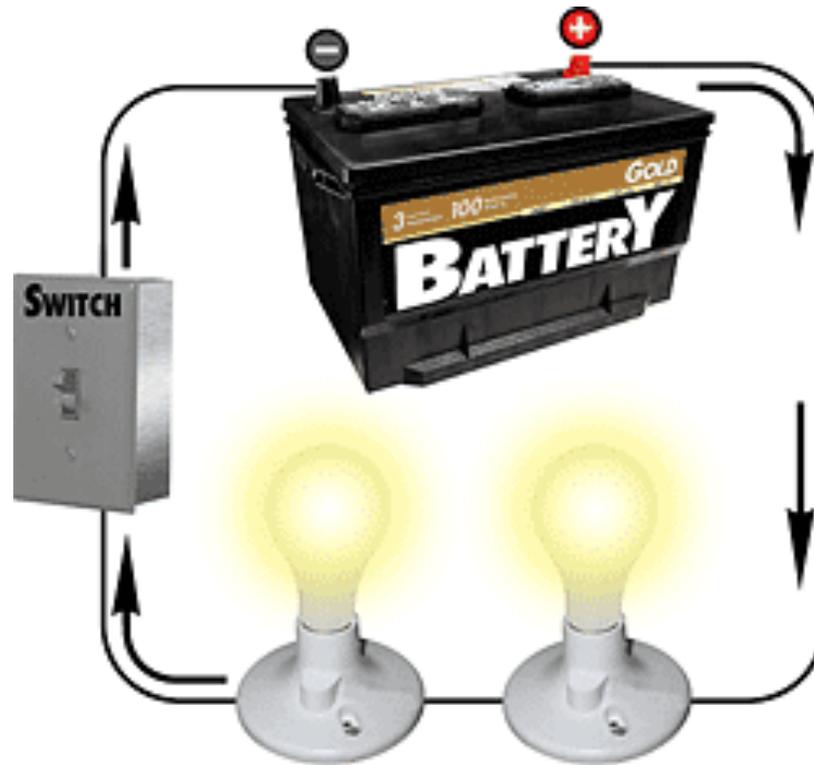


16.5

Series Circuits



Electric Circuits

- For a continuous flow of electrons, there must be a **complete circuit** with no gaps.
- Any path along which electrons can flow is a **circuit**.
- A gap is usually provided by an **electric switch** that can be opened or closed to either cut off or allow electron flow.

Electric Circuits

Most circuits have more than one device that receives electrical energy.

These devices are commonly connected in a circuit in one of two ways, **series or parallel**.

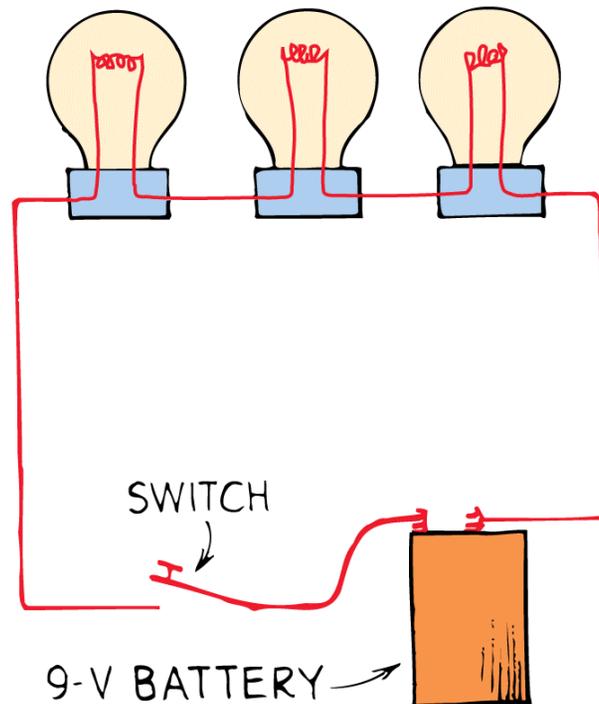
- When connected in **series**, the devices in a circuit form a **single** pathway for electron flow.
- When connected in **parallel**, the devices in a circuit form **branches**, each of which is a separate path for electron flow.

**CONCEPT
CHECK**

How can a circuit achieve a continuous flow of electrons?

Series Circuits

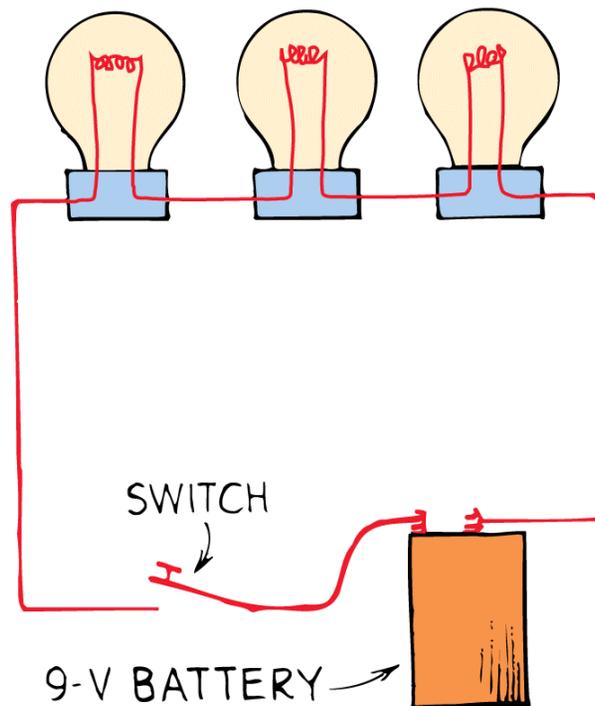
If three lamps are connected in series with a battery, they form a **series circuit**. Charge flows through each in turn.



Series Circuits

When the switch is closed, a current exists almost immediately in all three lamps.

The current does not “pile up” in any lamp but flows *through* each lamp. Electrons in all parts of the circuit begin to move at once.

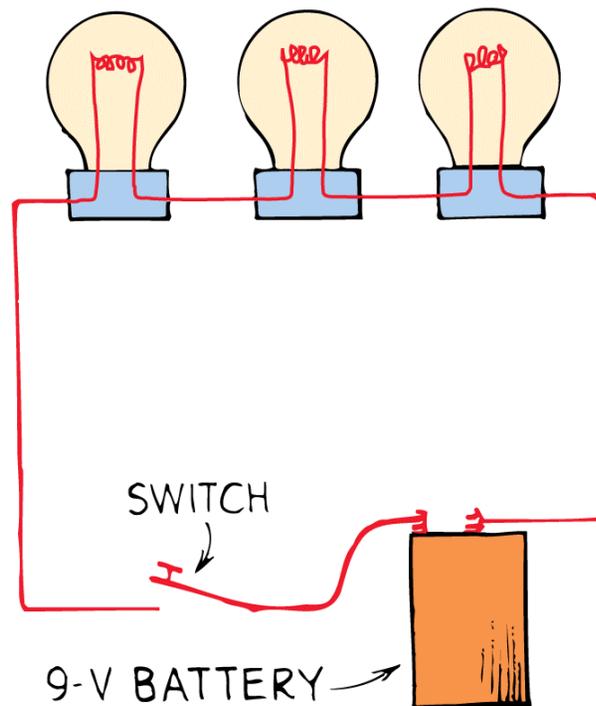


Series Circuits

Eventually the electrons move all the way around the circuit.

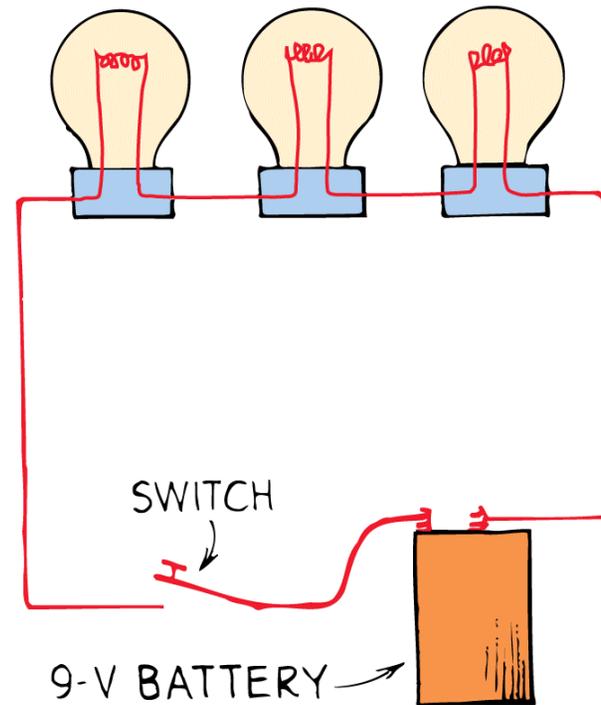
A break anywhere in the path results in an open circuit, and the flow of electrons ceases.

Burning out of one of the lamp filaments or simply opening the switch could cause such a break.



Series Circuits

In this simple series circuit, a 9-volt battery provides 3 volts across each lamp.



Series Circuits

The main disadvantage of a series circuit is that when one device fails, the current in the whole circuit stops.

Some old Christmas lights are connected in series. When one lamp burns out, you have to replace it or no lights work.

A series circuit is like a single-lane road with no alternate path. If there is a roadblock or cave-in, traffic will stop.

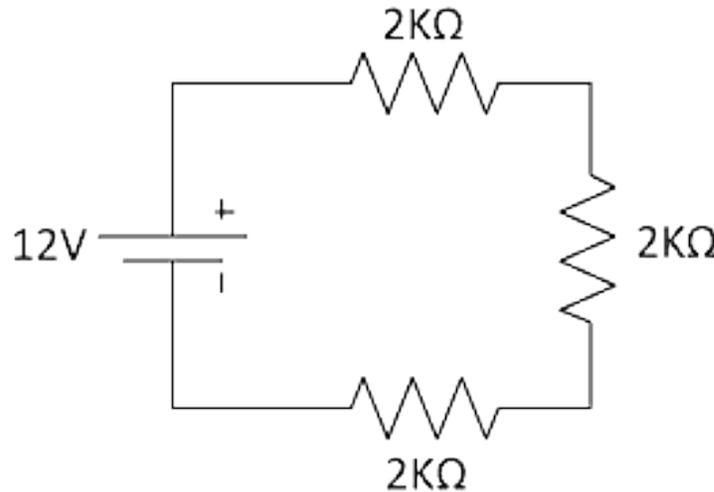
Series Circuits

**CONCEPT
CHECK:**

What happens to current in other lamps if one lamp in a series circuit burns out?

Resistance in a Series Circuit

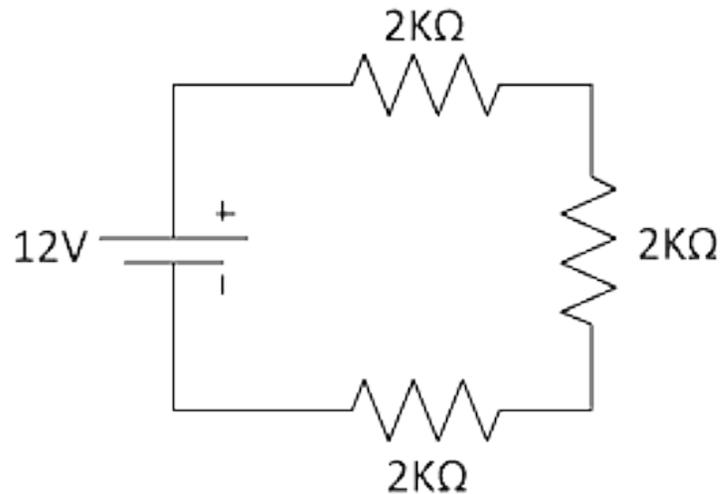
Let's look at a sample circuit, consisting of three 2000-ohm (2K) resistors:



There is only a single current path in the circuit, which travels through all three resistors. Instead of using three separate 2K resistors, we could replace the three resistors with one single resistor having an equivalent resistance.

To find the equivalent resistance of any number of series resistors, we just add up their individual resistances.

Resistance in a Series Circuit



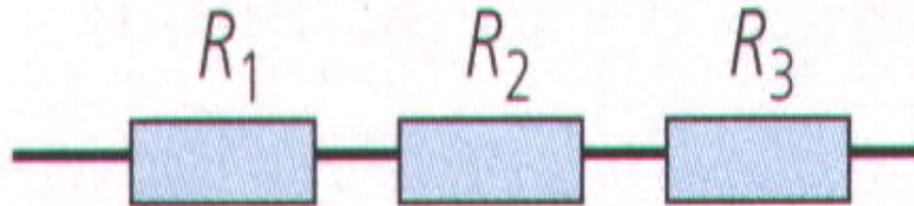
$$R_{eq} = R_1 + R_2 + R_3 + \dots$$

$$R_{eq} = 2000\Omega + 2000\Omega + 2000\Omega$$

$$R_{eq} = 6000\Omega = 6K\Omega$$

Because there is only a single current path, the same current must flow through each of the resistors.

Resistance in a Series Circuit



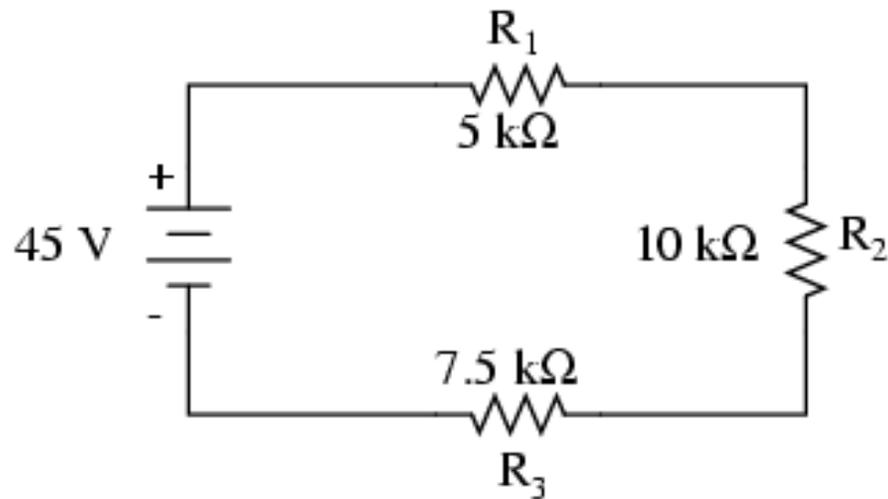
The total resistance in a series circuits is equal to the sum of the individual resistance. ($R_{\text{equivalent}}$)

$$R_{\text{eq}} = R_1 + R_2 + R_3 + \dots$$

Resistance in a Series Circuit

Example #1

What is the total resistance of the following circuit?



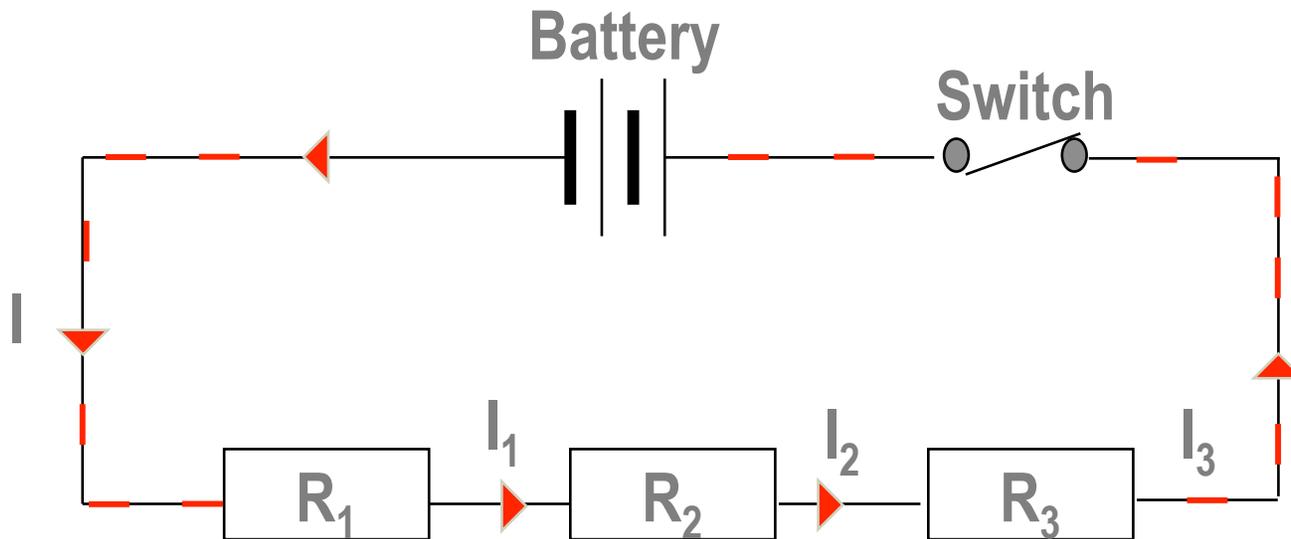
$$R_{eq} = R_1 + R_2 + R_3$$

$$R_{eq} = 5 \text{ k}\Omega + 10 \text{ k}\Omega + 7.5 \text{ k}\Omega$$

$$R_{eq} = 22.5 \text{ k}\Omega$$

Current in a Series Circuit

A series circuit has only **one path** in which charge can flow. Therefore it is the same everywhere



The current is same everywhere ($I = I_1 = I_2 = I_3$)

Current in a Series Circuit

To find the current of a series circuit you must know the TOTAL voltage and the TOTAL resistance of the circuit (R_{eq})

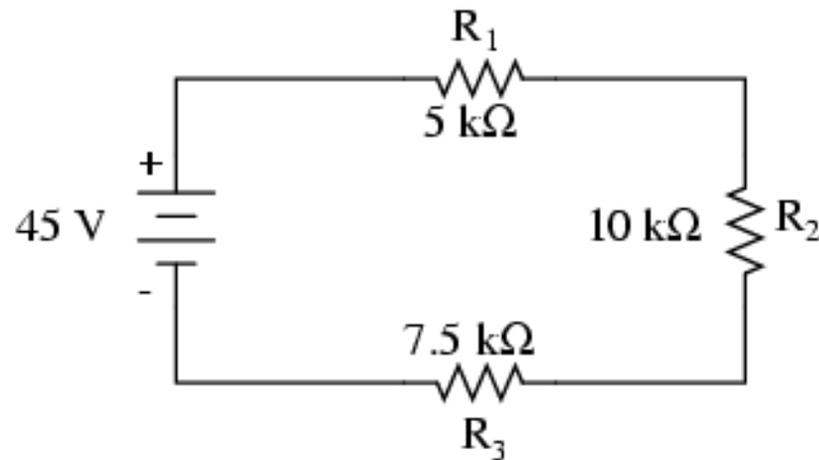
Formula:

$$I_{Total} = V_{Total} / R_{eq}$$

Current in a Series Circuit

Example #2

What is the current of the following series circuit?



$$\begin{aligned}V &= I \cdot R_{eq} \\45 \text{ v} &= I \cdot (22.5 \text{ k}\Omega) \\I &= 45 \text{ v} / (22.5 \text{ k}\Omega) \\I &= .002 \text{ A or } 2 \text{ mA}\end{aligned}$$

Voltage in a Series Circuit

The total voltage “around” the circuit is equal to the voltage drop across each component:

Formula:

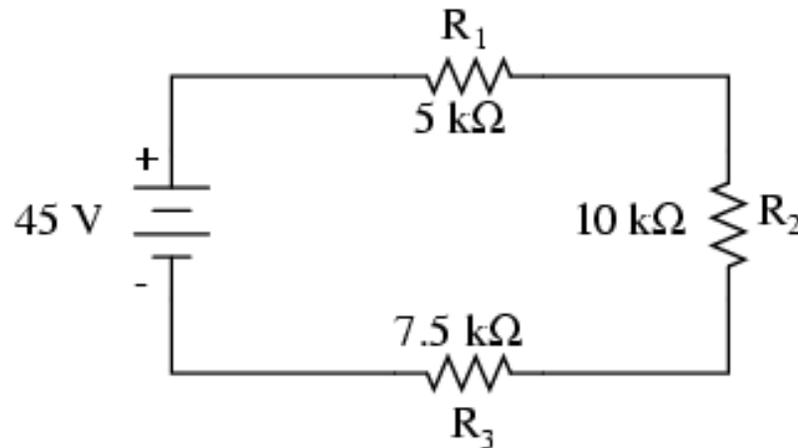
$$V_{\text{tot}} = V_1 + V_2 + V_3 + \dots$$

(Use Ohm's Laws on each device)

Series Circuits

Example #3

What is the voltage on each resistor?



$$V_1 = 10 \text{ v}$$

$$V_2 = 20 \text{ v}$$

$$V_3 = 15 \text{ v}$$

Series Circuits

CONCEPT CHECK

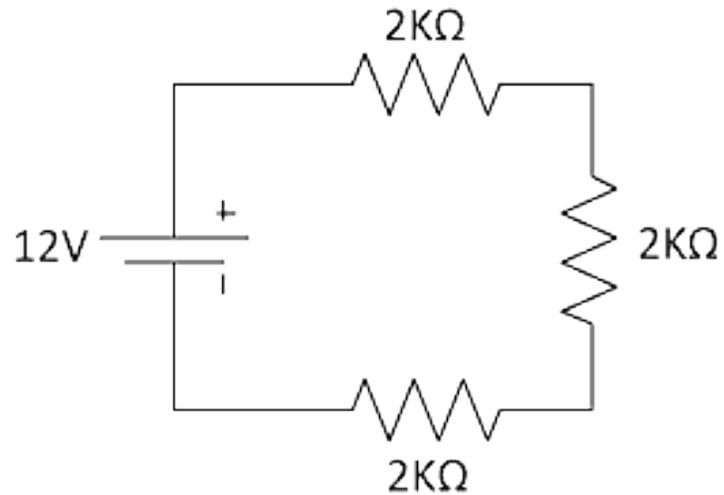
How are voltage, current and resistance calculated in a series circuit?

- *The total resistance to current in the circuit is the sum of the individual resistances along the circuit path.*
- *The current is equal to the voltage supplied by the source divided by the total resistance of the circuit. This is Ohm's law.*
- *The voltage drop, or potential difference, across each device depends directly on its resistance.*
- *The sum of the voltage drops across the individual devices is equal to the total voltage supplied by the source.*

VIRP Tables

- A simple and straightforward method for analyzing circuits involves creating a VIRP table for each circuit you encounter. Combining your knowledge of Ohm's Law, equivalent resistance, total voltage and current, you can use this table to solve for the details of any circuit.
- A VIRP table describes the potential drop (V-voltage), current flow (I-current), resistance (R) and power dissipated (P-power) for each element in your circuit, as well as for the circuit as a whole.
- Let's use our circuit with the three 2000-ohm resistors as an example to demonstrate how a VIRP table is used.
- To create the VIRP table, we first list our circuit elements, and total, in the rows of the table, then make columns for V, I, R, and P.

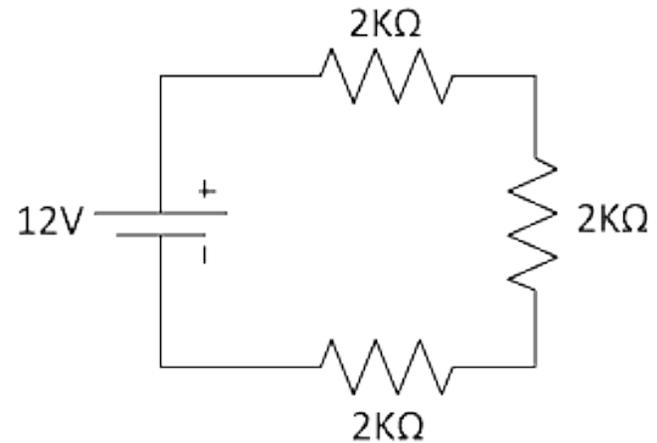
VIRP Example #1



VIRP Table				
	V	I	R	P
R1				
R2				
R3				
Total				

VIRP Example #1

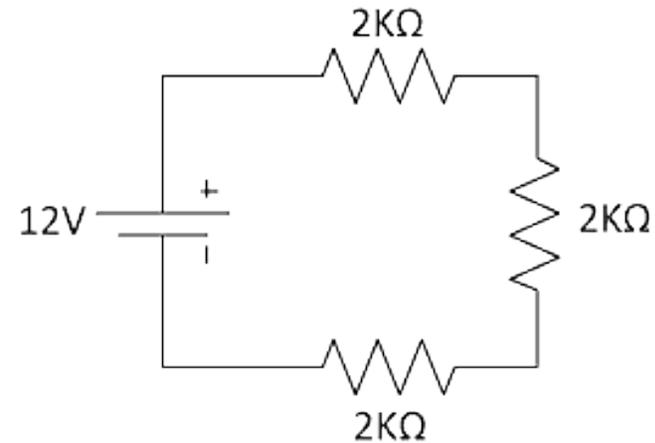
Fill in the information that is known.



VIRP Table				
	V	I	R	P
R1			2,000 Ω	
R2			2,000 Ω	
R3			2,000 Ω	
Total	12 V			

VIRP Example #1

Once the initial information has been filled in, use your knowledge of Ohm's Law and series circuits to complete the table.



VIRP Table				
	V	I	R	P
R1	4 V	0.002 A	2,000 Ω	0.008 W
R2	4 V	0.002 A	2,000 Ω	0.008 W
R3	4 V	0.002 A	2,000 Ω	0.008 W
Total	12 V	0.002 A	6,000 Ω	0.024 W

Series Circuits Assessment Questions

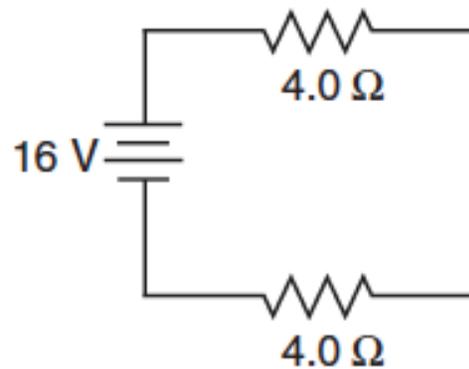
Example #2

A $2\text{-}\Omega$ resistor and a $4\text{-}\Omega$ resistor are connected in series with a 12-volt battery. If the current through the $2\text{-}\Omega$ resistor is 2 amps, what is the current through the $4\text{-}\Omega$ resistor?

Series Circuits Assessment Questions

Example #3

In the circuit diagram, two $4\text{-}\Omega$ resistors are connected to a 16- volt battery. What is the total power in this circuit?



Series Circuits Assessment Questions

Example #4

A light bulb in a series circuit, the amount of current in the filament is

- a. slightly less than the current in the connecting wires.
- b. the same as the current in the connecting wires.
- c. slightly greater than the current in the connecting wires.
- d. twice as great as the current that is in the connecting wires.

Series Circuits Assessment Questions

Example #5

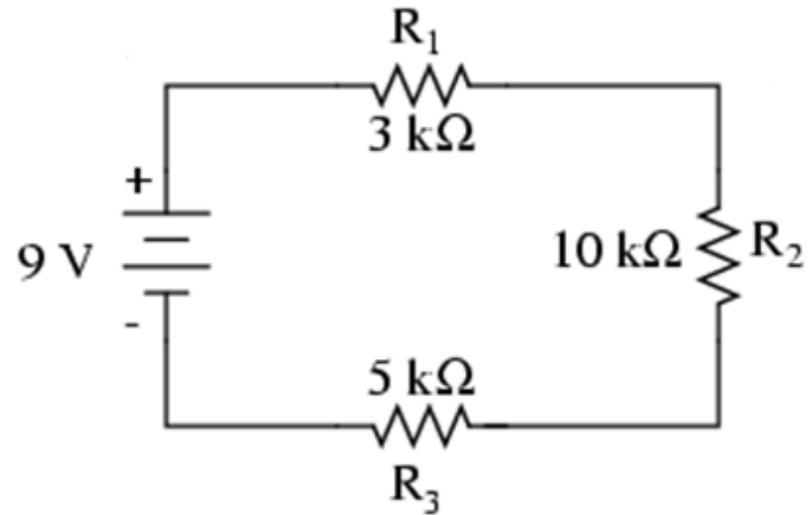
In a series circuit, if the current in one lamp is 2 amperes, the current in the battery is

- a. half, 1 A
- b. 2 A
- c. not necessarily 2 A, depending on internal battery resistance
- d. more than 2 A

VIRP Table

Example #6

Complete the VIRP table below.



VIRP Table				
	V	I	R	P
R1				
R2				
R3				
Total				