Ohm’s Law and Power

Al Penney
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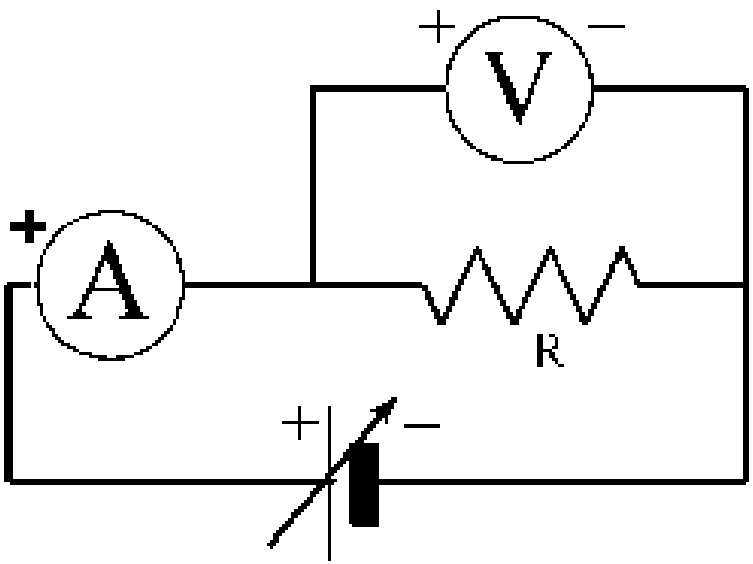
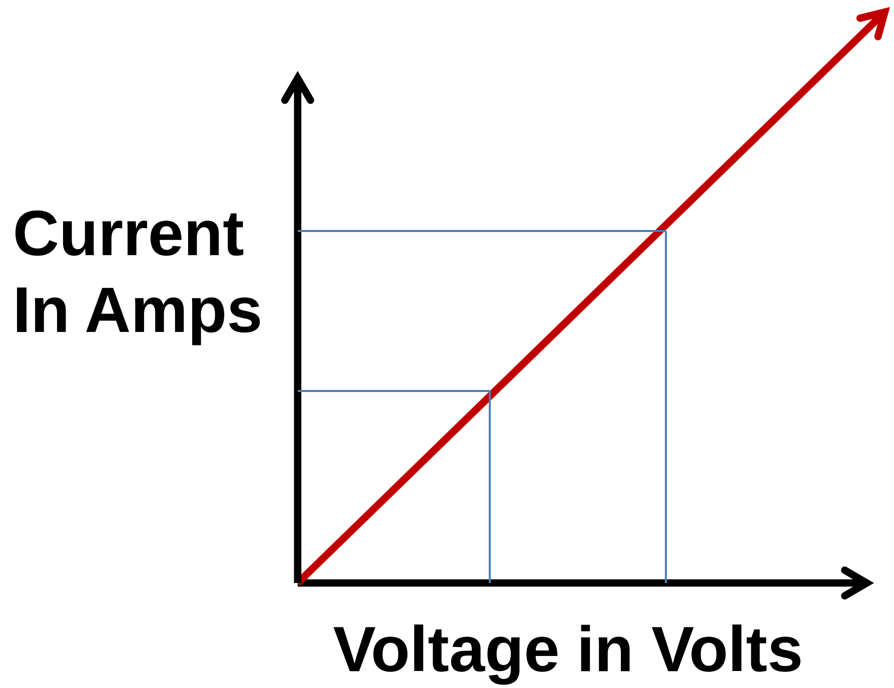
Chapter 3

Voltage and Current





As Voltage is increased, Current also increases.

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Ohm’s Law

- Relationship between Voltage, Current and Resistance can be expressed mathematically as:

$$E = I \times R$$

Where

E is measured in Volts;

I is measured in Amps; and

R is measured in Ohms.

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Ohm's Law

The equation can be re-written to determine any of the 3 variables if the other two are known:

$$I = E / R$$

And

$$R = E / I$$

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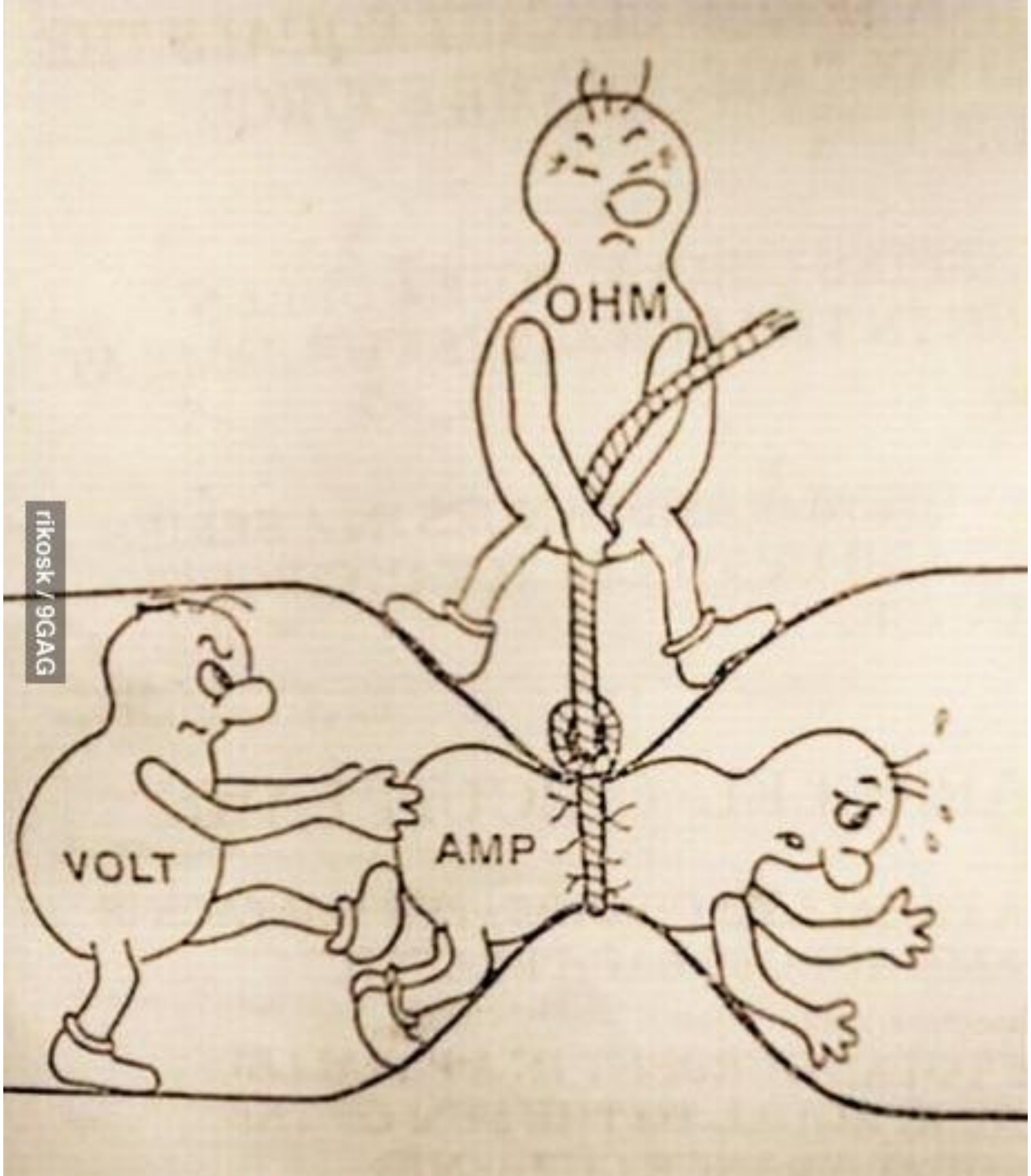

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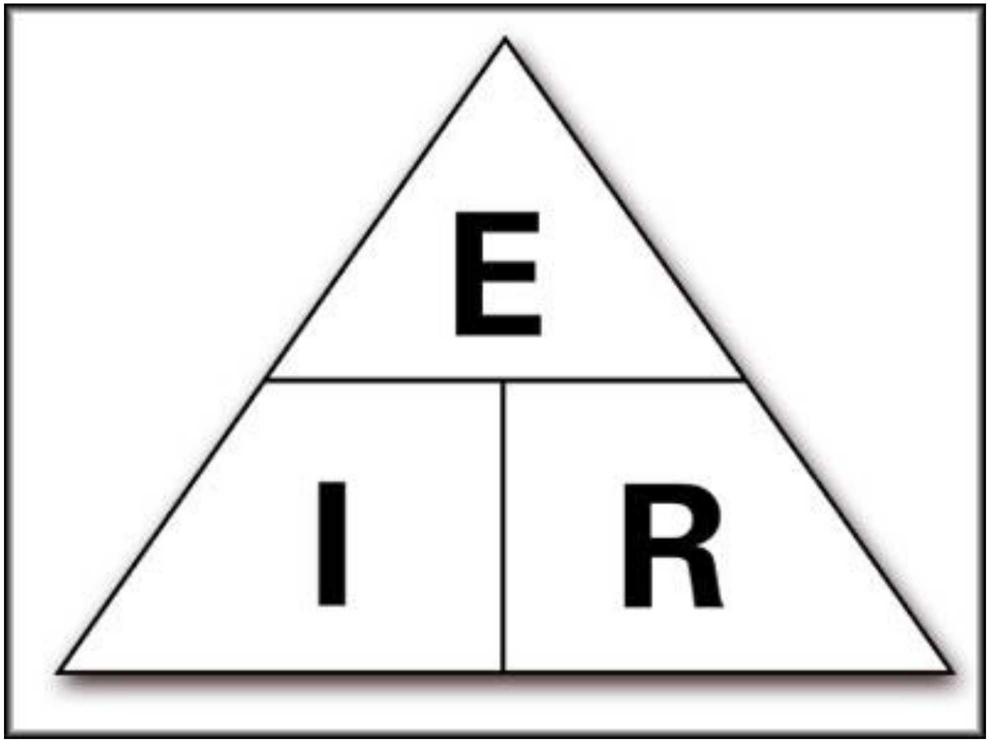
Ohms Law Triangle



Remember the Units:
- E is measured in **VOLTS**
- I is measured in **AMPS**
- R is measured in **OHMS**

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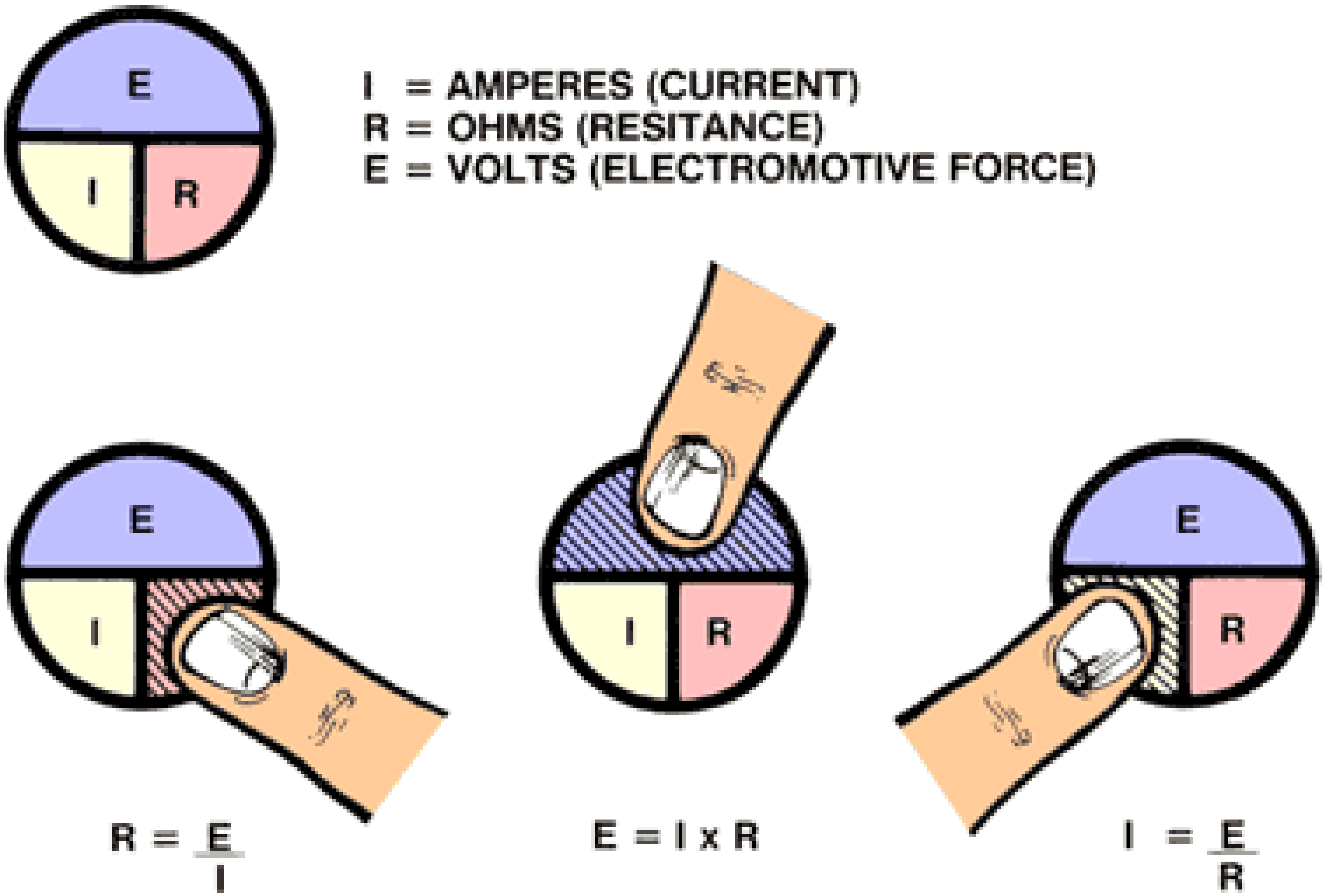
Ohms Law Triangle

(Okay – Circle!)



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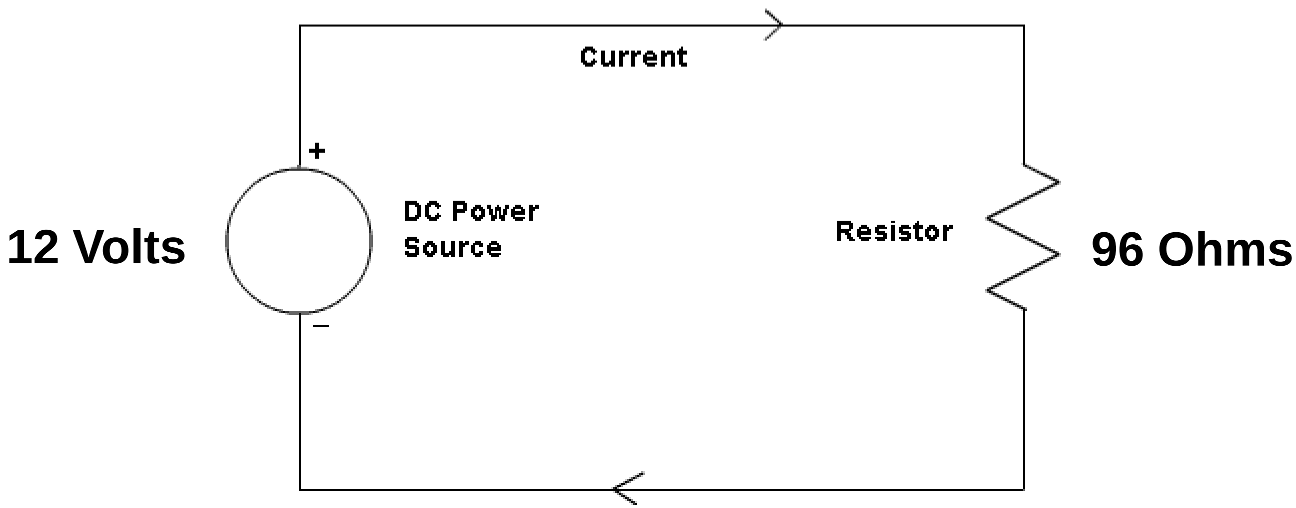
Ohms Law Problem #1

What is the current?



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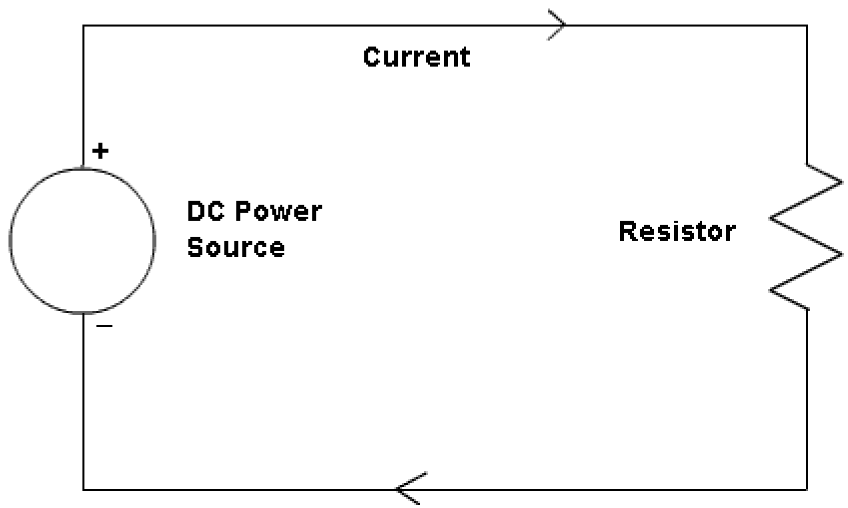
Ohms Law Problem #1

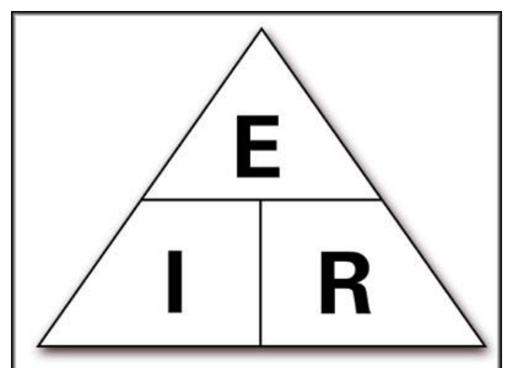
What is the current?

12 Volts



96 Ohms

Consult the Ohms Law Triangle:



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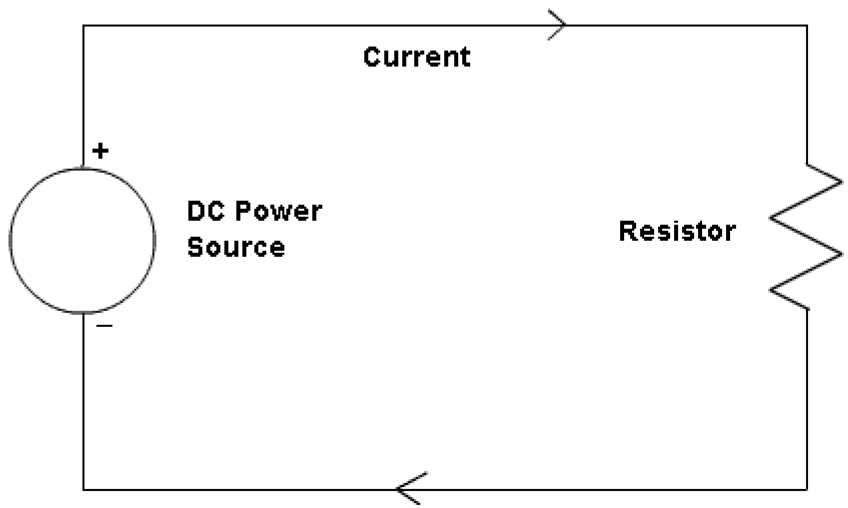
Ohms Law Problem #1

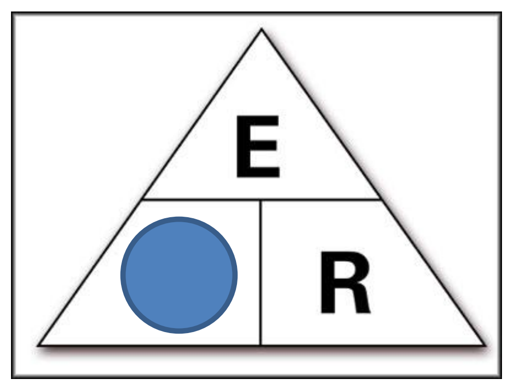
What is the current?

12 Volts



96 Ohms

Consult the Ohms Law Triangle:



$I = E / R$

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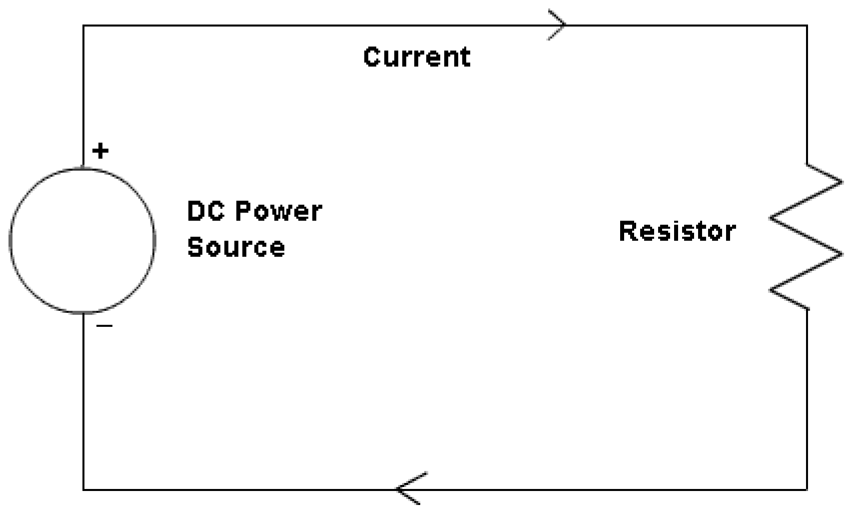
Ohms Law Problem #1

What is the current?

12 Volts



96 Ohms

I = E / R

I = 12 Volts / 96 Ohms

I =

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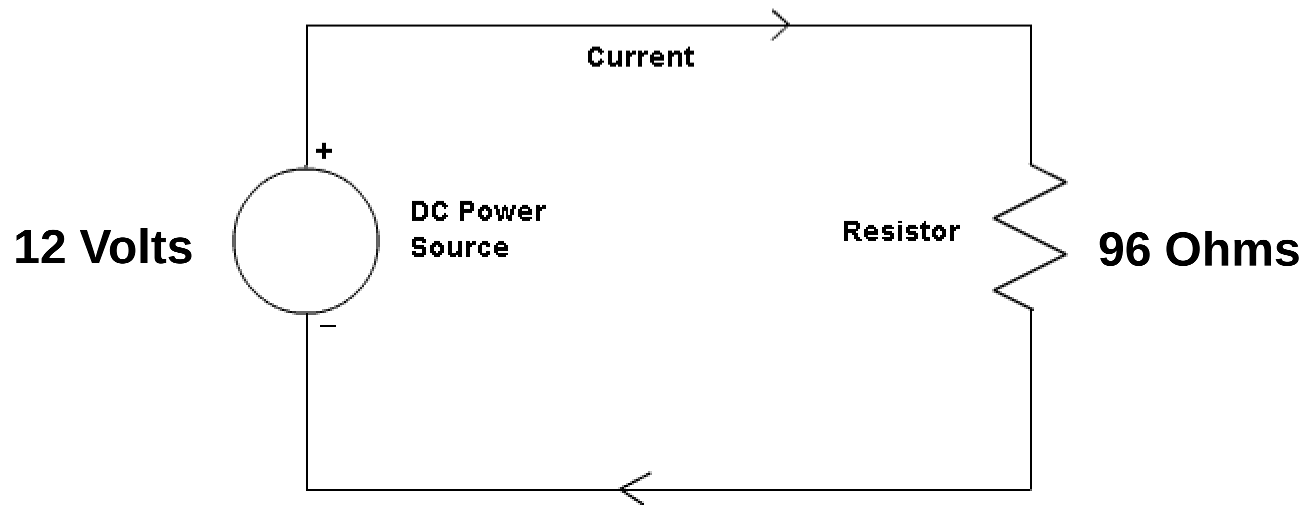
Ohms Law Problem #1

What is the current?



I = E / R

I = 12 Volts / 96 Ohms

I = 0.125 Amps

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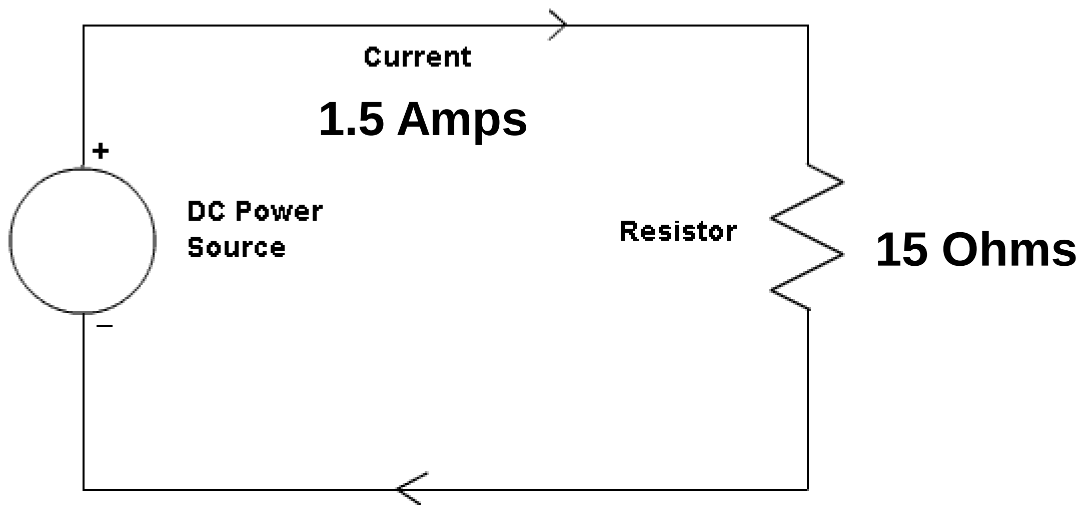
Ohms Law Problem #2

What is the voltage?



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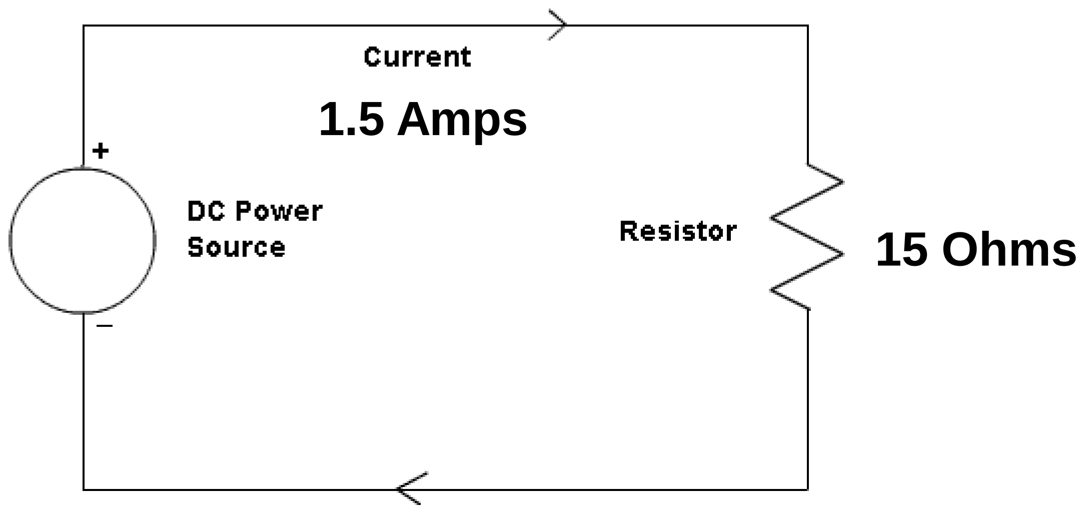
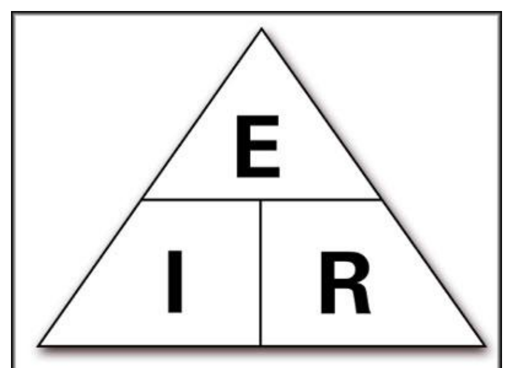
Ohms Law Problem #2

What is the voltage?



Consult the Ohms Law Triangle:



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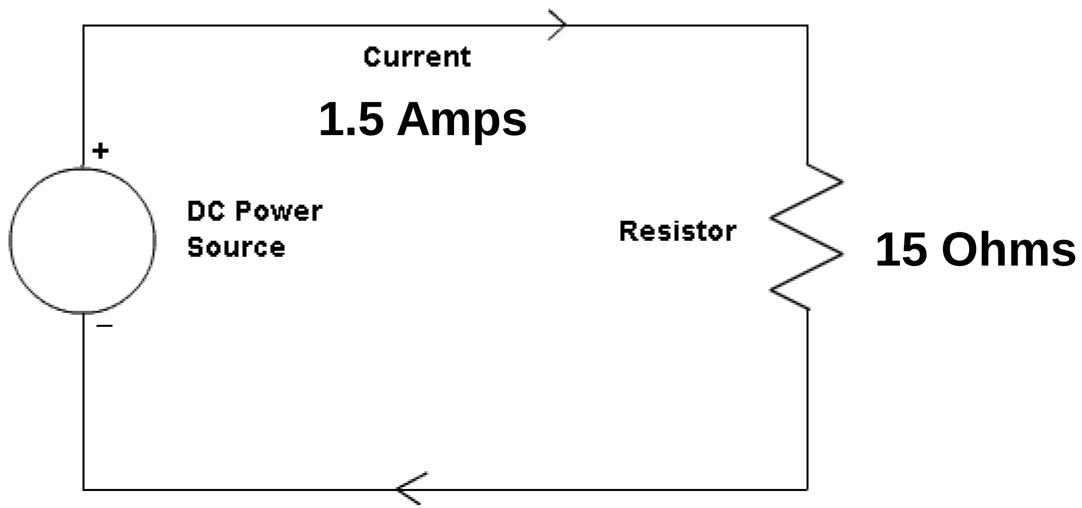
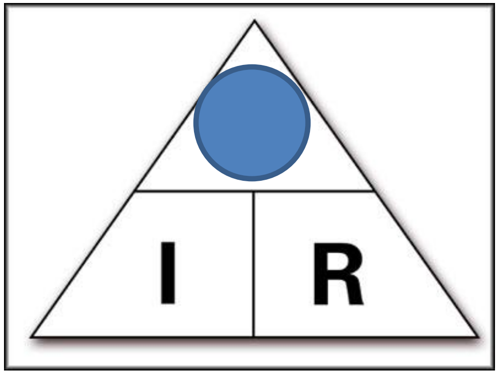
Ohms Law Problem #2

What is the voltage?



Consult the Ohms Law Triangle:



E = I x R

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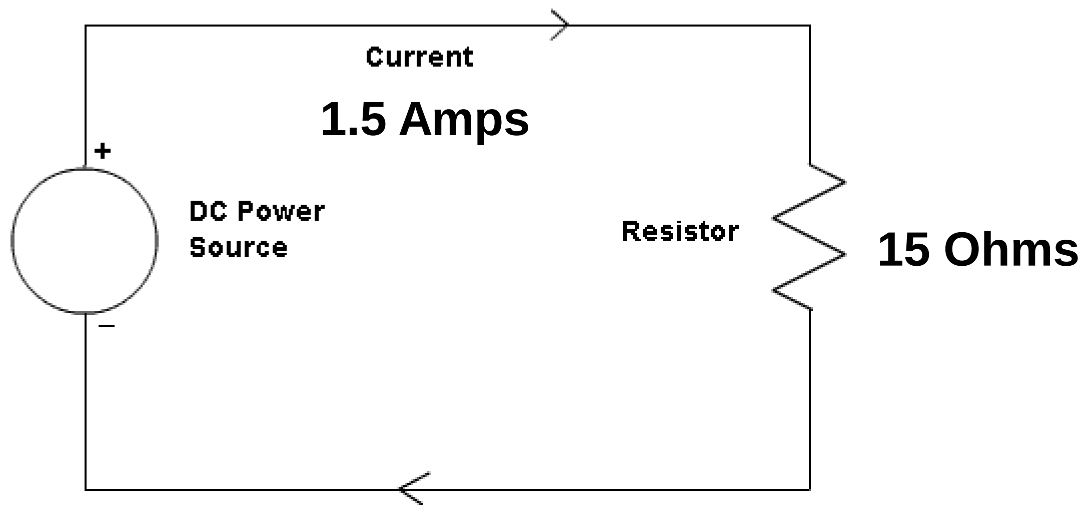
Ohms Law Problem #2

What is the voltage?



E = I x R

= 1.5 Amps x 15 Ohms

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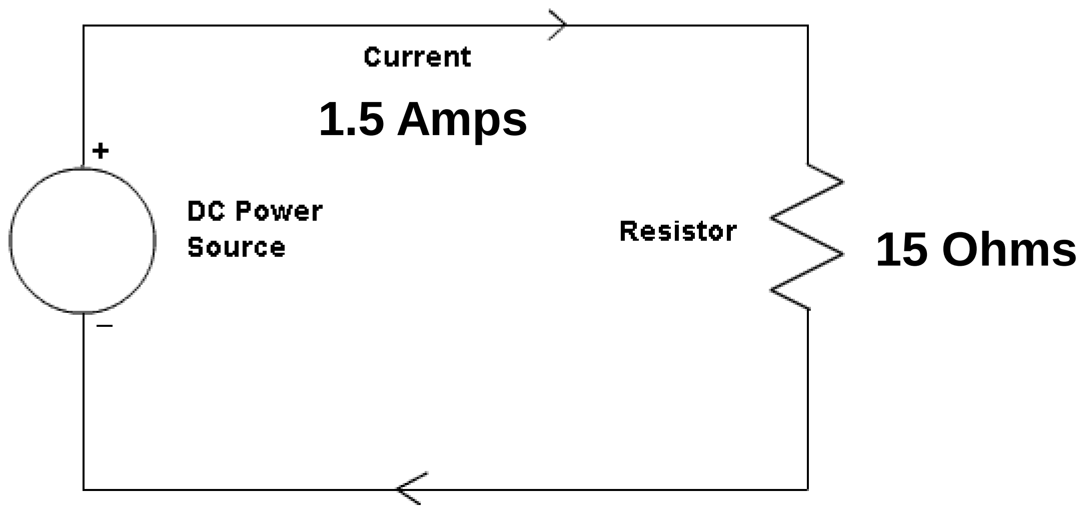
Ohms Law Problem #2

What is the voltage?



E = I x R

= 1.5 Amps x 15 Ohms

= 22.5 Volts

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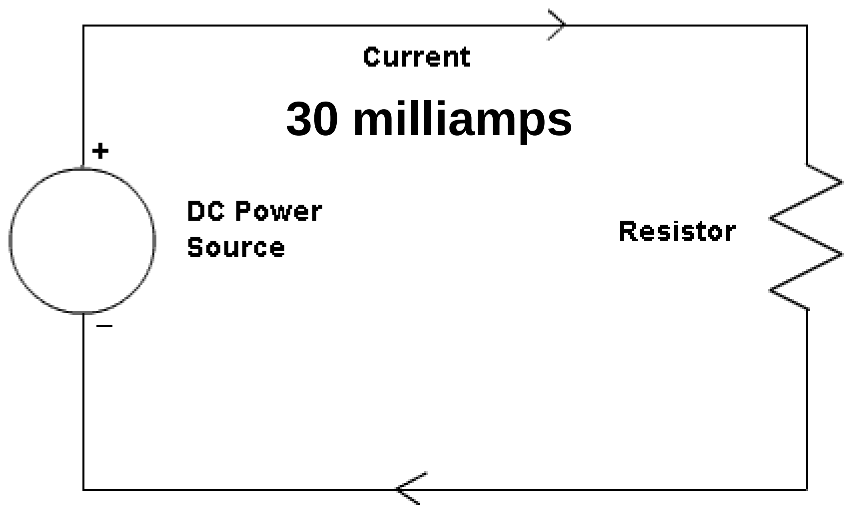
Ohms Law Problem #3

What is the resistance?

150 millivolts



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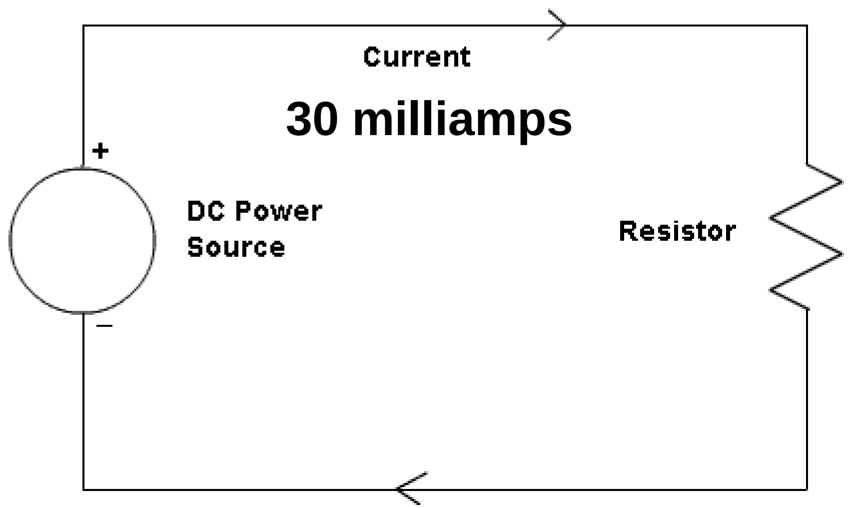
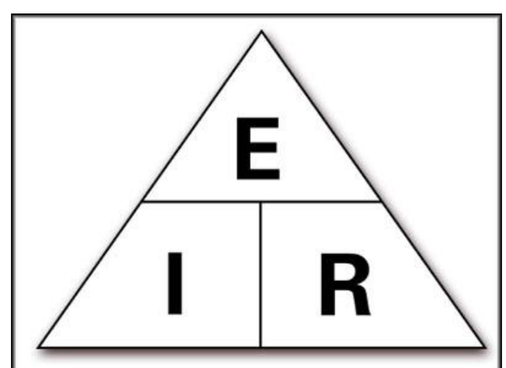
Ohms Law Problem #3

What is the resistance?

150 millivolts



Consult the Ohms Law Triangle:



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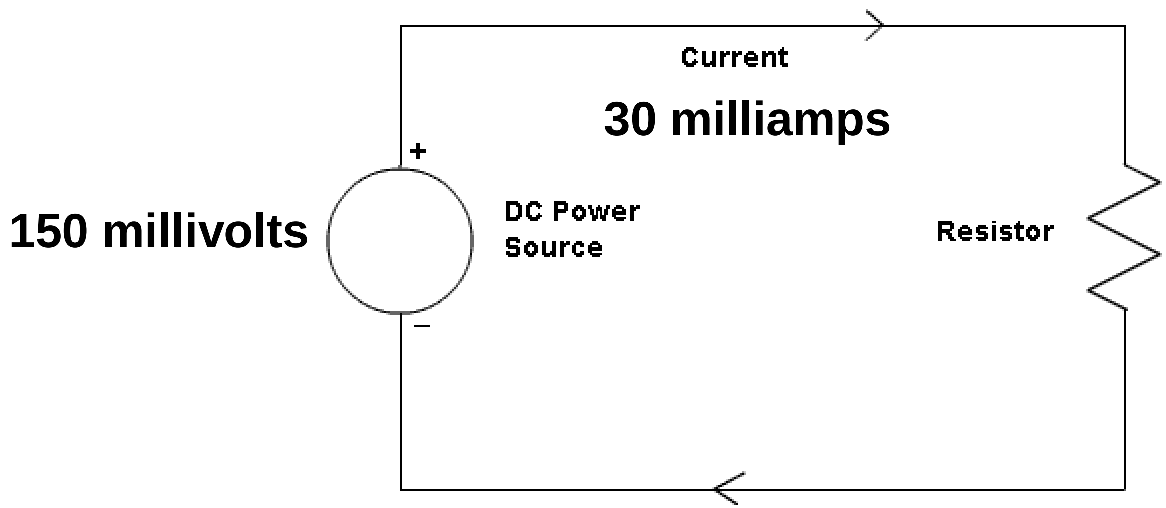
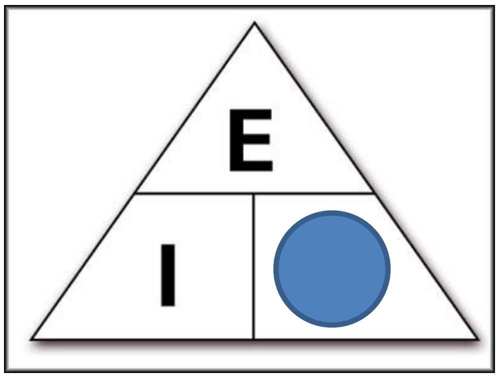
Ohms Law Problem #3

What is the resistance?



Consult the Ohms Law Triangle:



R = E / I

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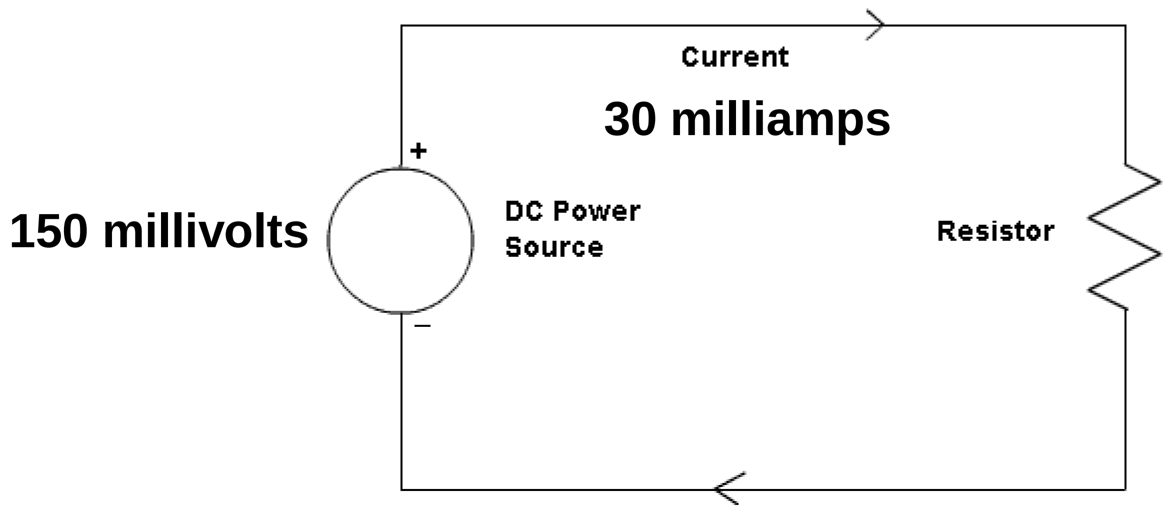
Ohms Law Problem #3

What is the resistance?



R = E / I

= 150 millivolts / 30 milliamps

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Ohms Law Problem #3

- **REMEMBER the UNITS!**
  - 150 **millivolts** = 150 / 1000 volts = 0.15 **volts**
  - 30 **milliamps** = 30 / 1000 amps = 0.03 **amps**

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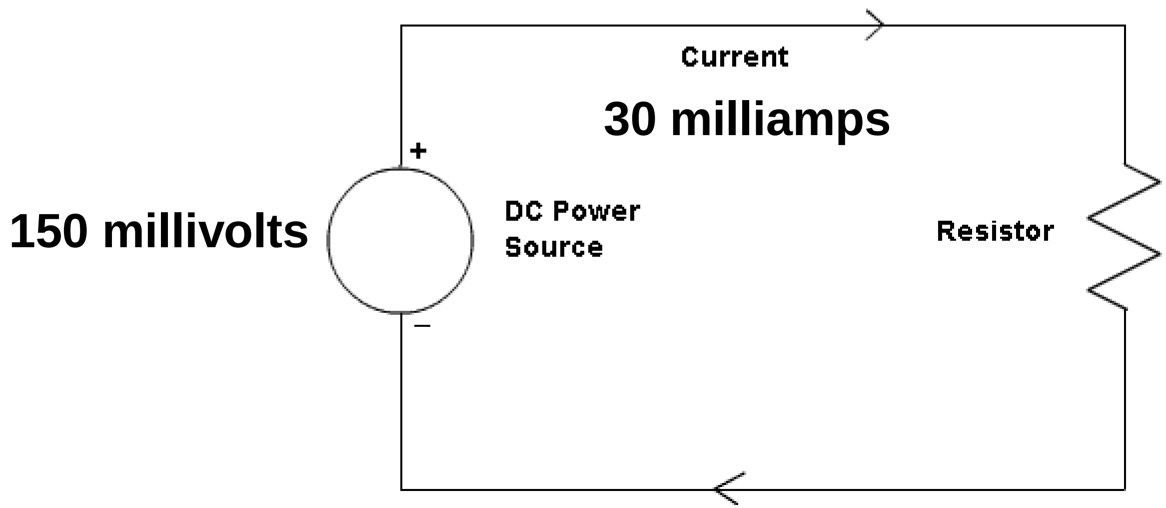
Ohms Law Problem #3

What is the resistance?



R = E / I

= 150 millivolts / 30 milliamps

= 0.15 Volts / 0.03 Amps

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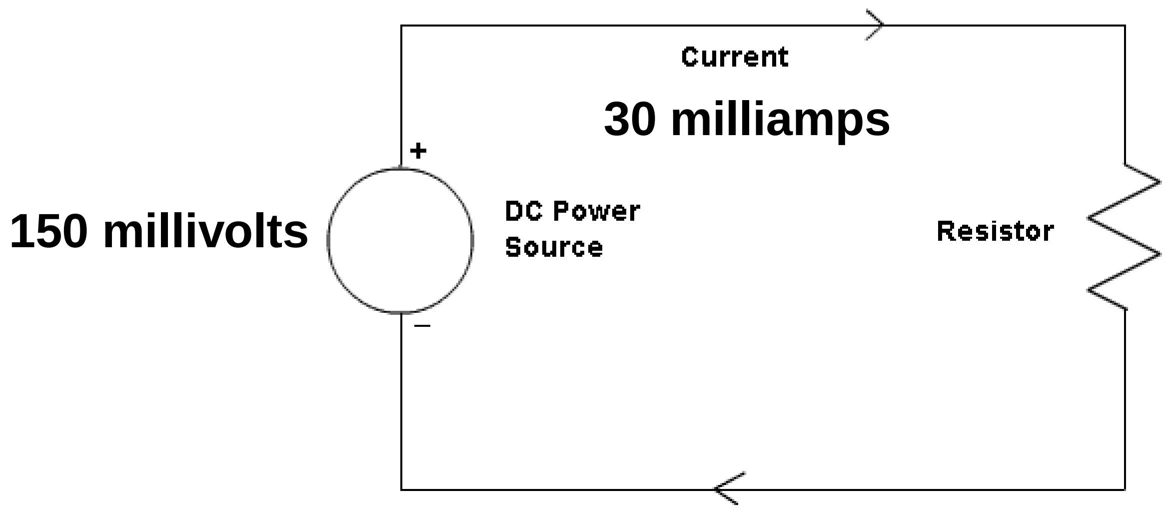
Ohms Law Problem #3

What is the resistance?



R = E / I

= 150 millivolts / 30 milliamps

= 0.15 Volts / 0.03 Amps

= 5 Ohms

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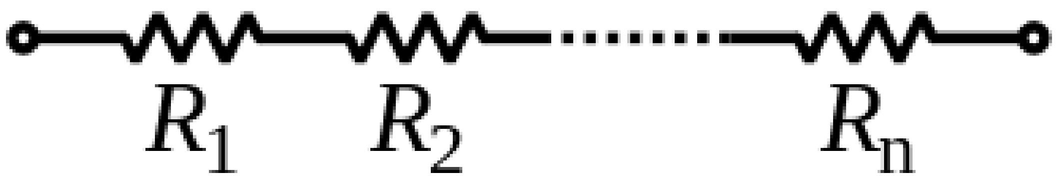
Resistors in Series

- When resistors are in **SERIES**, the total resistance is the **SUM** of the individual resistances.



$$R_{Total} = R_1 + R_2 + R_3 + \ldots.. + R_N$$

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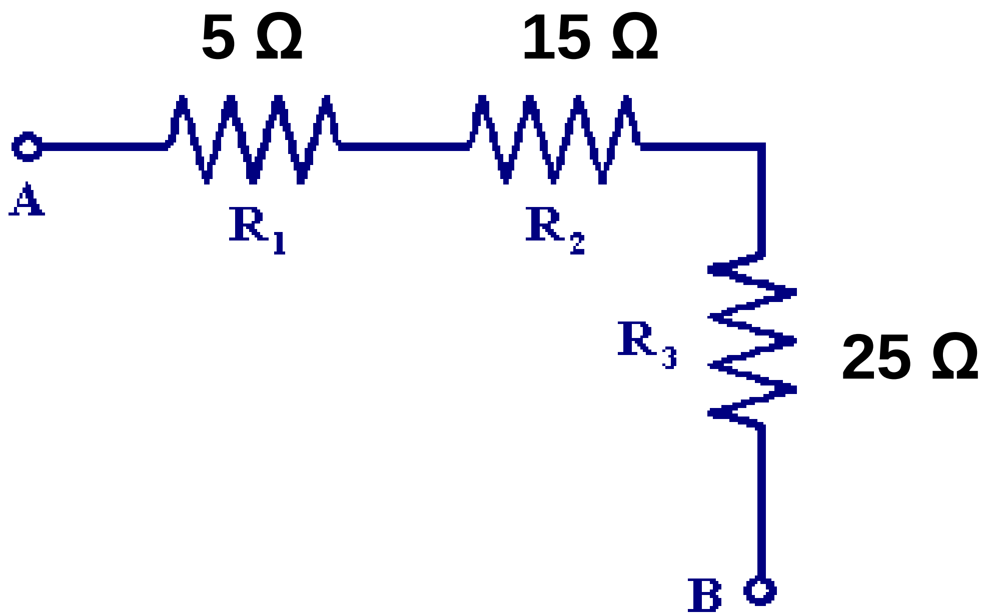
Resistors in Series



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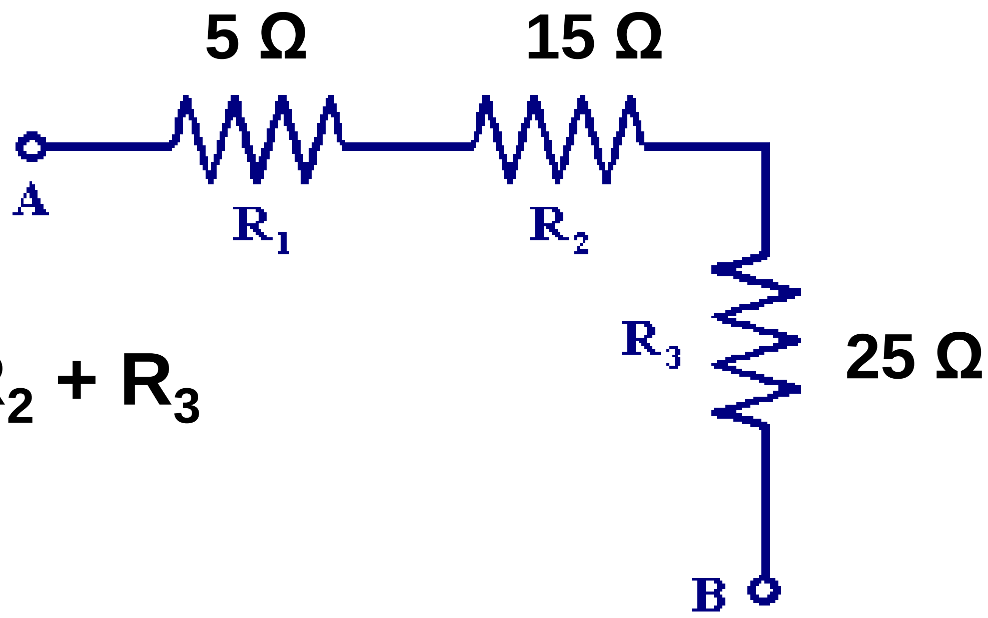
Resistors in Series



$$R_{Total} = R_1 + R_2 + R_3$$

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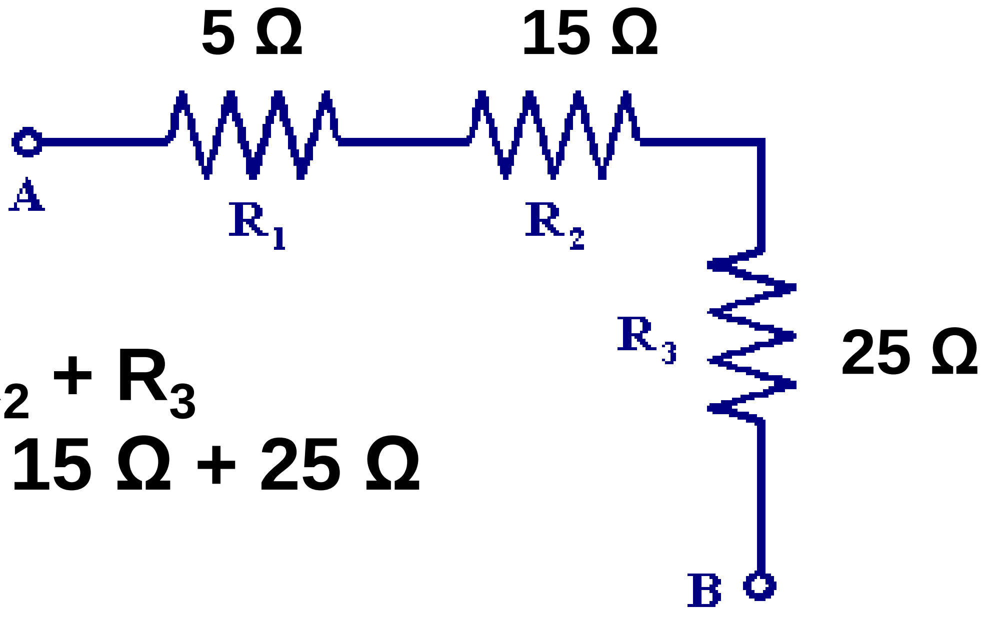
Resistors in Series



$R_{Total} = R_1 + R_2 + R_3$

$R_{Total} = 5\ \Omega + 15\ \Omega + 25\ \Omega$

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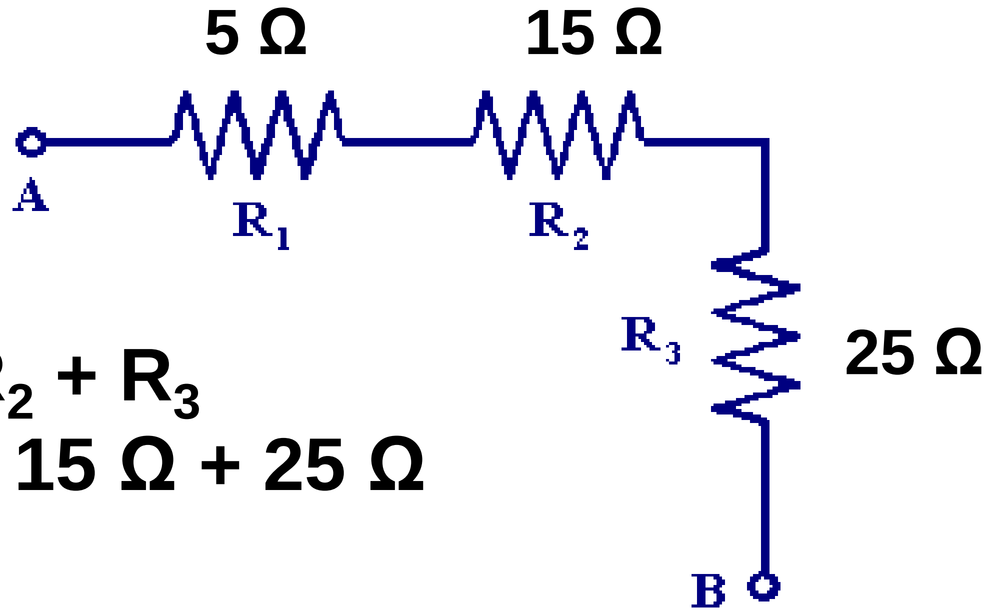
Resistors in Series



$R_{Total} = R_1 + R_2 + R_3$

$R_{Total} = 5\ \Omega + 15\ \Omega + 25\ \Omega$

$R_{Total} = 45\ \Omega$

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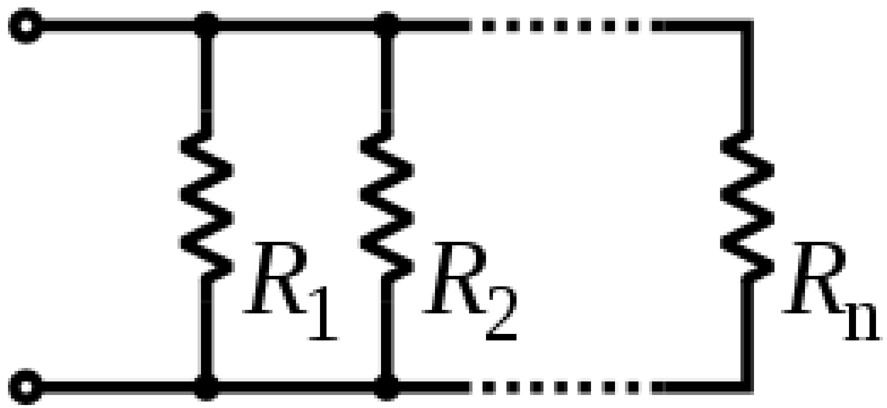
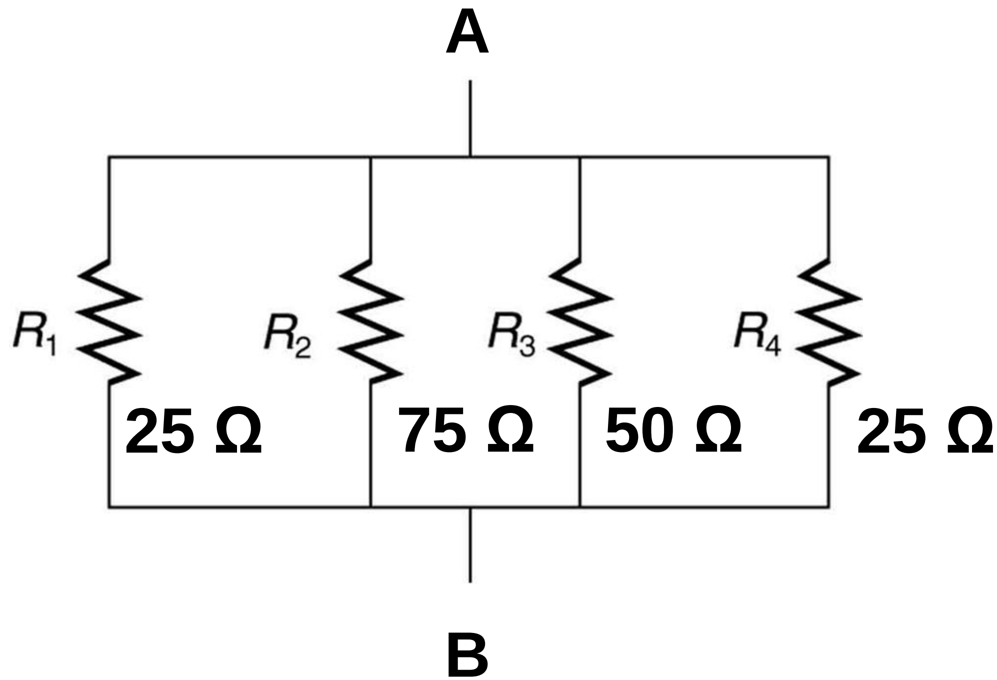
Resistors in Parallel

- When resistors are in Parallel, the total resistance is given by the following equation:

$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3 + \ldots.. + 1/R_N$



Resistors in Parallel



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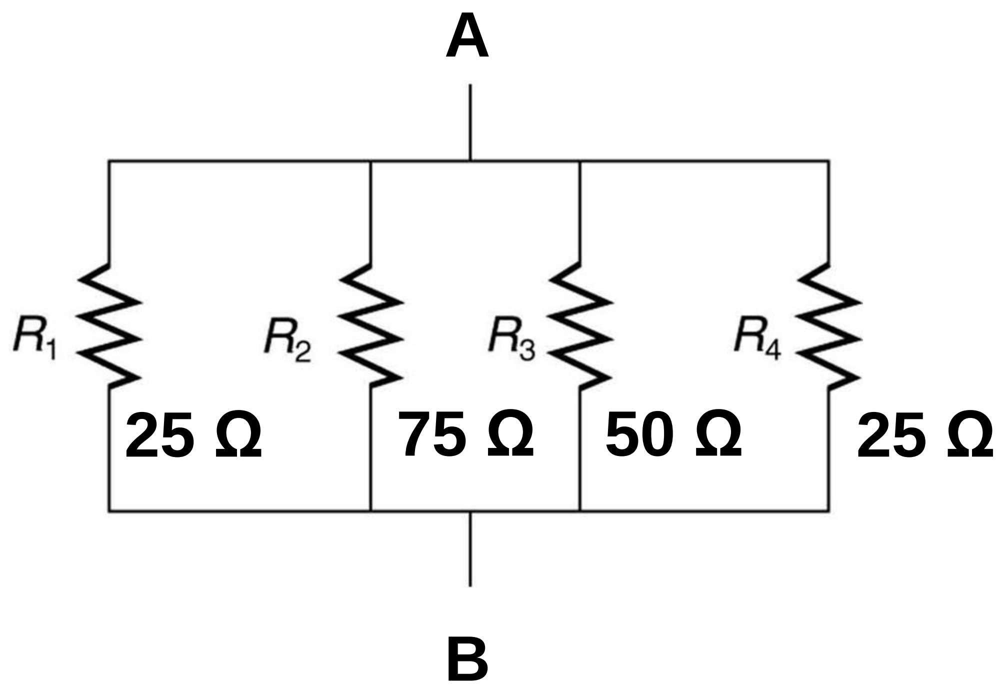
Resistors in Parallel



$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3 + 1/R_4$

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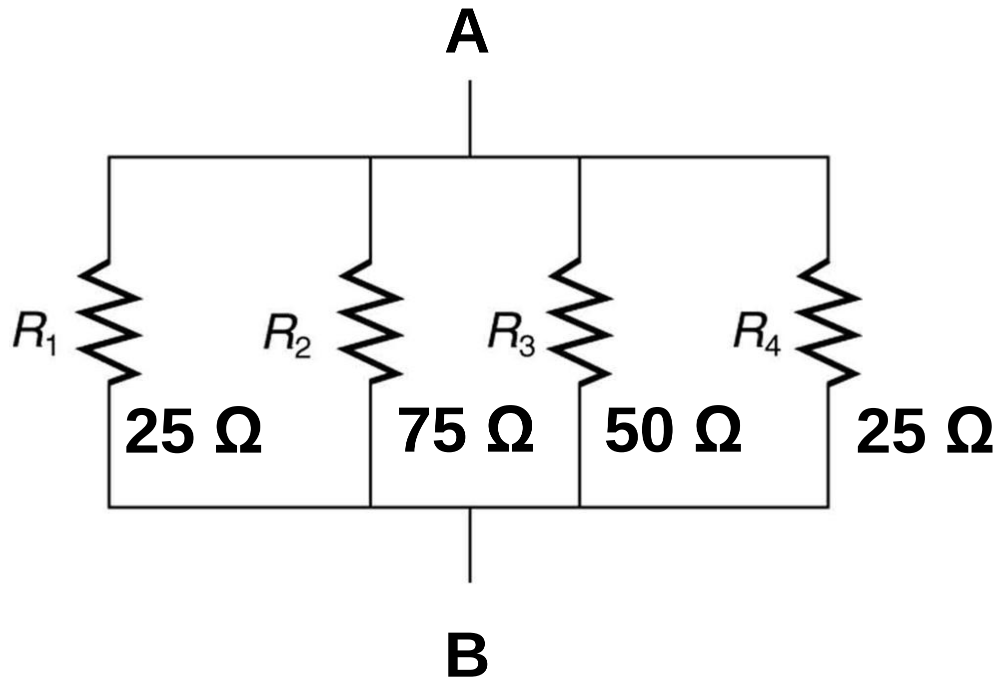
Resistors in Parallel



$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3 + 1/R_4$
$1/R_{Total} = 1/25 + 1/75 + 1/50 + 1/25$

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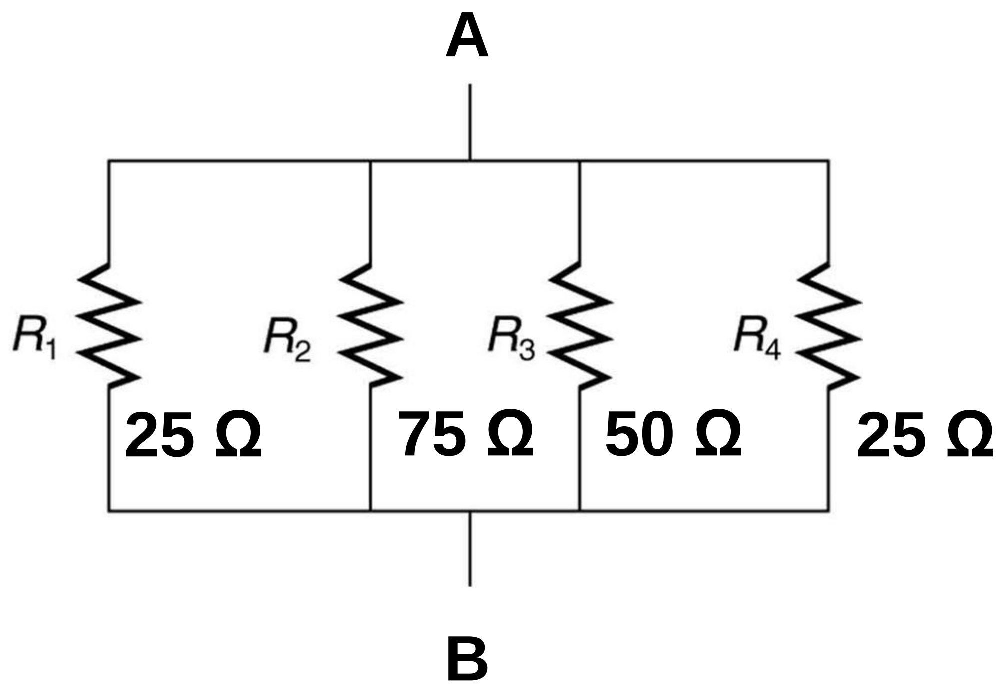
Resistors in Parallel



$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3 + 1/R_4$
$1/R_{Total} = 1/25 + 1/75 + 1/50 + 1/25 = 6/150 + 2/150 + 3/150 + 6/150$

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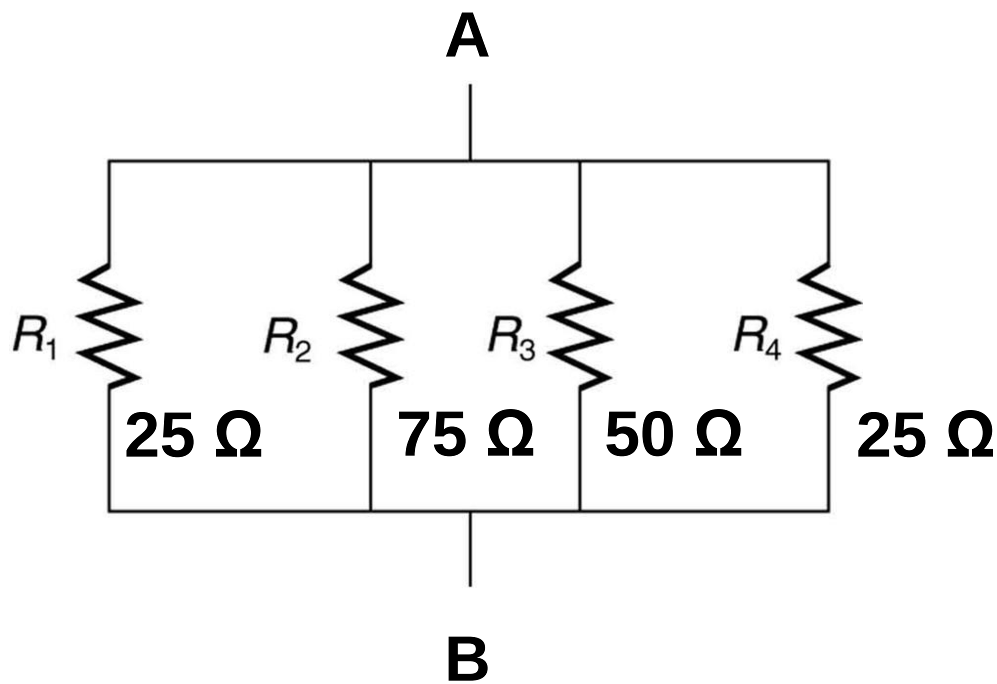
Resistors in Parallel



$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3 + 1/R_4$
$1/R_{Total} = 1/25 + 1/75 + 1/50 + 1/25 = 6/150 + 2/150 + 3/150 + 6/150$
$1/R_{Total} = 17/150\ \Omega$

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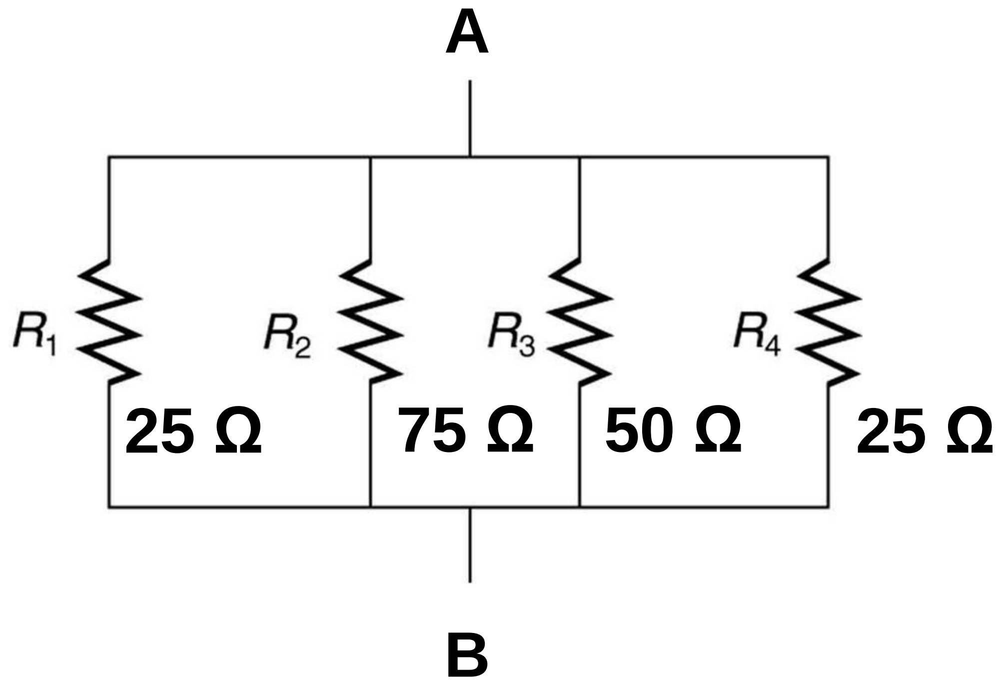
Resistors in Parallel



$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3 + 1/R_4$
$1/R_{Total} = 1/25 + 1/75 + 1/50 + 1/25 = 6/150 + 2/150 + 3/150 + 6/150$
$1/R_{Total} = 17/150\ \Omega$

$R_{Total} = 150/17\ \Omega = 8.82\ \Omega$

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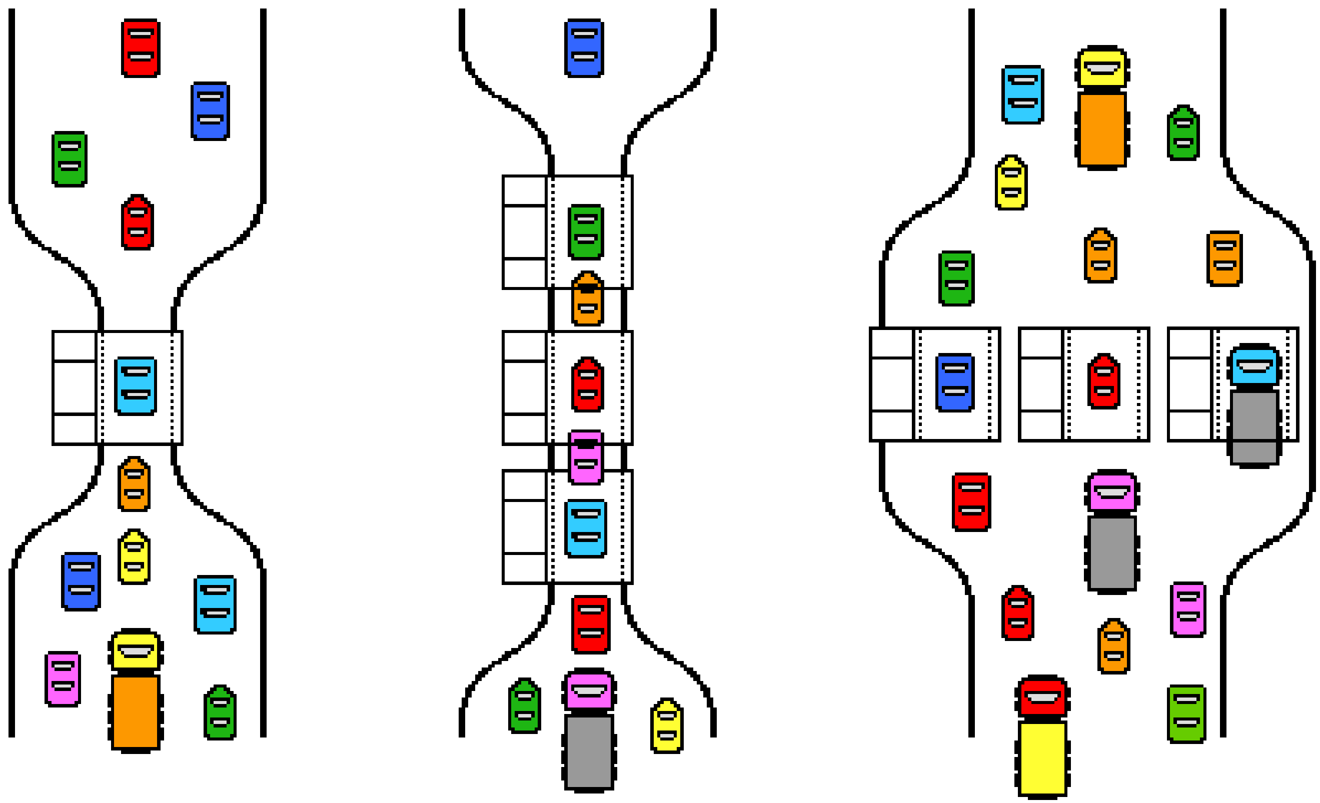
Influencing the Flow Rate on a Tollway



A Single Resistor

Three Resistors
Placed in Series

Three Resistors
Placed in Parallel

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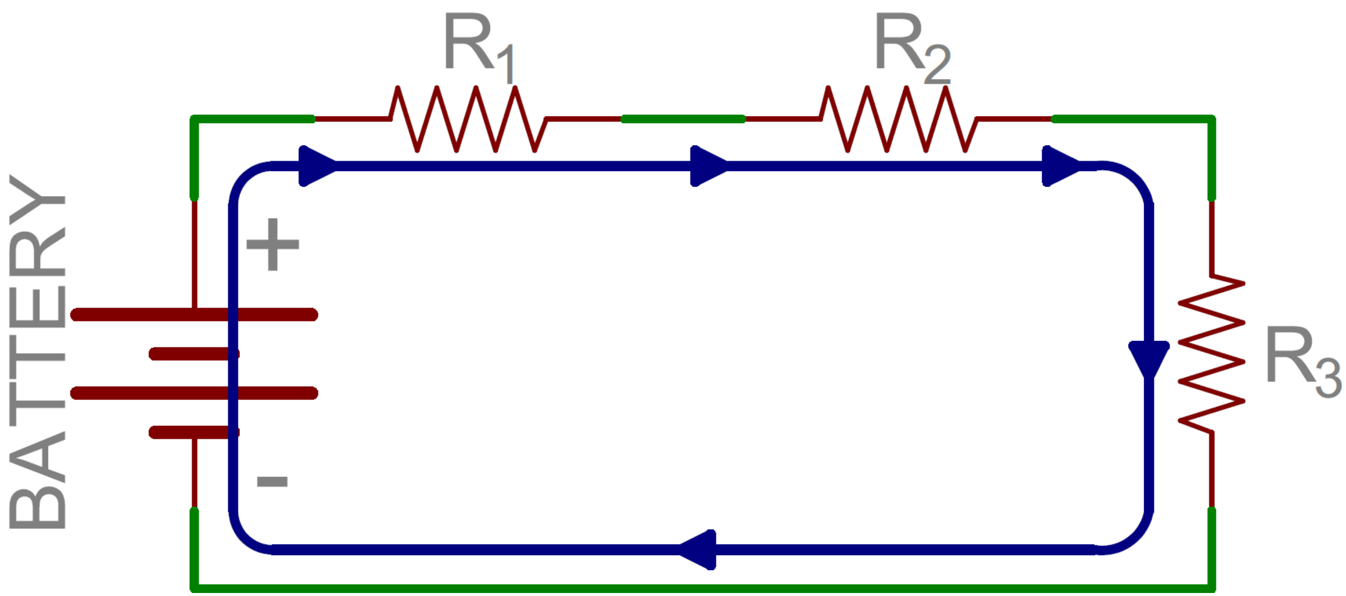
Current in a Series Circuit

- The current through each resistor in a Series Circuit is identical.



$$I_{Total} = I_{R1} = I_{R2} = I_{R3}$$

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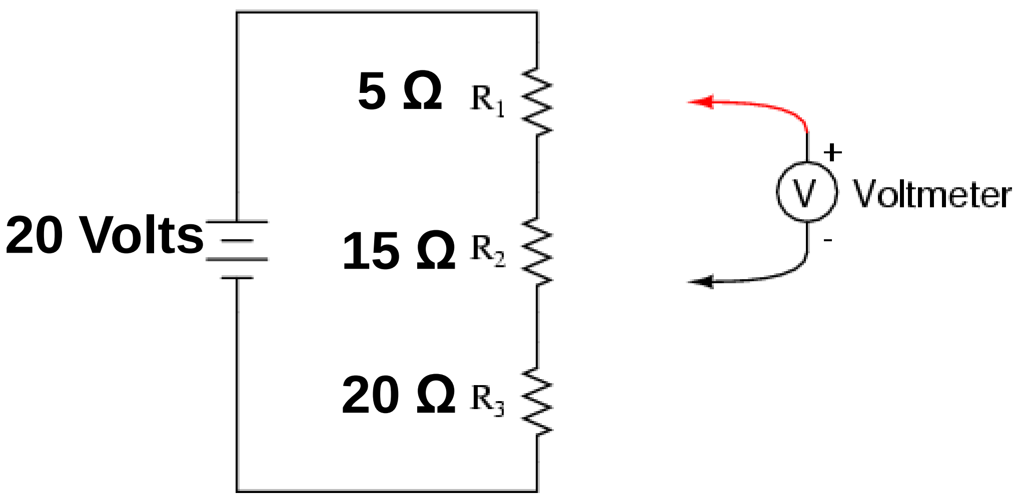
Voltage in Series Circuits

- The sum of all the voltages across each resistor in a Series Circuit will equal the source voltage.



$$E_{source} = E_{R1} + E_{R2} + E_{R3}$$

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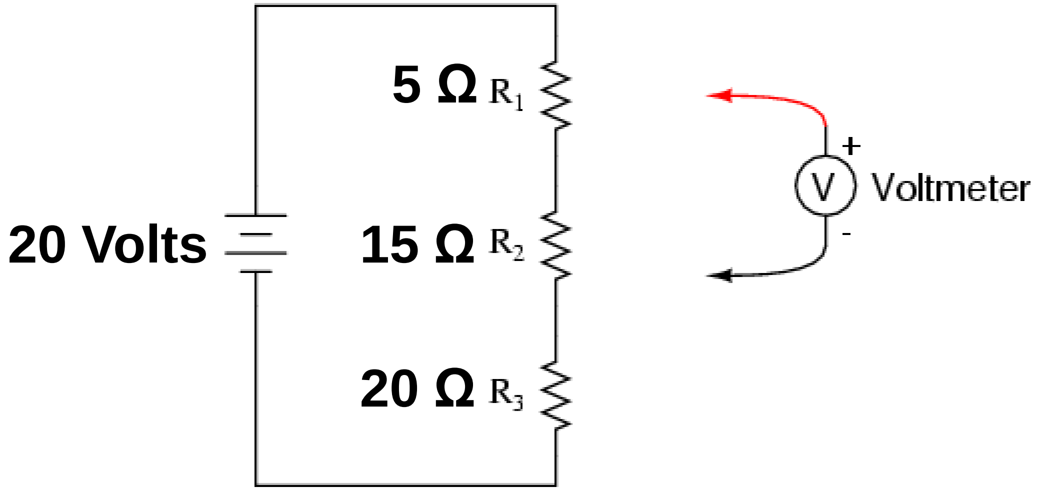
To Calculate Voltage Drop…



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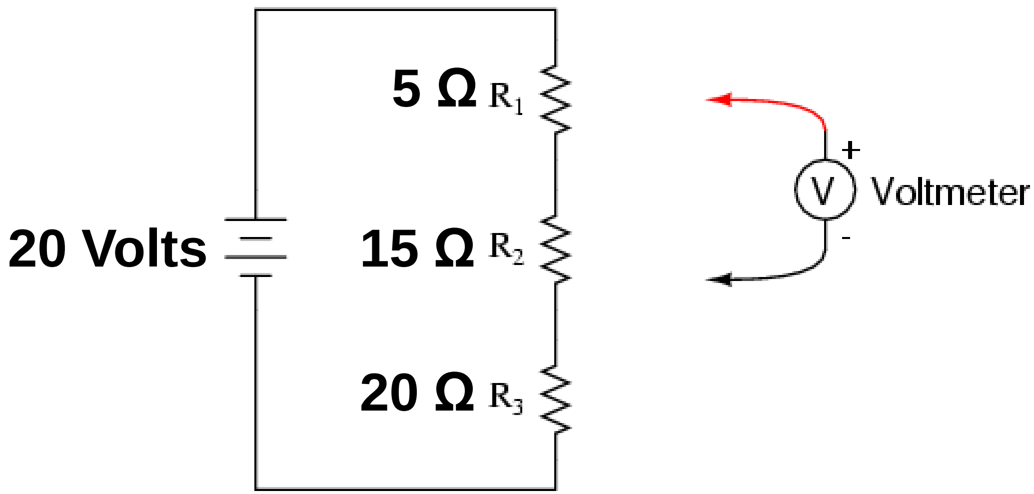
1. Determine Total Resistance



$$R_{Total} = R_1 + R_2 + R_3$$
$$R_{Total} =$$

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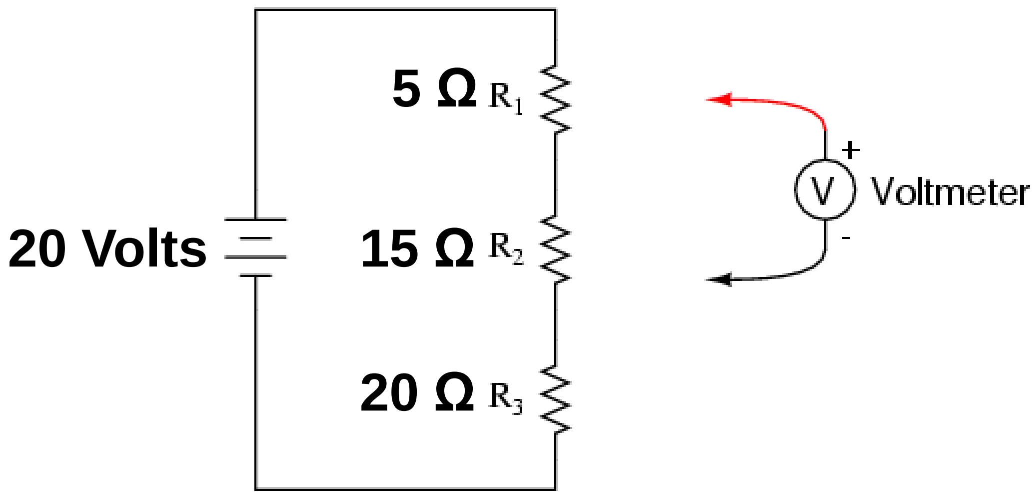
1. Determine Total Resistance



$R_{Total} = R_1 + R_2 + R_3$

$R_{Total} = 5\ \Omega + 15\ \Omega + 20\ \Omega$

$R_{Total} = 40\ \Omega$

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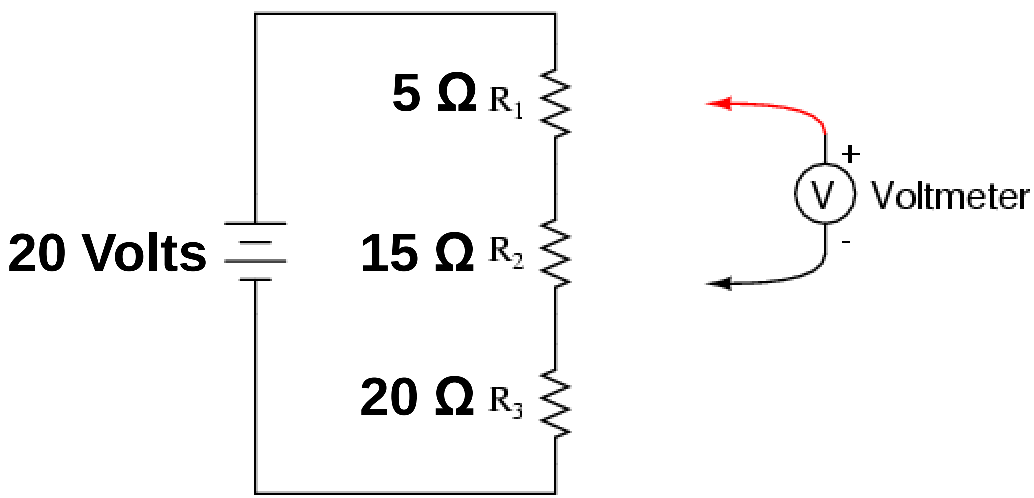
2. Determine Current



$R_{Total} = R_1 + R_2 + R_3$
$R_{Total} = 5\ \Omega + 15\ \Omega + 20\ \Omega$
$R_{Total} = 40\ \Omega$

$I = E / R$
$I =$

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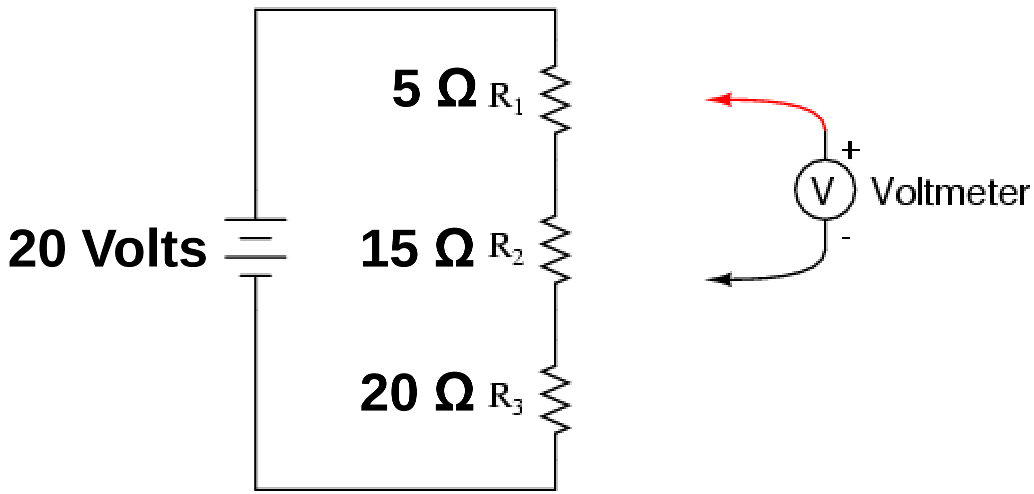
2. Determine Current



$R_{Total} = R_1 + R_2 + R_3$
$R_{Total} = 5\ \Omega + 15\ \Omega + 20\ \Omega$
$R_{Total} = 40\ \Omega$

I = E / R
I = 20 Volts / 40 Ohms
I = 0.5 Amps

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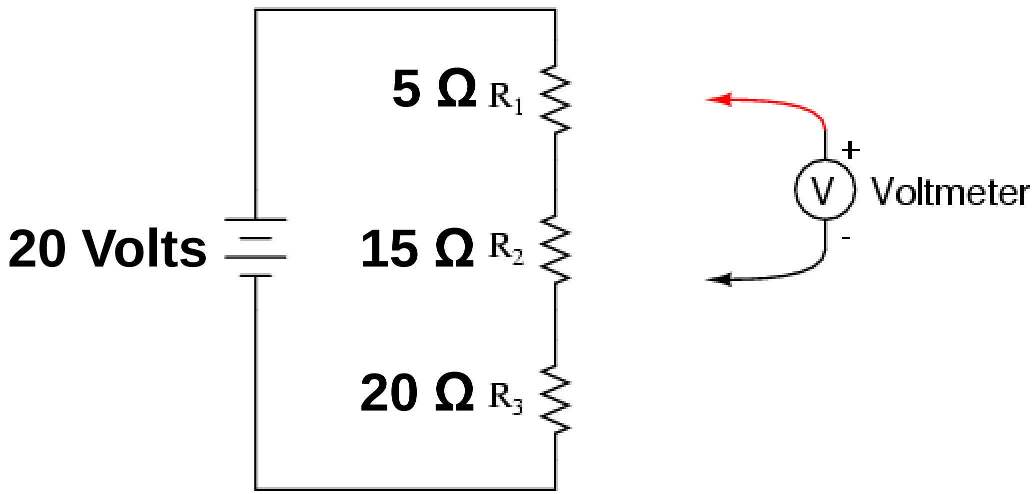
3. Determine Voltage Drops



$R_{Total} = R_1 + R_2 + R_3$
$R_{Total} = 5\ \Omega + 15\ \Omega + 20\ \Omega$
$R_{Total} = 40\ \Omega$

$I = E / R$
$I = 20$ Volts / 40 Ohms
$I = 0.5$ Amps

$E_{R1} = I \times R_1$
$E_{R1} =$

$E_{R2} = I \times R_2$
$E_{R2} =$

$E_{R3} = I \times R_3$
$E_{R3} =$

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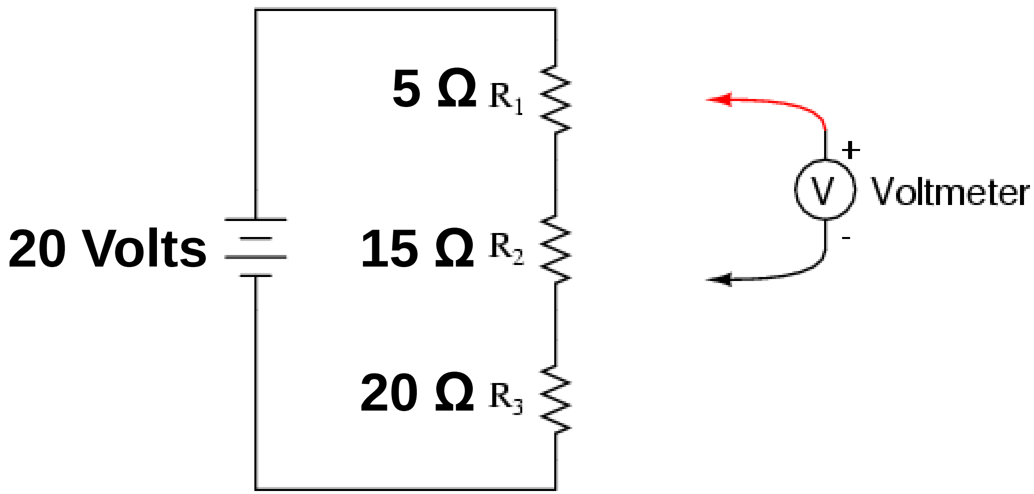
3. Determine Voltage Drops



$R_{Total} = R_1 + R_2 + R_3$
$R_{Total} = 5\ \Omega + 15\ \Omega + 20\ \Omega$
$R_{Total} = 40\ \Omega$

$I = E / R$
$I = 20$ Volts / 40 Ohms
$I = 0.5$ Amps

$E_{R1} = I \times R_1$
$E_{R1} = 0.5$ Amps x 5 Ω
$E_{R1} = 2.5$ Volts

$E_{R2} = I \times R_2$
$E_{R2} = 0.5$ Amps x 15 Ω
$E_{R2} = 7.5$ Volts

$E_{R3} = I \times R_3$
$E_{R3} = 0.5$ Amps x 20 Ω
$E_{R3} = 10$ Volts

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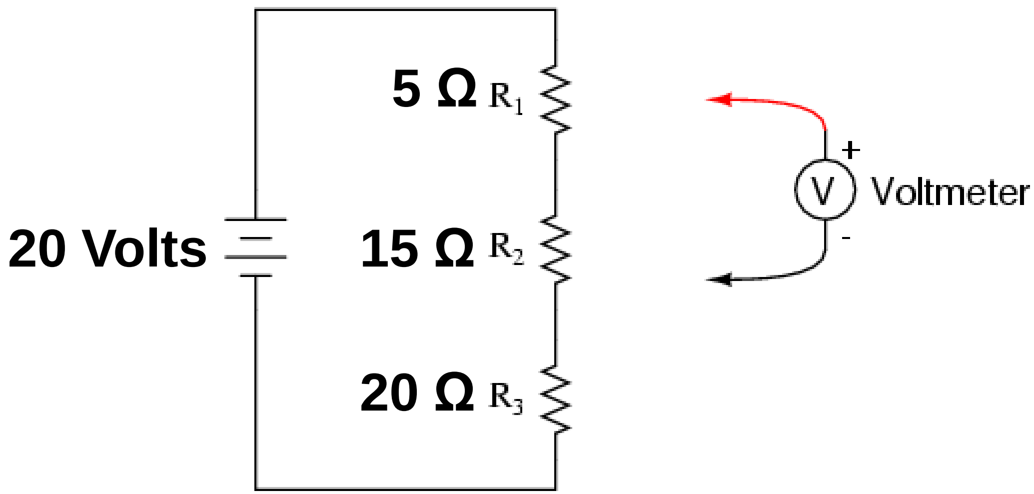
4. Check Your Results!



$R_{Total} = R_1 + R_2 + R_3$
$R_{Total} = 5\ \Omega + 15\ \Omega + 20\ \Omega$
$R_{Total} = 40\ \Omega$

$I = E / R$
$I = 20$ Volts / 40 Ohms
$I = 0.5$ Amps

$E_{R1} = I \times R_1$
$E_{R1} = 0.5$ Amps x $5\ \Omega$
$E_{R1} = 2.5$ Volts

$E_{R2} = I \times R_2$
$E_{R2} = 0.5$ Amps x $15\ \Omega$
$E_{R2} = 7.5$ Volts

$E_{R3} = I \times R_3$
$E_{R3} = 0.5$ Amps x $20\ \Omega$
$E_{R3} = 10$ Volts

$$E_{source} = E_{R1} + E_{R2} + E_{R3}$$
$$E_{source} = 2.5V + 7.5V + 10V = 20V$$

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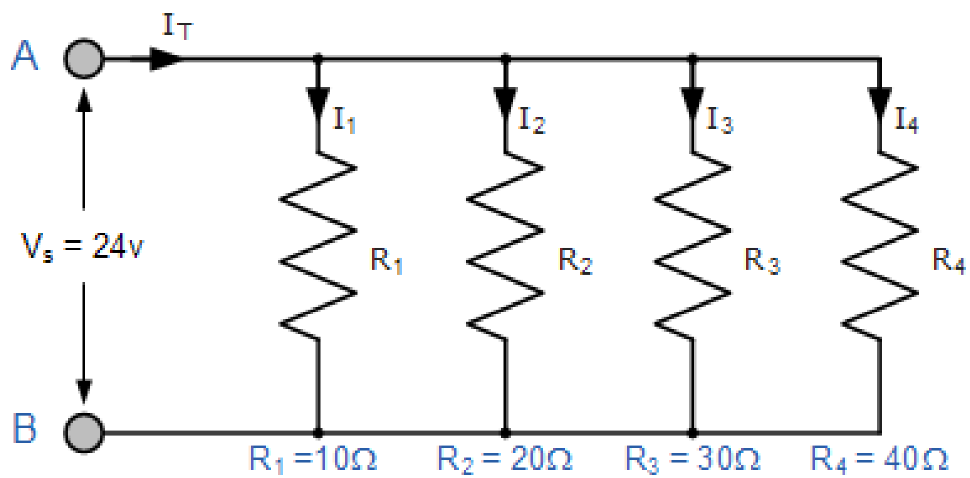
Voltage in Parallel Circuits

- The voltage applied to each resistor in a Parallel Circuit is the same as the source voltage.



$$E_{source} = E_{R1} = E_{R2} = E_{R3} = E_{R4}$$

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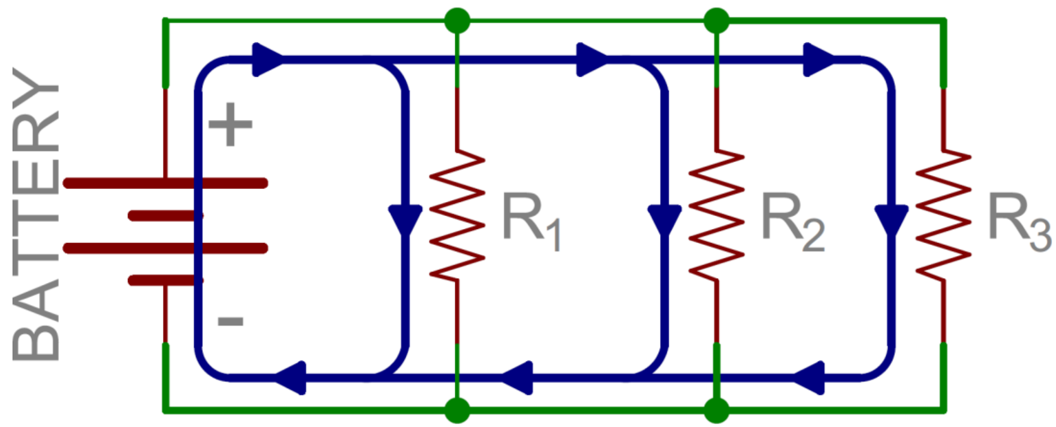
Current in a Parallel Circuit

- The total current in a Parallel Circuit is divided among the resistors.
- The sum of the currents through each resistor equals the total current.



$$I_{Total} = I_{R1} + I_{R2} + I_{R3}$$

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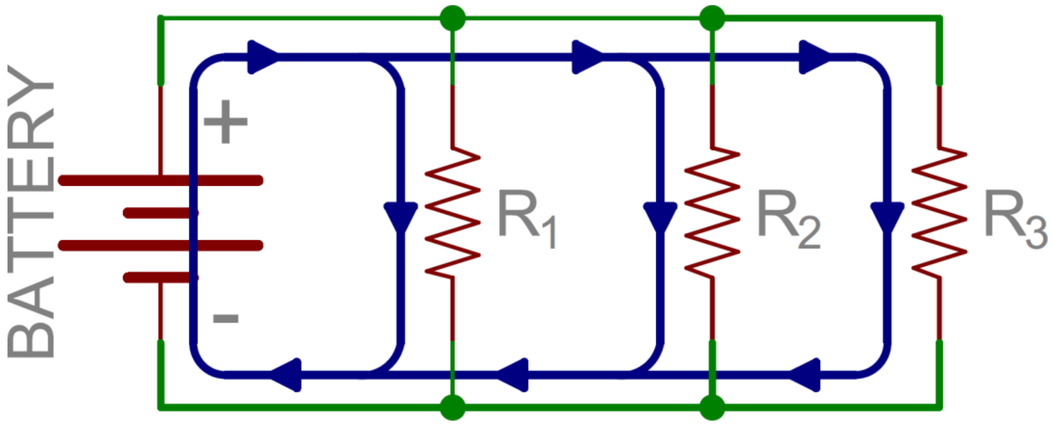
To Calculate Currents…



100 Volts 500 Ω 500 Ω 1KΩ

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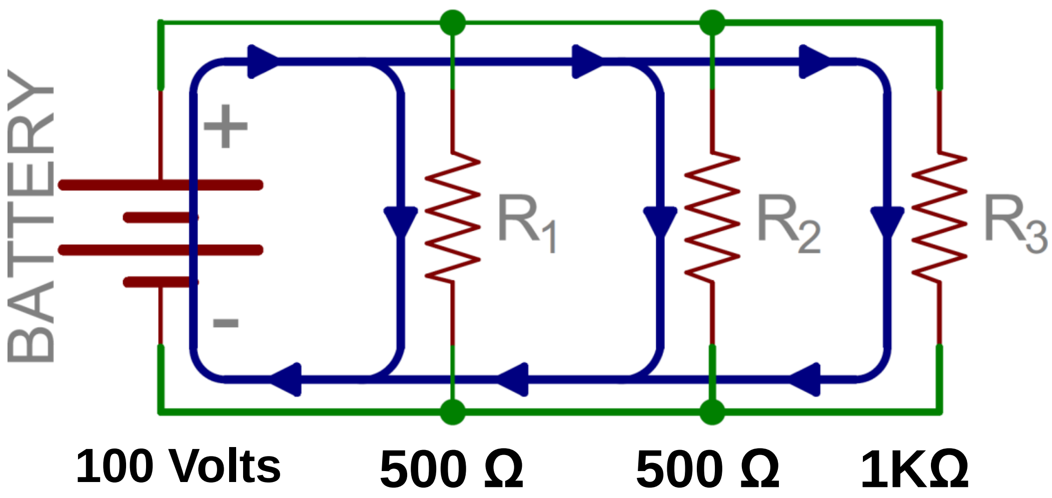
Determine Equivalent Resistance



$1/R_{Total}$ =

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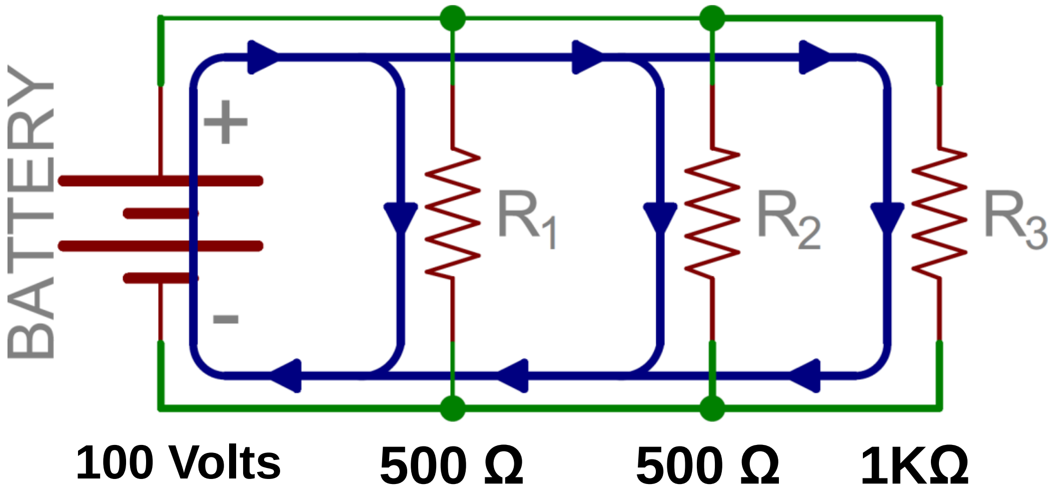
Determine Equivalent Resistance



$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3$

$1/R_{Total} = 1/500 + 1/500 + 1/1K$

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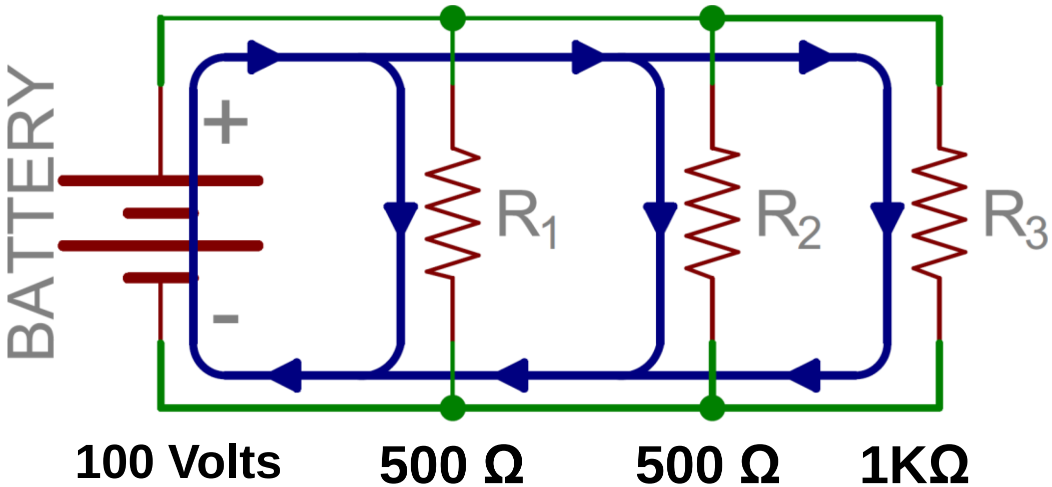
Determine Equivalent Resistance



$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3$

$1/R_{Total} = 1/500 + 1/500 + 1/1K$

$1/R_{Total} = 2/1000 + 2/1000 + 1/1000$

$1/R_{Total} = 5/1000$

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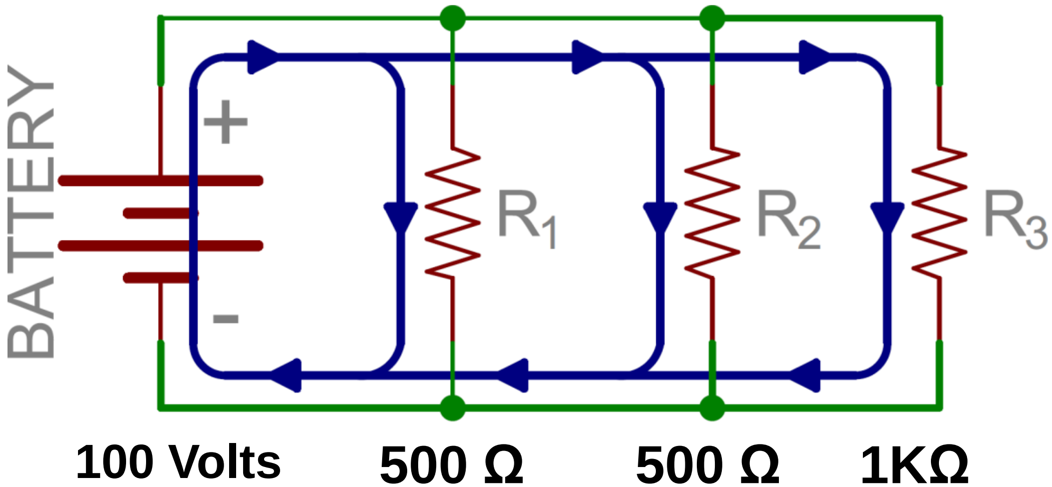
Determine Equivalent Resistance



$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3$

$1/R_{Total} = 1/500 + 1/500 + 1/1K$

$1/R_{Total} = 2/1000 + 2/1000 + 1/1000$

$1/R_{Total} = 5/1000$

$R_{Total} = 1000/5 = 200\ \Omega$

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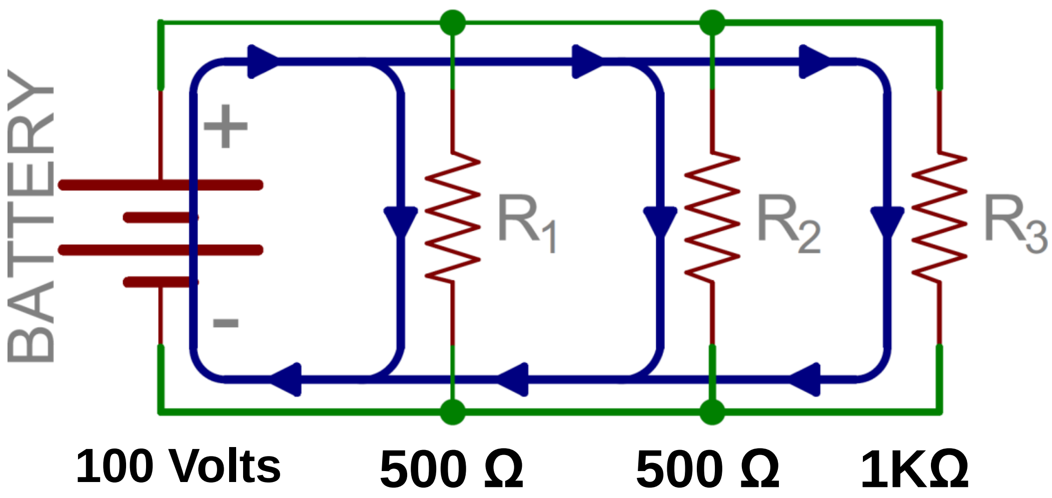
Determine Overall Current



$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3$
$1/R_{Total} = 1/500 + 1/500 + 1/1K$
$1/R_{Total} = 2/1000 + 2/1000 + 1/1000$
$1/R_{Total} = 5/1000$

$R_{Total} = 1000/5 = 200\ \Omega$

I =

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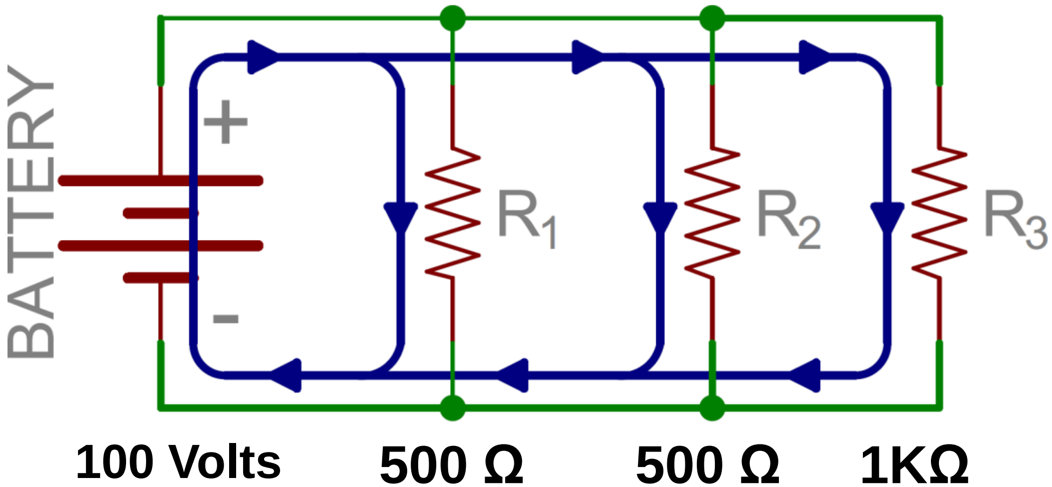
Determine Overall Current



$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3$

$1/R_{Total} = 1/500 + 1/500 + 1/1K$

$1/R_{Total} = 2/1000 + 2/1000 + 1/1000$

$1/R_{Total} = 5/1000$

$R_{Total} = 1000/5 = 200\ \Omega$

$I = E / R$

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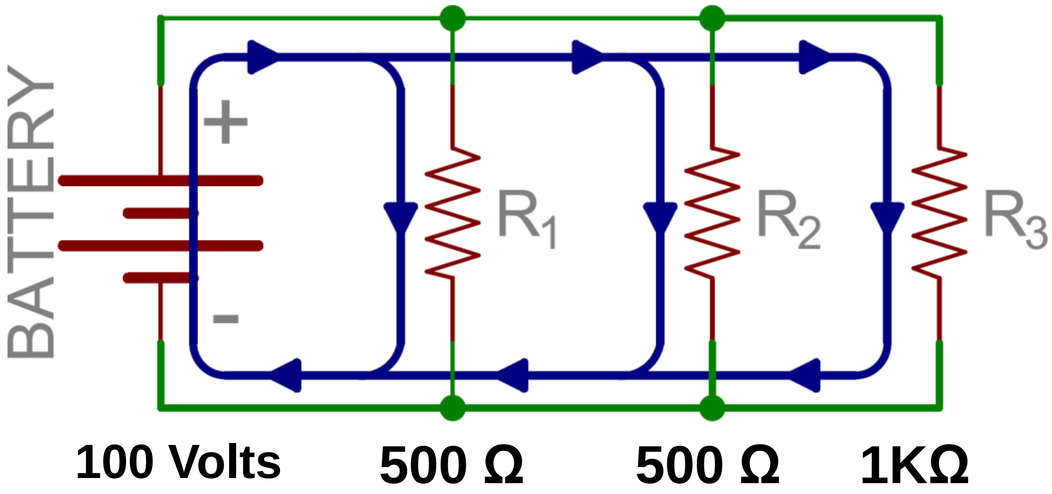
Determine Overall Current



$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3$

$1/R_{Total} = 1/500 + 1/500 + 1/1K$

$1/R_{Total} = 2/1000 + 2/1000 + 1/1000$

$1/R_{Total} = 5/1000$

$R_{Total} = 1000/5 = 200\ \Omega$

$I = E / R$

$I = 100\ V / 200\ \Omega$

$I = 0.5$ Amps

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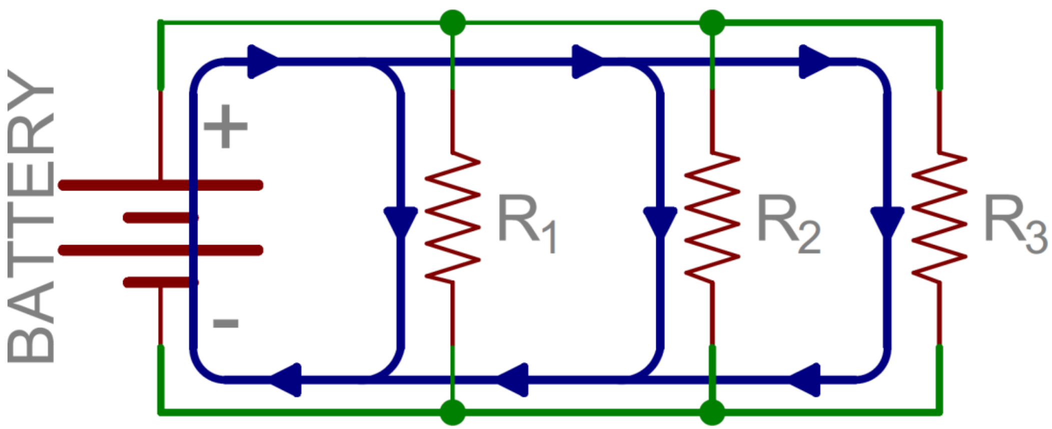
Determine Individual Currents



100 Volts 500 Ω 500 Ω 1KΩ

$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3$

$1/R_{Total} = 1/500 + 1/500 + 1/1K$

$1/R_{Total} = 2/1000 + 2/1000 + 1/1000$

$1/R_{Total} = 5/1000$

$R_{Total} = 1000/5 = 200\ \Omega$

$I = E / R$

$I = 100\ V / 200\ \Omega$

$I = 0.5$ Amps

$I_{R1} =$

$I_{R2} =$

$I_{R3} =$

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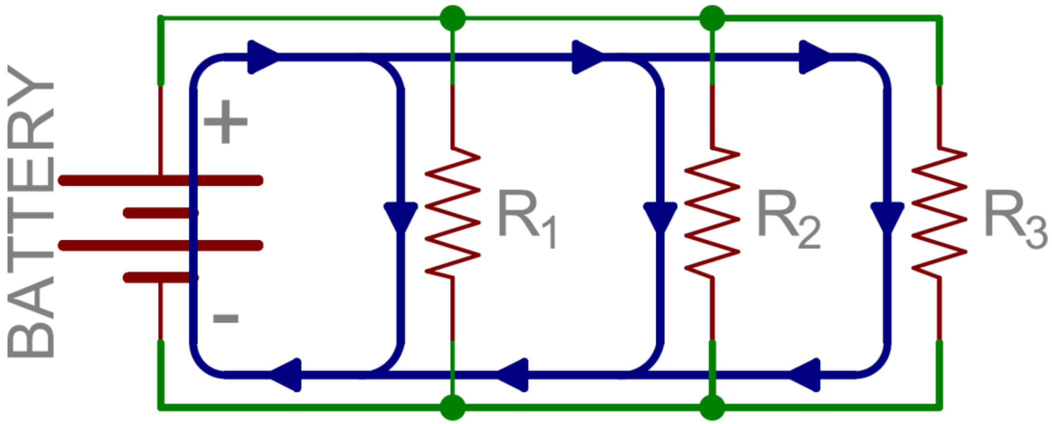
Determine Individual Currents



100 Volts   500 Ω   500 Ω   1KΩ

$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3$
$1/R_{Total} = 1/500 + 1/500 + 1/1K$
$1/R_{Total} = 2/1000 + 2/1000 + 1/1000$
$1/R_{Total} = 5/1000$

$R_{Total} = 1000/5 = 200\ \Omega$

$I = E / R$
$I = 100\ V / 200\ \Omega$
$I = 0.5$ Amps

$I_{R1} = E / R_1$ **$I_{R2} = E / R_2$**   **$I_{R3} = E / R_3$**

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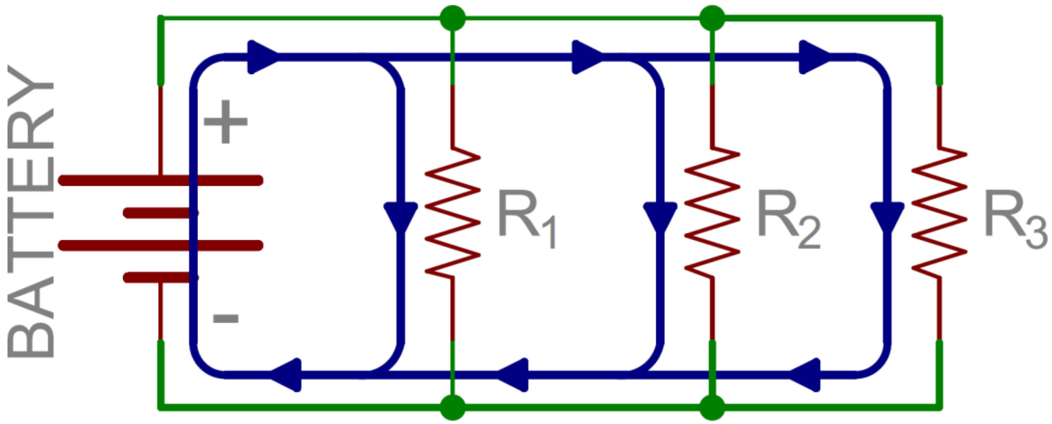
Determine Individual Currents



100 Volts 500 Ω 500 Ω 1KΩ

$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3$
$1/R_{Total} = 1/500 + 1/500 + 1/1K$
$1/R_{Total} = 2/1000 + 2/1000 + 1/1000$
$1/R_{Total} = 5/1000$

$R_{Total} = 1000/5 = 200\ \Omega$

$I = E / R$
$I = 100\ V / 200\ \Omega$
$I = 0.5$ Amps

$I_{R1} = E / R_1$
$I_{R1} = 100\ V / 500\ \Omega$
$I_{R1} =$

$I_{R2} = E / R_2$
$I_{R2} = 100\ V / 500\ \Omega$
$I_{R2} =$

$I_{R3} = E / R_3$
$I_{R3} = 100\ V / 1000\ \Omega$
$I_{R3} =$

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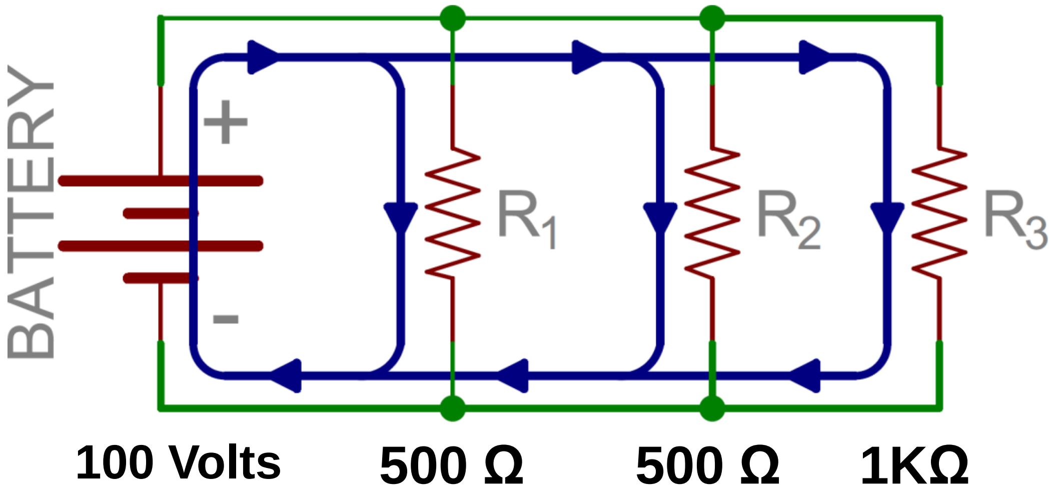
Determine Individual Currents



$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3$

$1/R_{Total} = 1/500 + 1/500 + 1/1K$

$1/R_{Total} = 2/1000 + 2/1000 + 1/1000$

$1/R_{Total} = 5/1000$

$R_{Total} = 1000/5 = 200\ \Omega$

$I = E / R$

$I = 100\ V / 200\ \Omega$

$I = 0.5$ Amps

$I_{R1} = E / R_1$

$I_{R1} = 100\ V / 500\ \Omega$

$I_{R1} = 0.2$ Amps

$I_{R2} = E / R_2$

$I_{R2} = 100\ V / 500\ \Omega$

$I_{R2} = 0.2$ Amps

$I_{R3} = E / R_3$

$I_{R3} = 100\ V / 1000\ \Omega$

$I_{R3} = 0.1$ Amps

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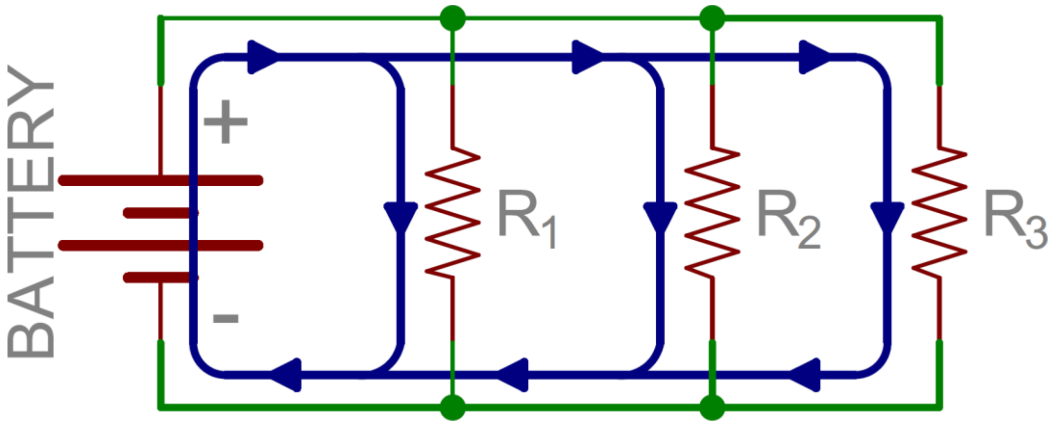
Check your Answer!



100 Volts 500 Ω 500 Ω 1KΩ

$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3$
$1/R_{Total} = 1/500 + 1/500 + 1/1K$
$1/R_{Total} = 2/1000 + 2/1000 + 1/1000$
$1/R_{Total} = 5/1000$

$R_{Total} = 1000/5 = 200\ \Omega$

$I = E / R$
$I = 100\ V / 200\ \Omega$
$I = 0.5$ Amps

$I_{R1} = E / R_1$
$I_{R1} = 100\ V / 500\ \Omega$
$I_{R1} = 0.2$ Amps

$I_{R2} = E / R_2$
$I_{R2} = 100\ V / 500\ \Omega$
$I_{R2} = 0.2$ Amps

$I_{R3} = E / R_3$
$I_{R3} = 100\ V / 1000\ \Omega$
$I_{R3} = 0.1$ Amps

$I_{Total} =$

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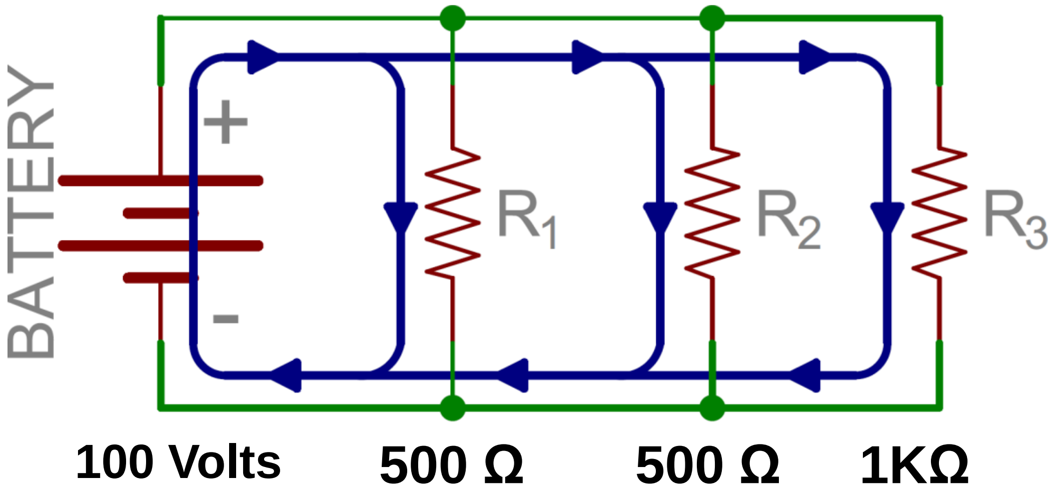
Check your Answer!



$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3$
$1/R_{Total} = 1/500 + 1/500 + 1/1K$
$1/R_{Total} = 2/1000 + 2/1000 + 1/1000$
$1/R_{Total} = 5/1000$

$R_{Total} = 1000/5 = 200\ \Omega$

$I = E / R$
$I = 100\ V / 200\ \Omega$
$I = 0.5$ Amps

$I_{R1} = E / R_1$
$I_{R1} = 100\ V / 500\ \Omega$
$I_{R1} = 0.2$ Amps

$I_{R2} = E / R_2$
$I_{R2} = 100\ V / 500\ \Omega$
$I_{R2} = 0.2$ Amps

$I_{R3} = E / R_3$
$I_{R3} = 100\ V / 1000\ \Omega$
$I_{R3} = 0.1$ Amps

$I_{Total} = I_{R1} + I_{R2} + I_{R3} =$

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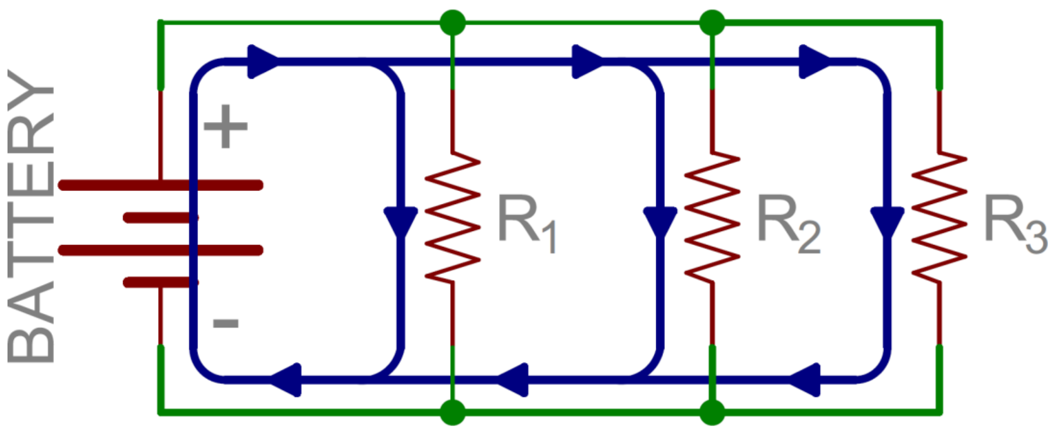
VO1NO

Check your Answer!



100 Volts　　500 Ω　　500 Ω　　1KΩ

$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3$
$1/R_{Total} = 1/500 + 1/500 + 1/1K$
$1/R_{Total} = 2/1000 + 2/1000 + 1/1000$
$1/R_{Total} = 5/1000$

$R_{Total} = 1000/5 = 200\ \Omega$

$I = E / R$
$I = 100\ V / 200\ \Omega$
$I = 0.5$ Amps

$I_{R1} = E / R_1$
$I_{R1} = 100\ V / 500\ \Omega$
$I_{R1} = 0.2$ Amps

$I_{R2} = E / R_2$
$I_{R2} = 100\ V / 500\ \Omega$
$I_{R2} = 0.2$ Amps

$I_{R3} = E / R_3$
$I_{R3} = 100\ V / 1000\ \Omega$
$I_{R3} = 0.1$ Amps

$I_{Total} = I_{R1} + I_{R2} + I_{R3} = 0.2 + 0.2 + 0.1 = 0.5$ Amp

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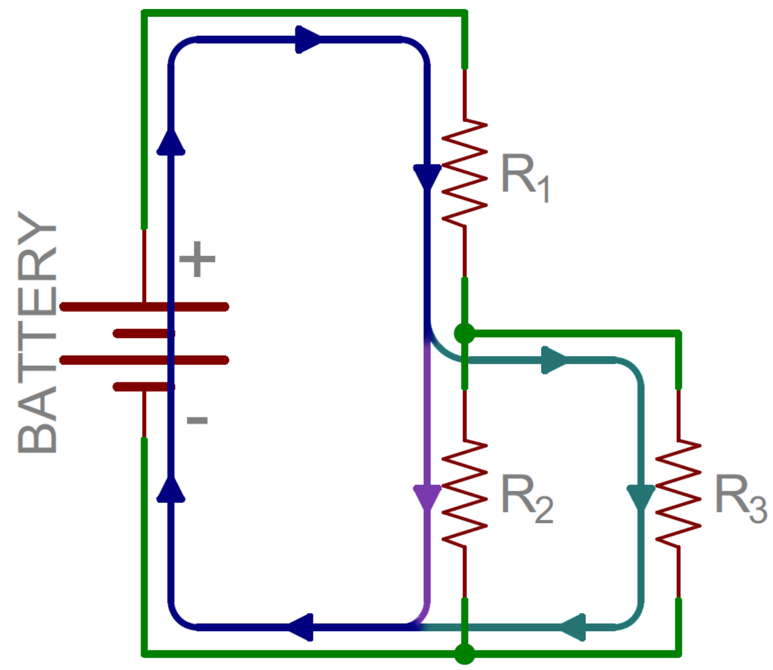
Series Parallel Combinations



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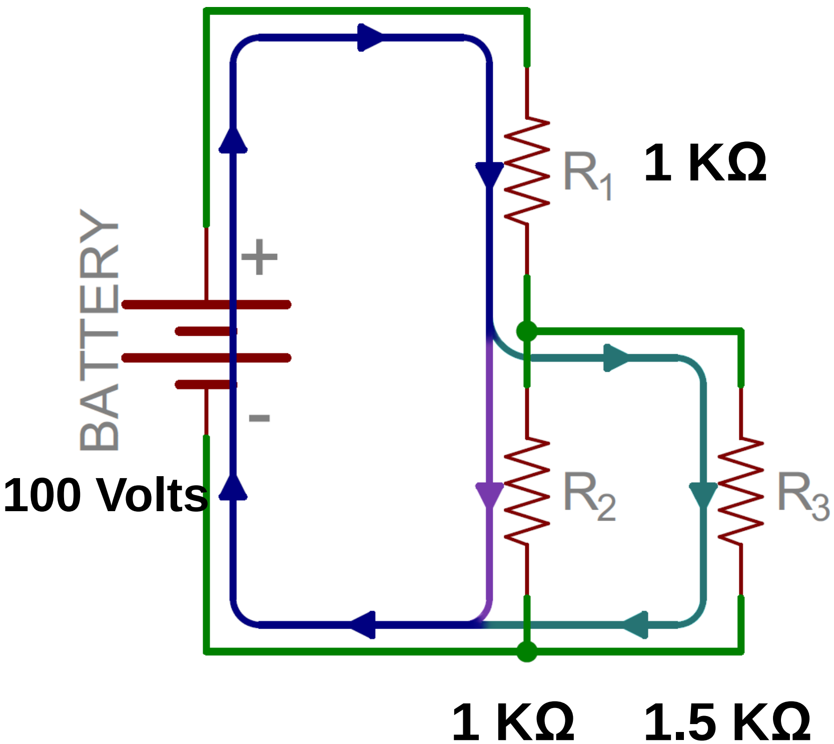
Series Parallel Combinations



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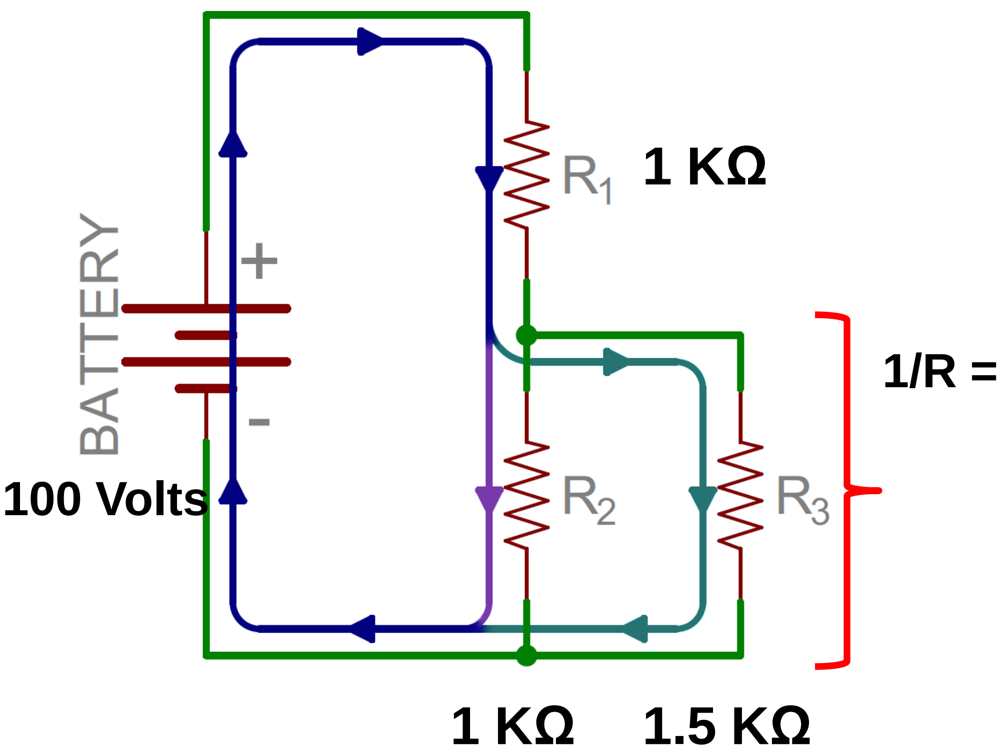
VO1NO

Series Parallel Combinations



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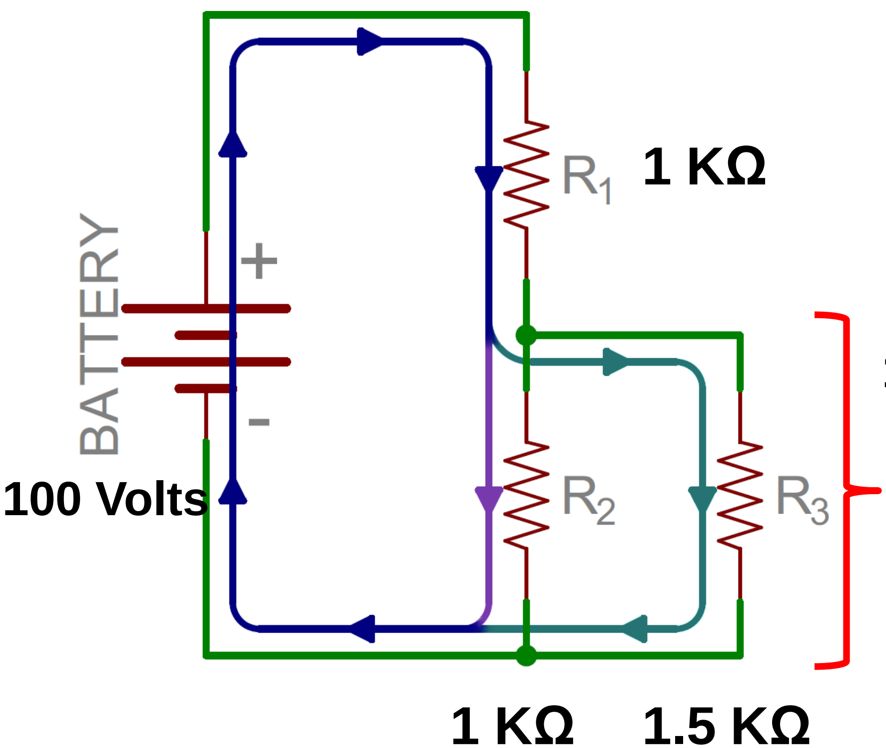
VO1NO

Series Parallel Combinations



$1/R = 1/R_2 + 1/R_3$

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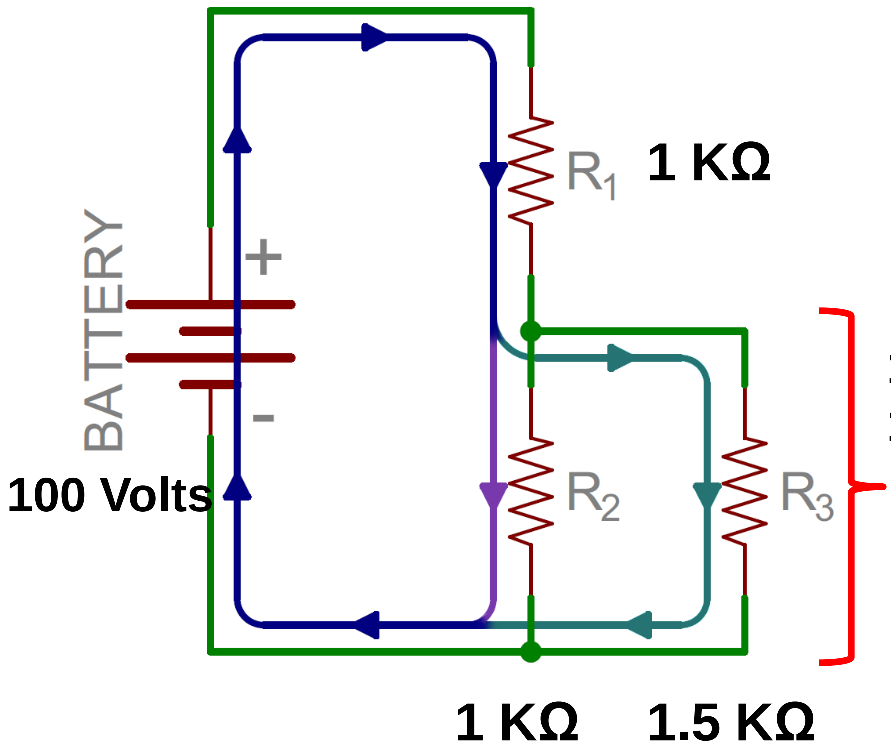
Series Parallel Combinations



$1/R = 1/R_1 + 1/R_2$

$1/R = 1/1\ K + 1/1.5\ K$

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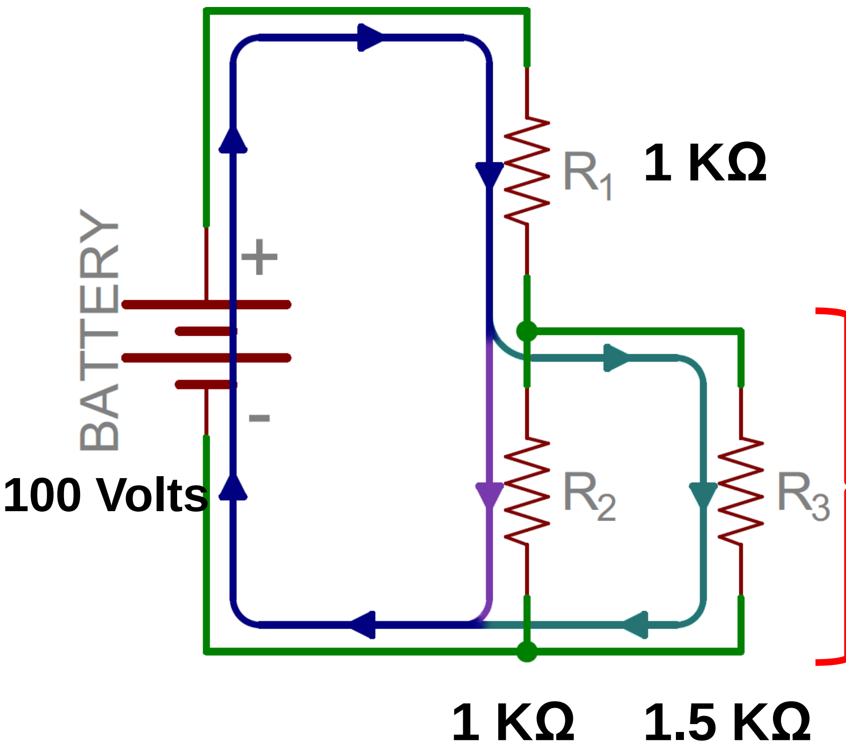
Series Parallel Combinations



$1/R = 1/R_1 + 1/R_2$

$1/R = 1/1\ K + 1/1.5\ K$

$1/R = 3/3\ K + 2/3\ K$

$1/R = 5/3\ K$

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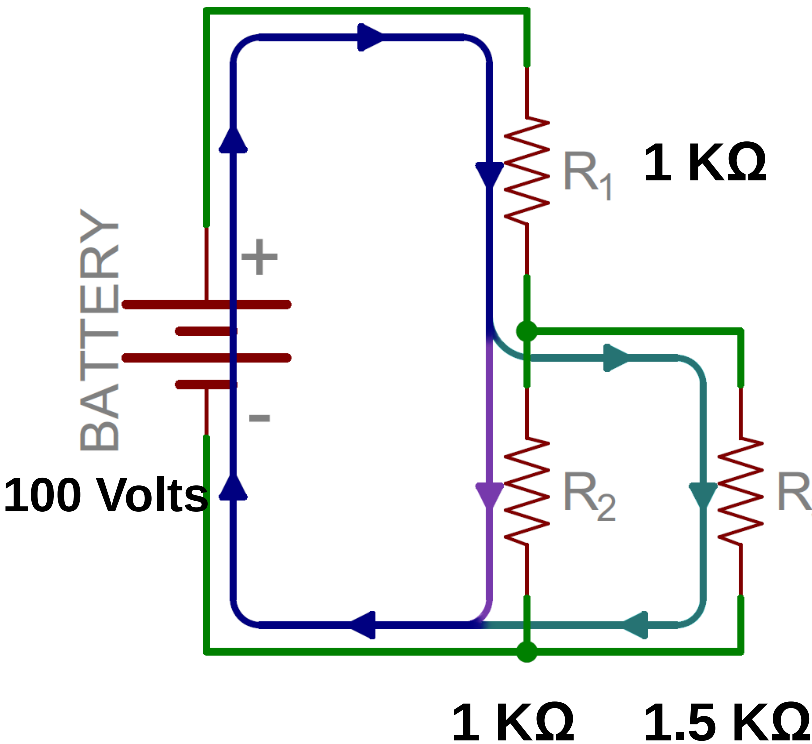
VO1NO

Series Parallel Combinations



$1/R = 1/R_1 + 1/R_2$

$1/R = 1/1\ K + 1/1.5\ K$

$1/R = 3/3\ K + 2/3\ K$

$1/R = 5/3\ K$

$R = 3000/5 = 600\ \Omega$

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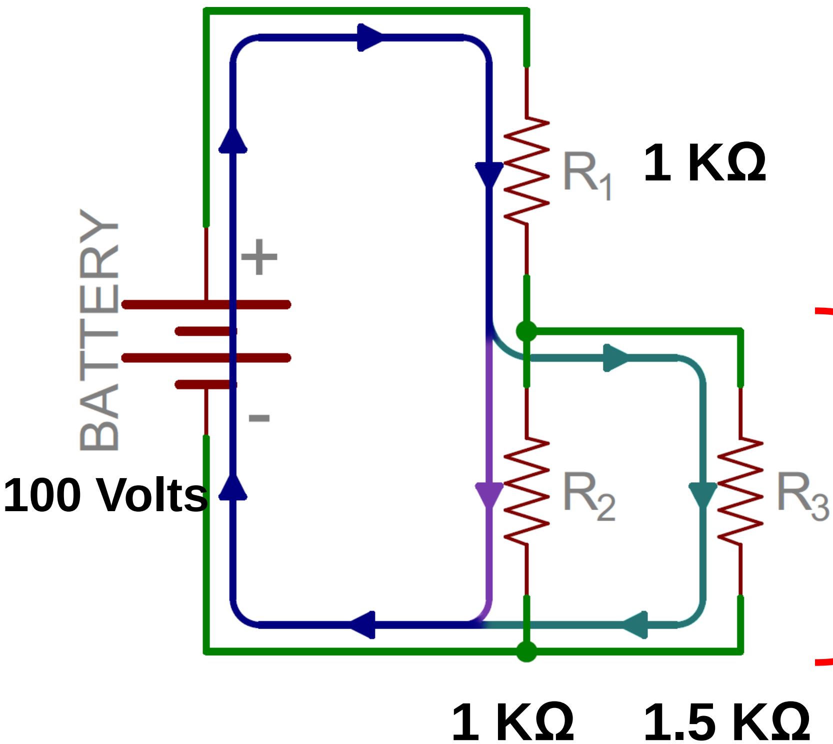
VO1NO

Series Parallel Combinations



$1/R = 1/R_1 + 1/R_2$

$1/R = 1/1\ K + 1/1.5\ K$

$1/R = 3/3\ K + 2/3\ K$

$1/R = 5/3\ K$

$R = 3000/5 = 600\ \Omega$

$R_{Total} =$

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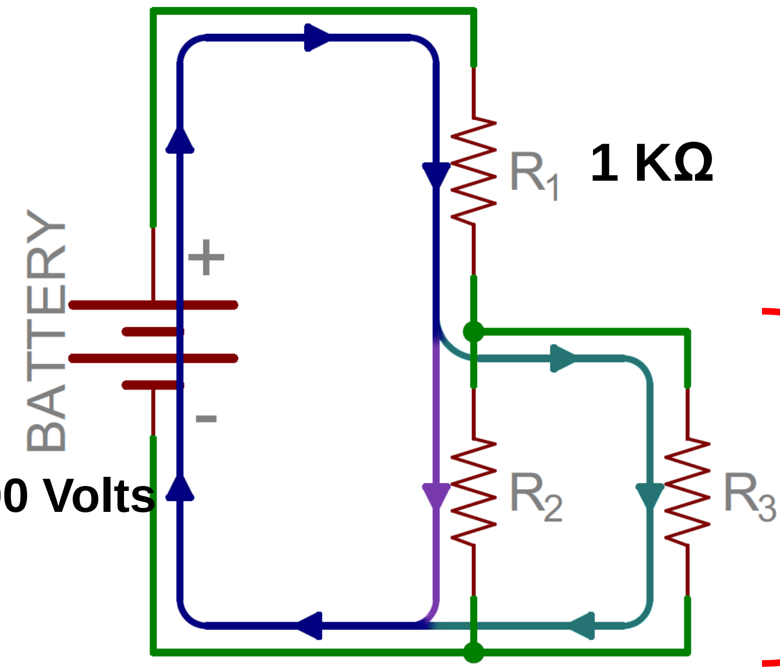
Series Parallel Combinations



1 KΩ

100 Volts

1 KΩ   1.5 KΩ

$1/R = 1/R_1 + 1/R_2$
$1/R = 1/1\ K + 1/1.5\ K$
$1/R = 3/3\ K + 2/3\ K$
$1/R = 5/3\ K$

$R = 3000/5 = 600\ \Omega$

$R_{Total} = 1\ K\Omega + 600\ \Omega$

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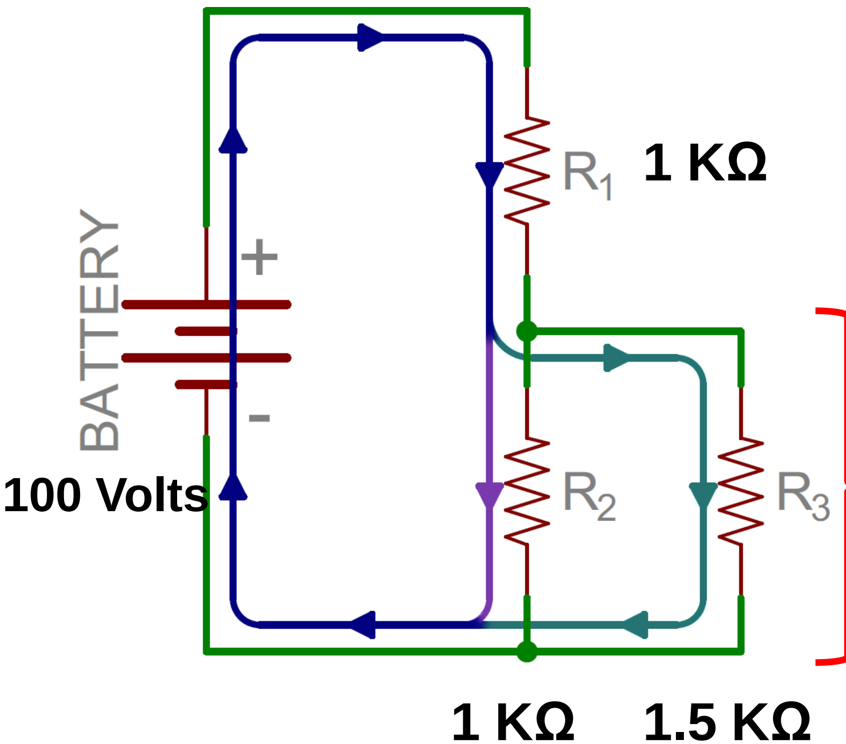
Series Parallel Combinations



$1/R = 1/R_1 + 1/R_2$
$1/R = 1/1\text{ K} + 1/1.5\text{ K}$
$1/R = 3/3\text{ K} + 2/3\text{ K}$
$1/R = 5/3\text{ K}$

$R = 3000/5 = 600\ \Omega$

$R_{Total} = 1\text{ K}\Omega + 600\ \Omega$
$R_{Total} = 1600\ \Omega$

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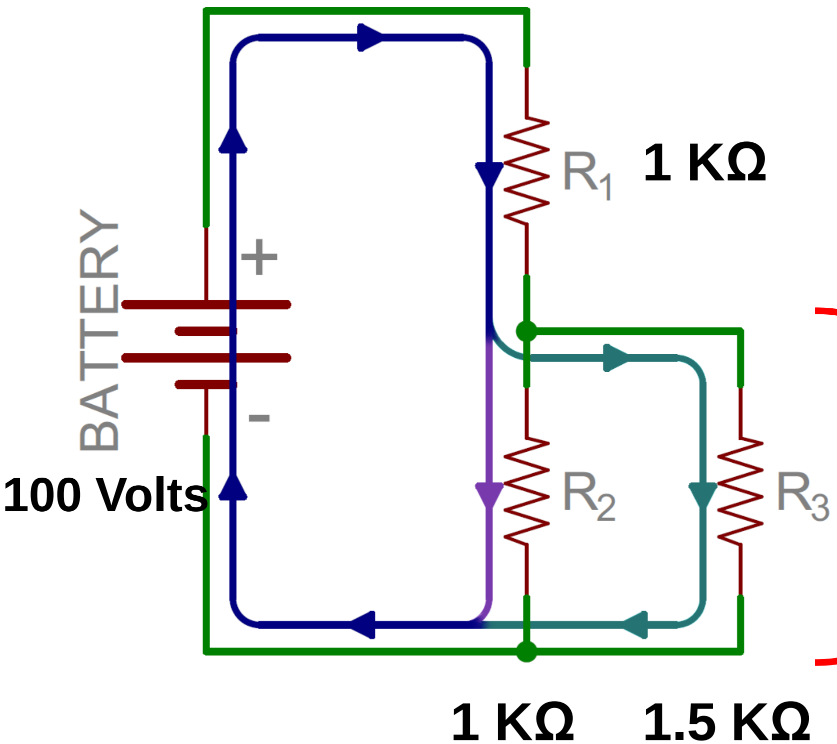
Series Parallel Combinations



$1/R = 1/R_1 + 1/R_2$

$1/R = 1/1\ K + 1/1.5\ K$

$1/R = 3/3\ K + 2/3\ K$

$1/R = 5/3\ K$

$R = 3000/5 = 600\ \Omega$

$R_{Total} = 1\ K\Omega + 600\ \Omega$

$R_{Total} = 1600\ \Omega$

$R_{Total} = 1.6\ K\Omega$

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Energy and Power

- Energy is the ability to do work.
- Two types: Kinetic and Potential
- A cell has Potential Energy – it stores chemical energy that can be released to do work.
- When electrons move against a resistance, work is done.
- The rate at which work is done is called Power

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Power

- Basic unit of Power is the Watt, abbreviated W.
- In electrical systems, we can calculate power if we know any two of
  - Voltage;
  - Current; or
  - Resistance.

$$P = E \times I = E^2 / R = I^2 \times R$$

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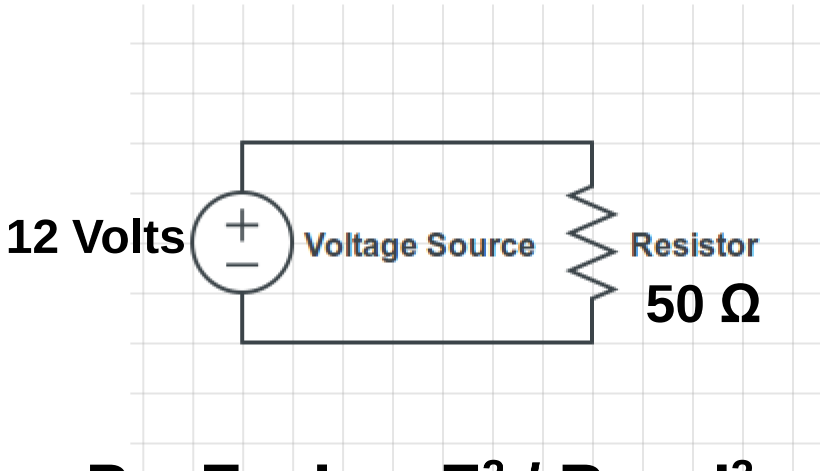
Calculating Power #1



$$P = E \times I = E^2 / R = I^2 \times R$$

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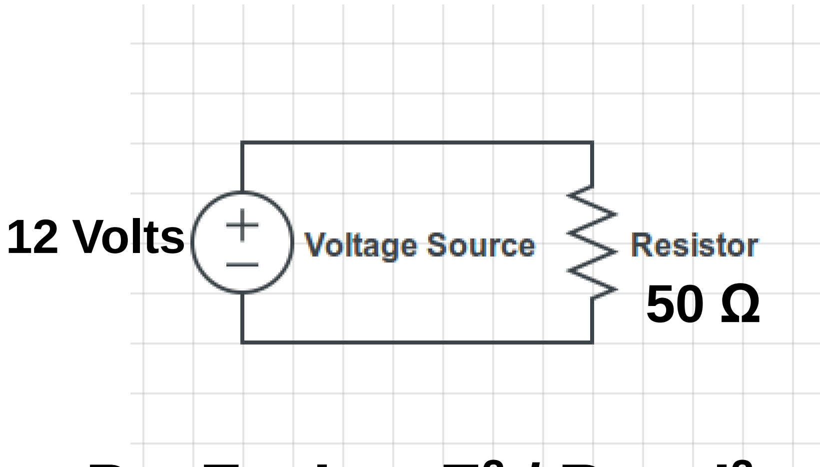
VO1NO

Calculating Power #1



$P = E \times I = E^2 / R = I^2 \times R$

$P = E^2 / R$

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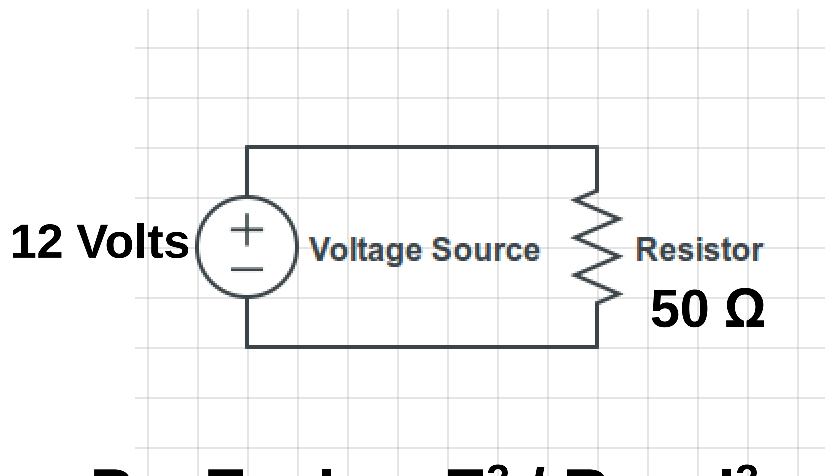
Calculating Power #1



$P = E \times I = E^2 / R = I^2 \times R$

$P = E^2 / R$

$P = 12^2 / 50$

$P = 144 / 50$

P = 2.88 Watts

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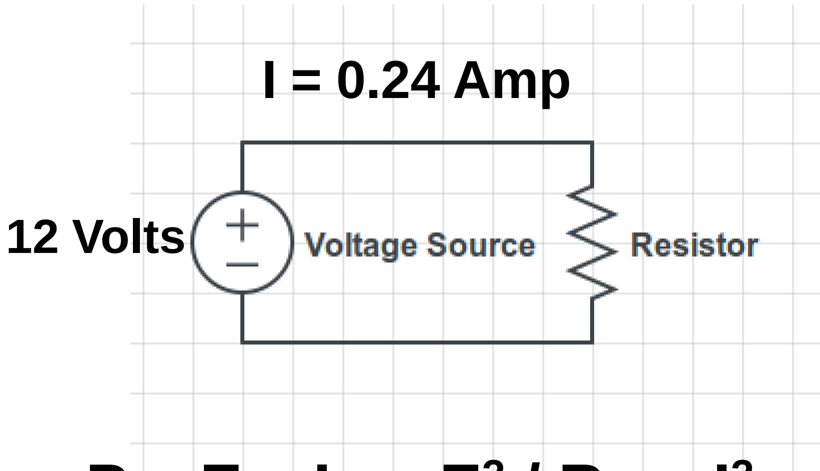
Calculating Power #2

I = 0.24 Amp



$$P = E \times I = E^2 / R = I^2 \times R$$

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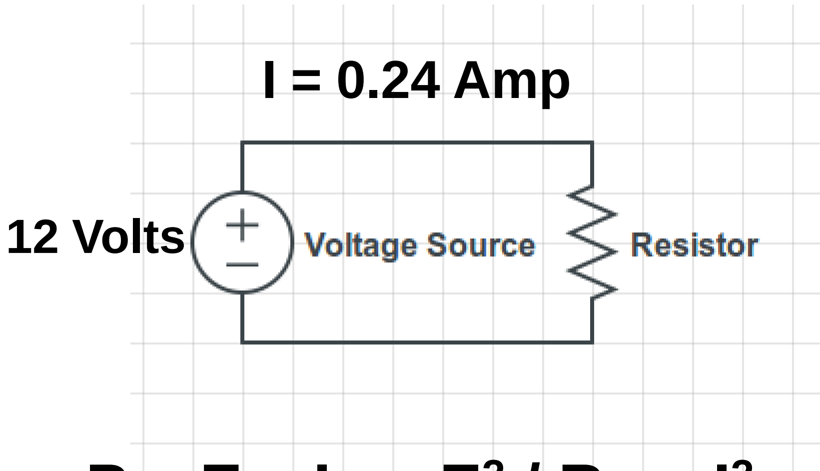
VO1NO

Calculating Power #2

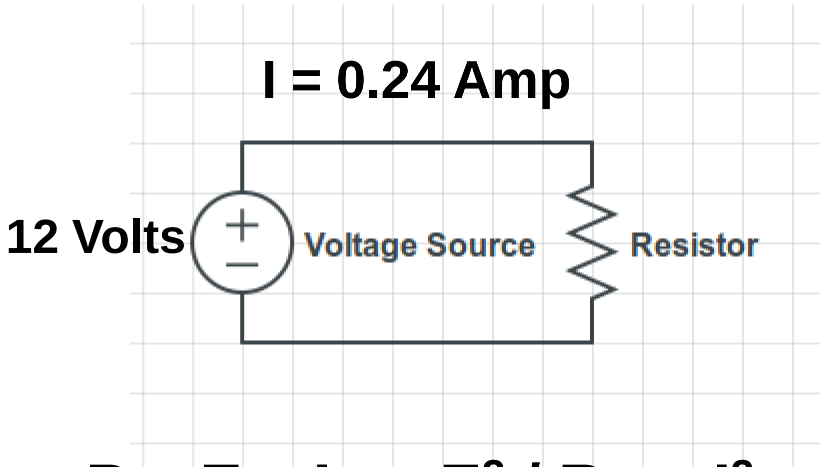


$$P = E \times I = E^2 / R = I^2 \times R$$

$$P = E \times I$$

Al Penney
VO1NO

Calculating Power #2



$$P = E \times I = E^2 / R = I^2 \times R$$

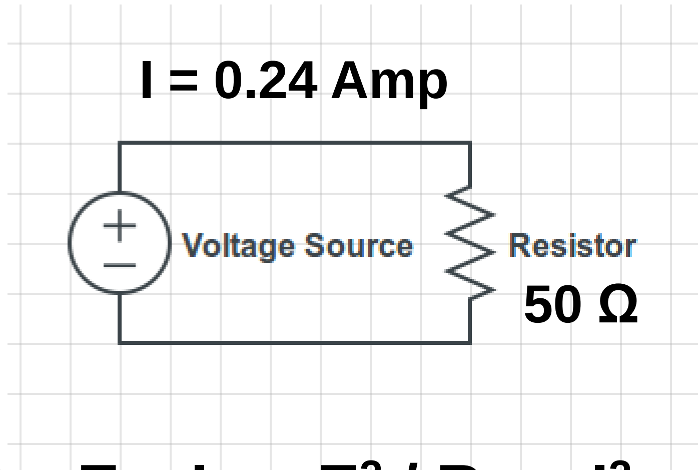
$$P = E \times I$$

$$P = 12 \times 0.24$$

$P = 2.88$ Watts

Al Penney
VO1NO

Calculating Power #3



$$P = E \times I = E^2 / R = I^2 \times R$$

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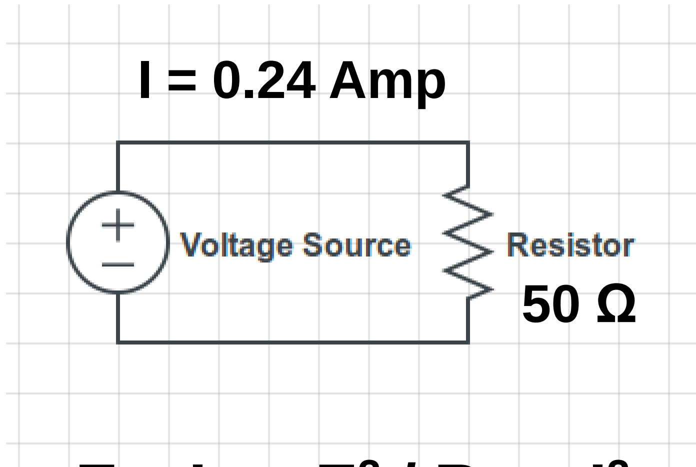
VO1NO

Calculating Power #3



$P = E \times I = E^2 / R = I^2 \times R$

$P = I^2 \times R$

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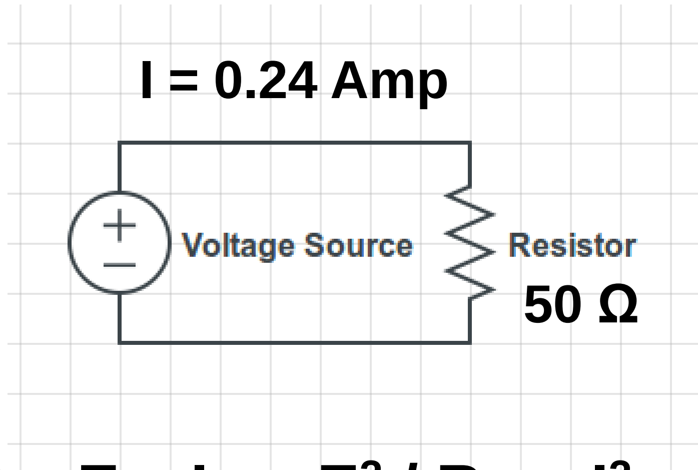
Calculating Power #3



$$P = E \times I = E^2 / R = I^2 \times R$$

$$P = I^2 \times R$$

$$P = 0.24^2 \times 50$$

$$P = 0.0576 \times 50$$

P = 2.88 Watts

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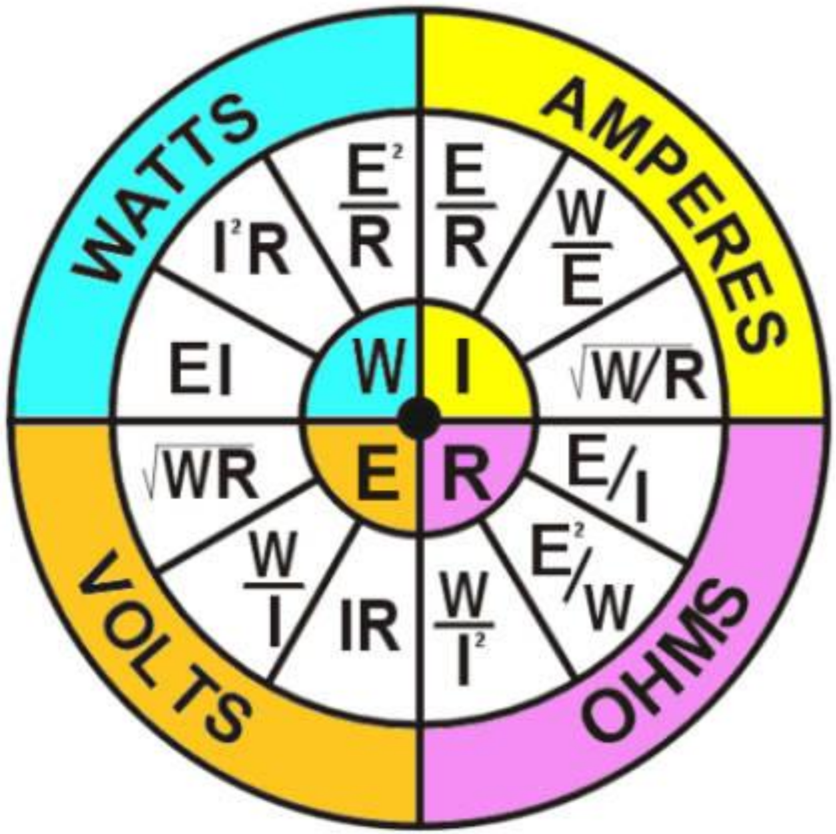
Circuit Calculator



Remember the Units – Ohms, Volts, Amps, Watts!!

Al Penney
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Questions?