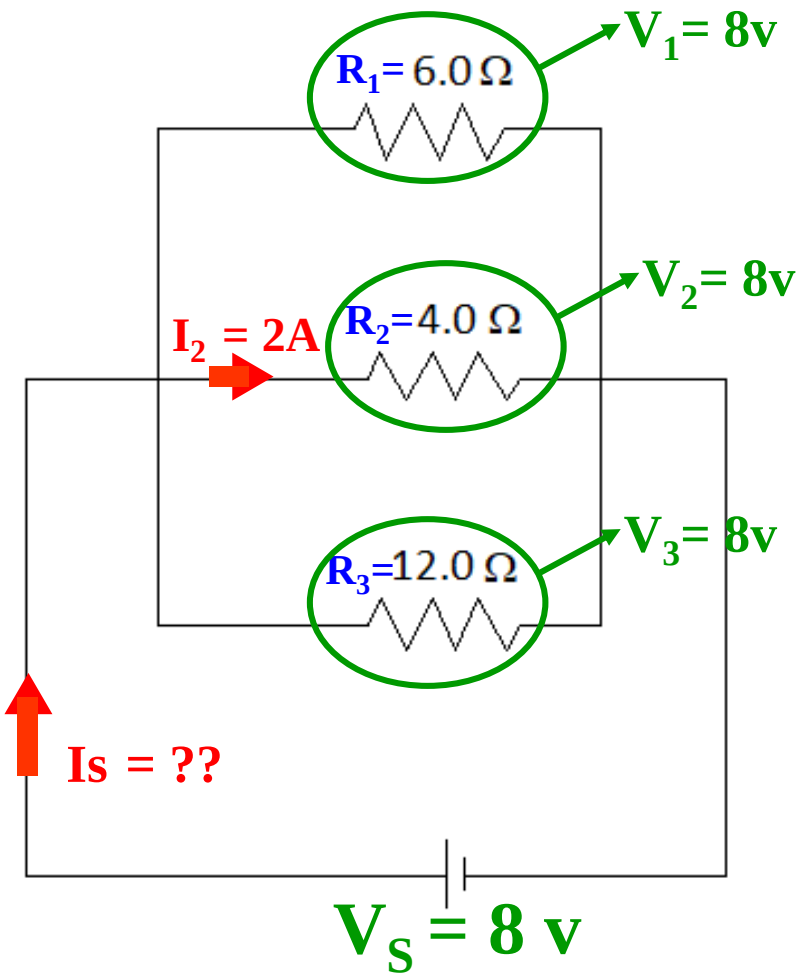

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Parallel

$V_S = 8\ V$

(Voltage is same in every branch)

Kirchoff's Laws Problems:

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Fill in your circuit diagram with any known information

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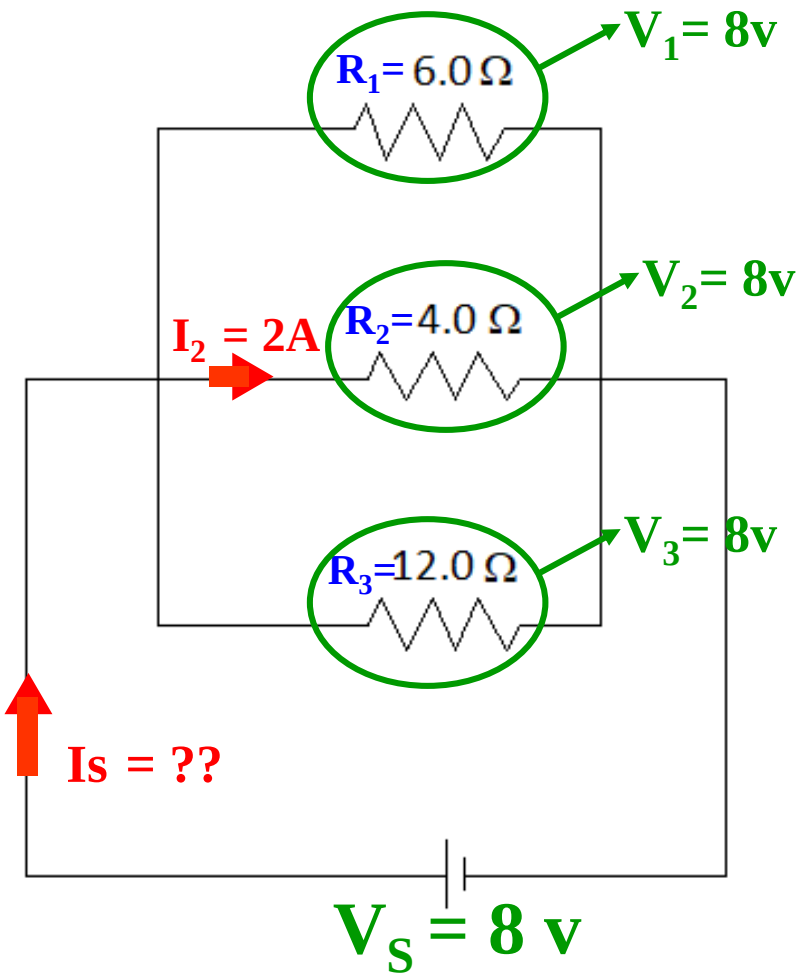

METHOD 1

Step:3

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Parallel

$$\frac{1}{R_T} = \frac{1}{6} + \frac{1}{4} + \frac{1}{12}$$

$$\frac{1}{R_T} = \frac{1(2) + 1(3) + 1(1)}{12}$$

$$R_T = 2\ \Omega$$

Kirchoff's Laws Problems:

2 METHODS CAN BE USED TO SOLVE THIS PROBLEM

Fill in your circuit diagram with any known information

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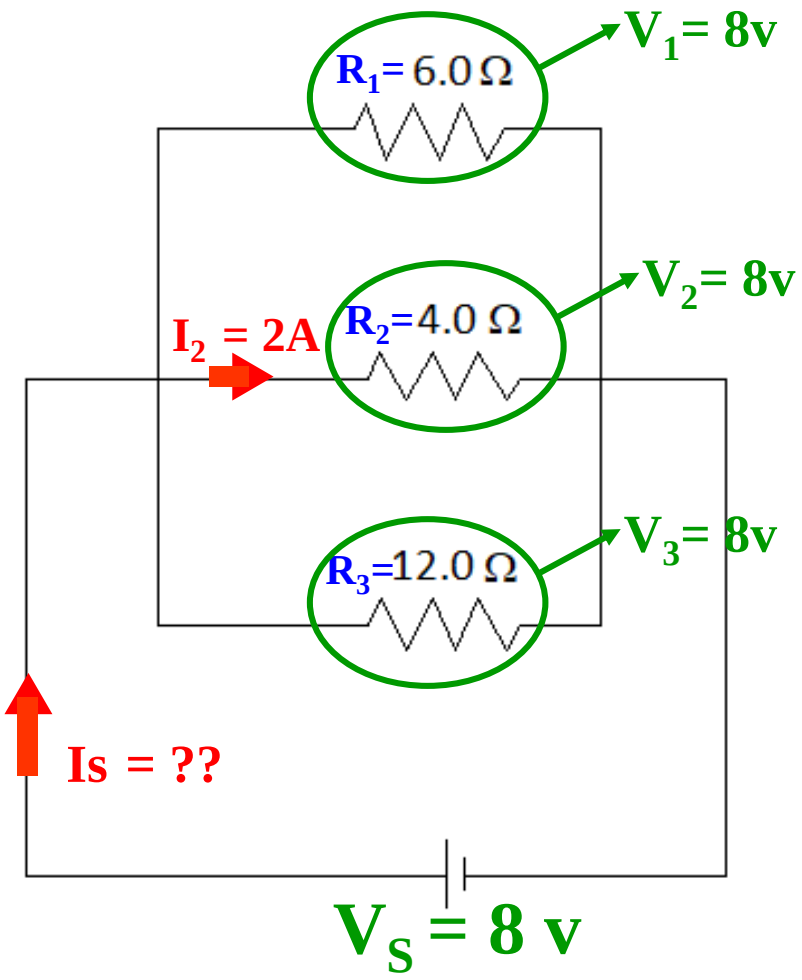


METHOD 1

Step:4

$$I_S = \frac{V_S}{R_T}$$

$$I_S = \frac{8}{2}$$

$$\boxed{I_S = 4A}$$

Kirchoff's Laws Problems:

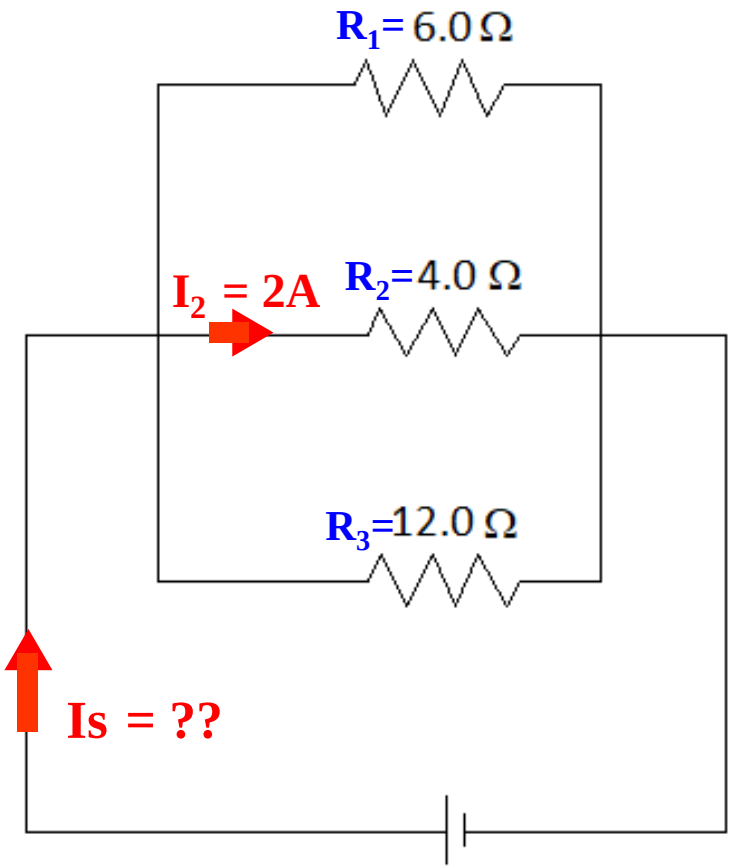
2 METHODS CAN BE USED TO SOLVE THIS PROBLEM

Fill in your circuit diagram with any known information

Ex:5 Three known resistances are connected in parallel to the terminals of a power source. The current passing through the 4.0 Ω resistance is 2.0 A.

What is the intensity of the current coming from the power source (I_S) ?

METHOD 2



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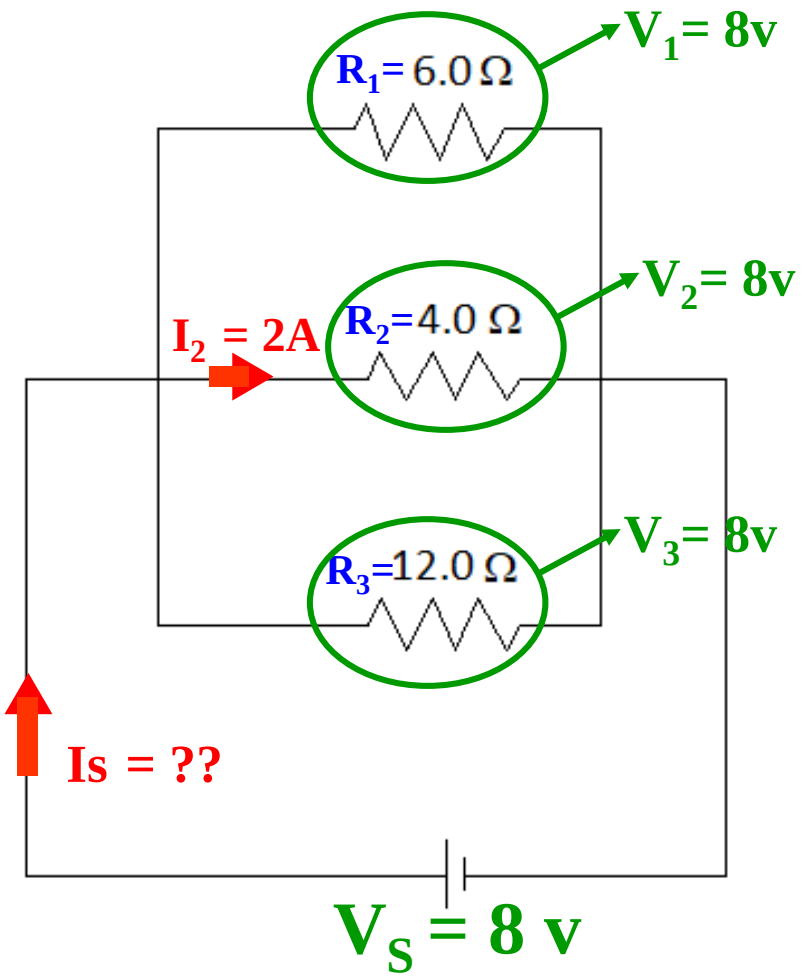

METHOD 2

Step:1

$$V_2 = I_2R_2$$

$$V_2 = 2\ (4)$$

$$V_2 = 8\ V$$

Step:2

$$V_S = V_1 = V_2 = V_3$$

Parallel

$$V_S = 8\ V$$

(Voltage is same in every branch)

Kirchoff's Laws Problems:

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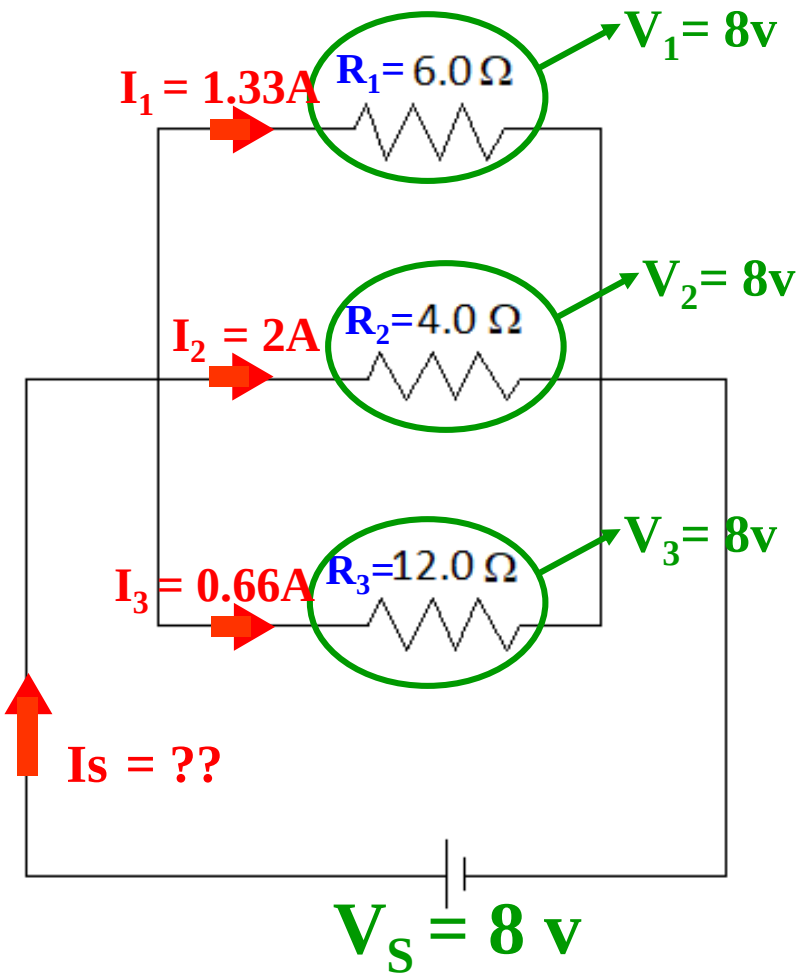

METHOD 2

Step:3 $I_1 = \frac{V_1}{R_1}$

$I_1 = \frac{8}{6}$

$I_1 = 1.33A$

Step:4 $I_3 = \frac{V_3}{R_3}$

$I_3 = \frac{8}{12}$

$I_3 = 0.66A$

Kirchoff's Laws Problems:

2 METHODS CAN BE USED TO SOLVE THIS PROBLEM

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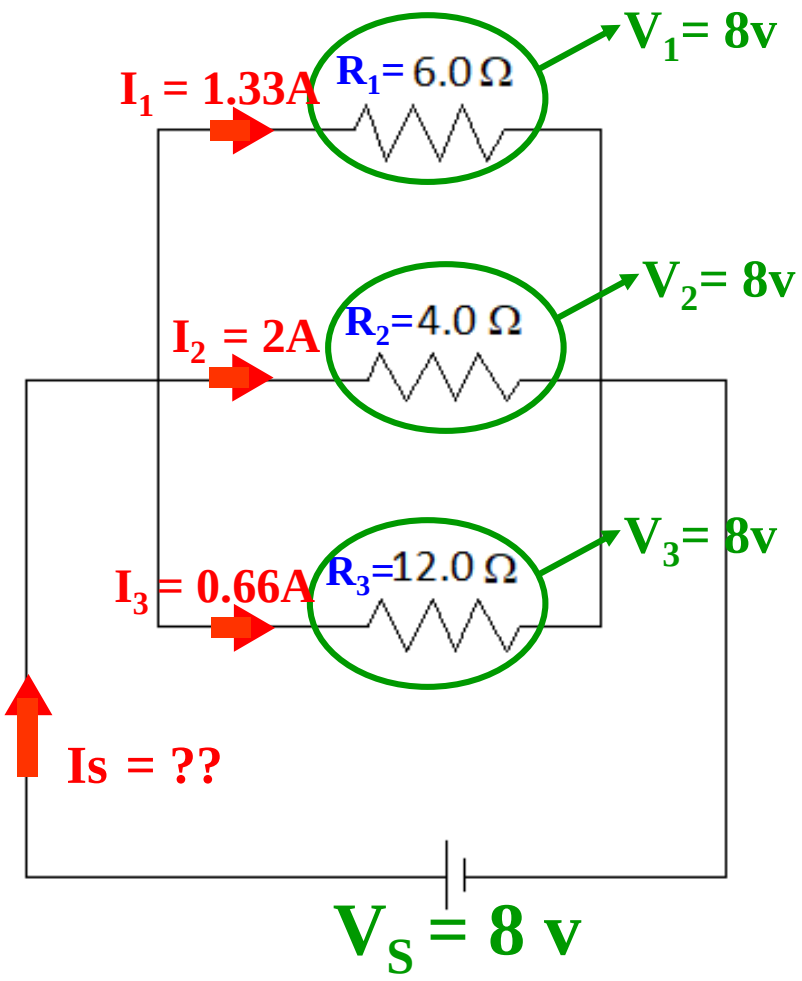

METHOD 2

Step:5

$I_S = I_1 + I_2 + I_3$ (Parallel)

$I_S = 1.33 + 2 + 0.66$

$I_S = 4$ A

(Total current is added in parallel)