Ohm's Law

- Ohm's law states that:

"the current in an electric circuit is directly proportional to the voltage across its terminals, provided that the physical parameters like temperature, etc. remain constant"

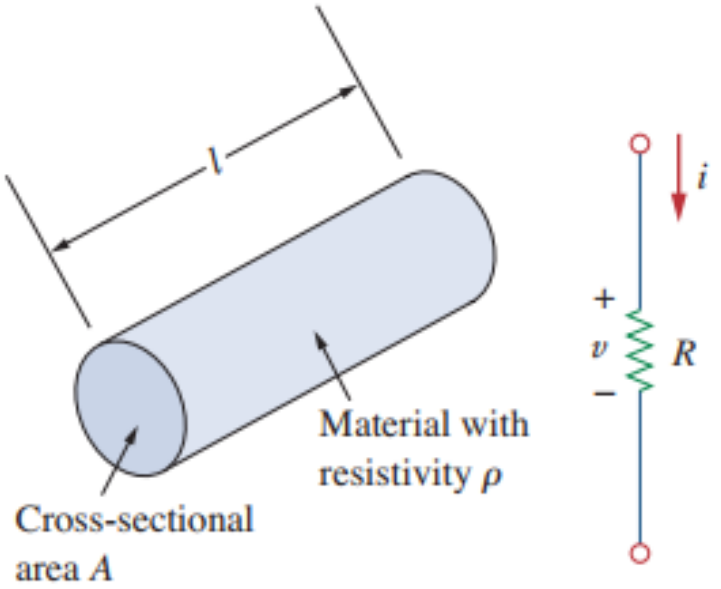
Mathematically,

$$I \propto V$$

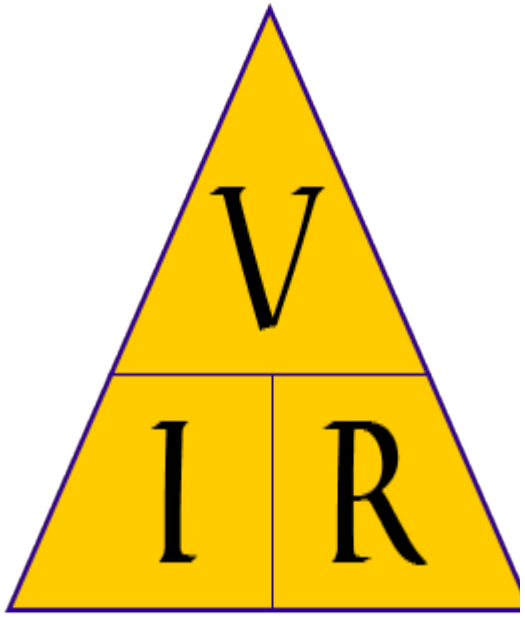
Or,

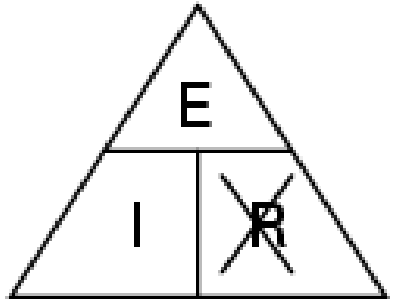
$$I = \frac{V}{R}$$

Where, Resistance $R = \frac{\rho l}{A}$

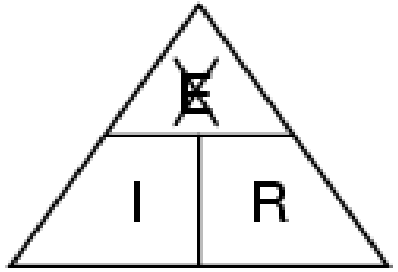


Ohm's law magic triangle

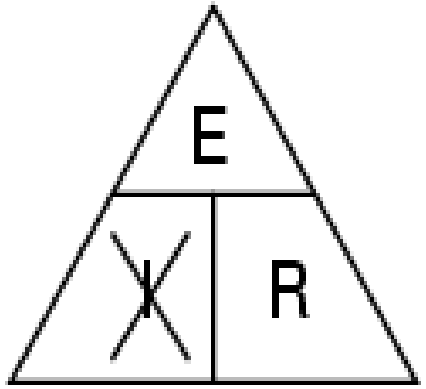




$$R = \frac{E}{I}$$



$$E = I\,R$$



$$I = \frac{E}{R}$$

Voltage measured in *volts*, symbolized by the letters "E" or "V".

Current measured in *amps*, symbolized by the letter "I".

Resistance measured in *ohms*, symbolized by the letter "R".

Resistivity Table

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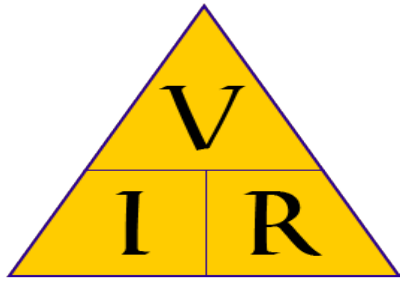
Material	Resistivity ($\Omega \cdot m$)	Usage
Silver	1.64×10^{-8}	Conductor
Copper	1.72×10^{-8}	Conductor
Aluminum	2.8×10^{-8}	Conductor
Gold	2.45×10^{-8}	Conductor
Carbon	4×10^{-5}	Semiconductor
Germanium	47×10^{-2}	Semiconductor
Silicon	6.4×10^{2}	Semiconductor
Paper	10^{10}	Insulator
Mica	5×10^{11}	Insulator
Glass	10^{12}	Insulator
Teflon	3×10^{12}	Insulator



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Practice problems

In a circuit, 0.5 A is flowing through the bulb. The voltage across the bulb is 4.0 V. What is the bulbs resistance?

1. Write the equation → $R = \frac{V}{I}$
2. Replace the known values → $R = \frac{4.0}{0.5}$
3. Solve → $R = 8$
4. Label → $R = 8\ \Omega$

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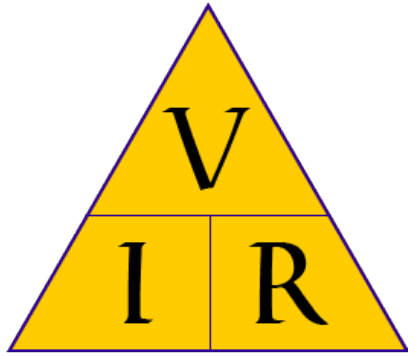
Practice problem

- You light a light bulb with a 1.5 volt battery. If the bulb has a resistance of 10 ohms, how much current is flowing?



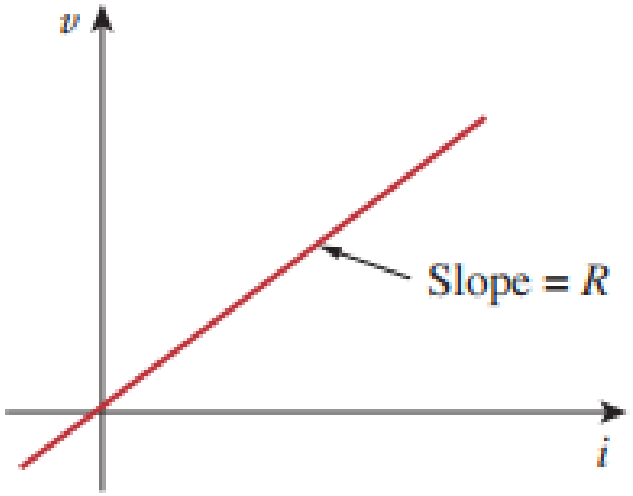
1. Write the equation → $I = \frac{V}{R}$
2. Replace the known values → $I = \frac{1.5}{10}$
3. Solve → $I = 0.15$

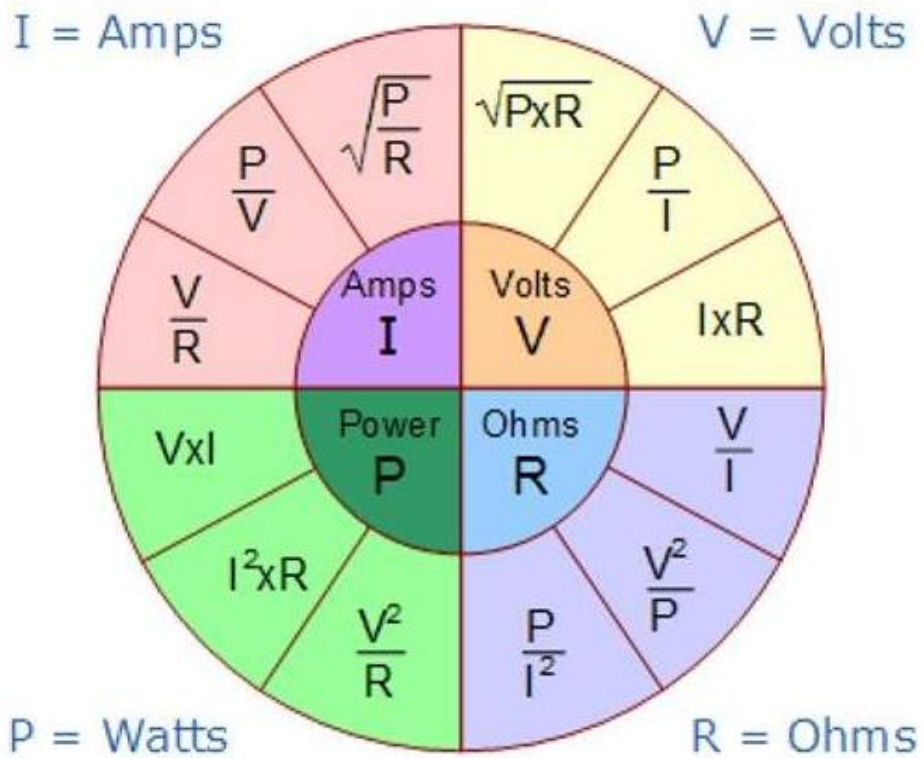
Conductance

- A useful quantity in circuit analysis is the reciprocal of resistance R, known as conductance and denoted by G
- $G = \frac{1}{R} = \frac{I}{V}$
- S.I Unit: mho (ohm spelled backwards) or Siemens
- Symbol: $\mho$, the inverted omega.

$$1\,\mathrm{S} = 1\,\mho = 1\,\mathrm{A/V}$$

- Power dissipated in the resistor can be expressed as:
- $P = VI = I^2R = \frac{V^2}{R}$

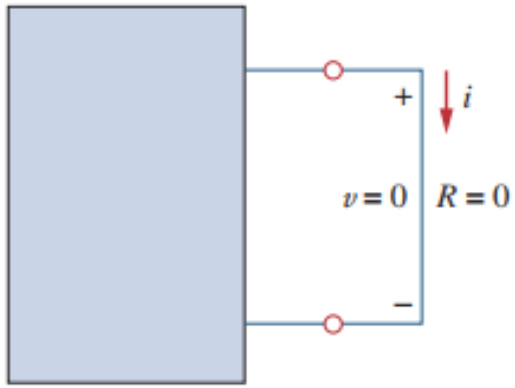




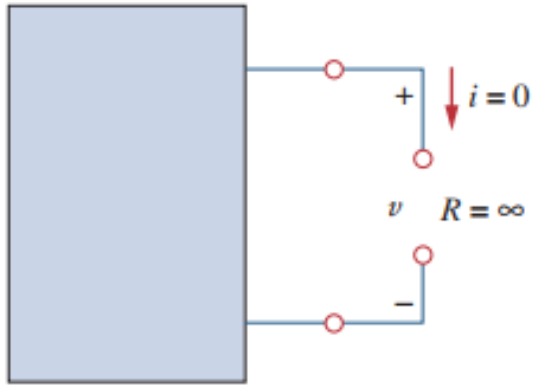
Ohm's Law Pie Chart (Source: Electronics-Tutorials.ws)

Short-circuit and Open-circuit

- For a short circuit, R = 0 Ω
- Therefore, V = I.R = 0 V
- NOTE: (current, I can be of any value)



- For an open circuit, R = ∞Ω
- Therefore, I = V/R = 0 V
- NOTE: (voltage,V can be of any value)



Applications of Ohm's Law

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1. To find unknown Voltage (V)
2. To Find unknown Resistance (R)
3. To Find unknown Current (I)
4. Can be used to find Unknown Conductance (G)=1/R
5. Can be used to find unknown Power (P)=VI
6. Can be used to find unknown conductivity or Resistivity

$v = iR$

$R = \frac{v}{i}$

I=V/R

$R = \rho\frac{\ell}{A}$

Applications of Ohm's Law

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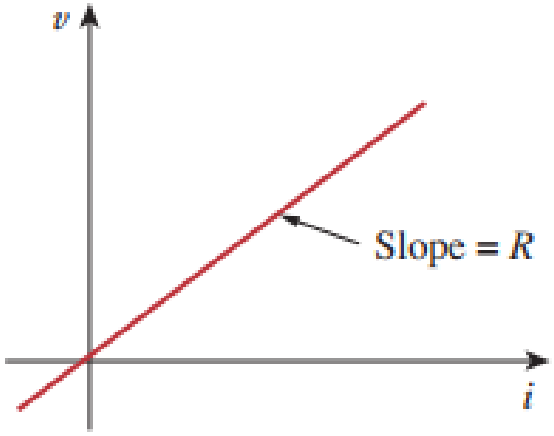
1. It is widely used in circuit analysis.
2. It is used in ammeter, multimeter, etc.
3. It is used to design resistors.
4. It is used to get the desired circuit drop in circuit design (Example, Domestic Fan Regulator).
5. Advanced laws such as Kirchhoff's Norton's law, Thevenin's law are based on ohm's law.
6. Electric heaters, kettles and other types of equipment working principle follow ohm's law.
7. A laptop and mobile charger using DC power supply in operation and working principle of DC power supply depend on ohm's law.

Limitations of Ohm's Law

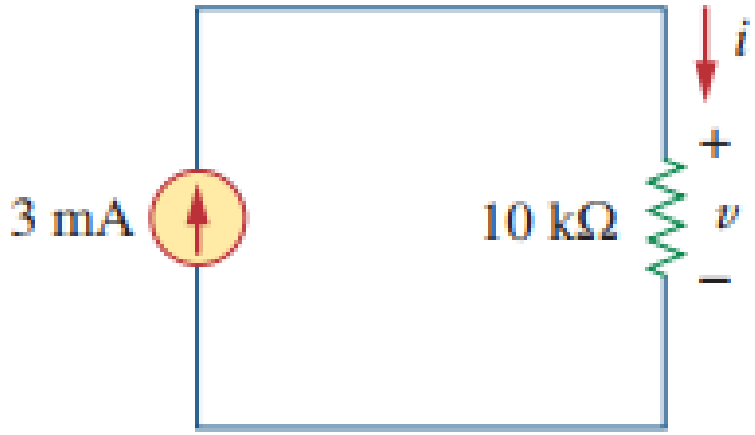
- Ohm's law holds true only for a conductor at a constant temperature. Resistivity changes with temperature.
- Ohm's law by itself is not sufficient to analyze circuits.
- It is NOT applicable to non linear elements, For example, Diodes, Transistors, Thyristors, etc.
- This law cannot be applied to unilateral networks.



QUICK QUIZ (Poll 7)

The voltage and the conductance of the given circuit is:

A. 30 V, 10 µS
B. 30 mV, 100 µS
C. 30 V, 100 µS
D. 30 mV, 10 µS



QUICK QUIZ (Poll 8)

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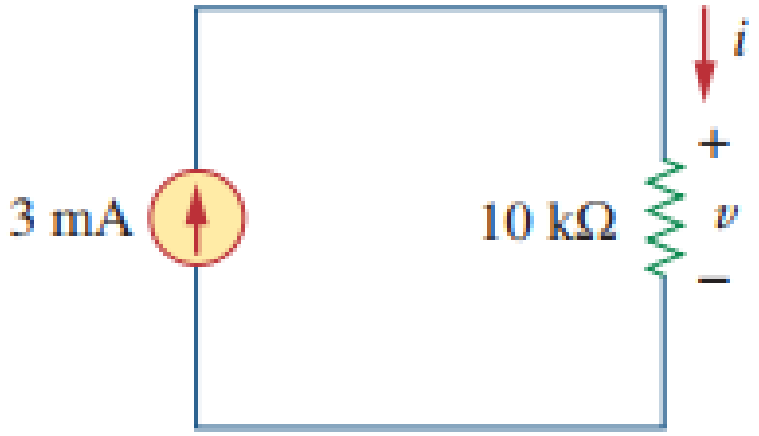
The power of the given circuit is:

A. 60 mW

B. 70 mW

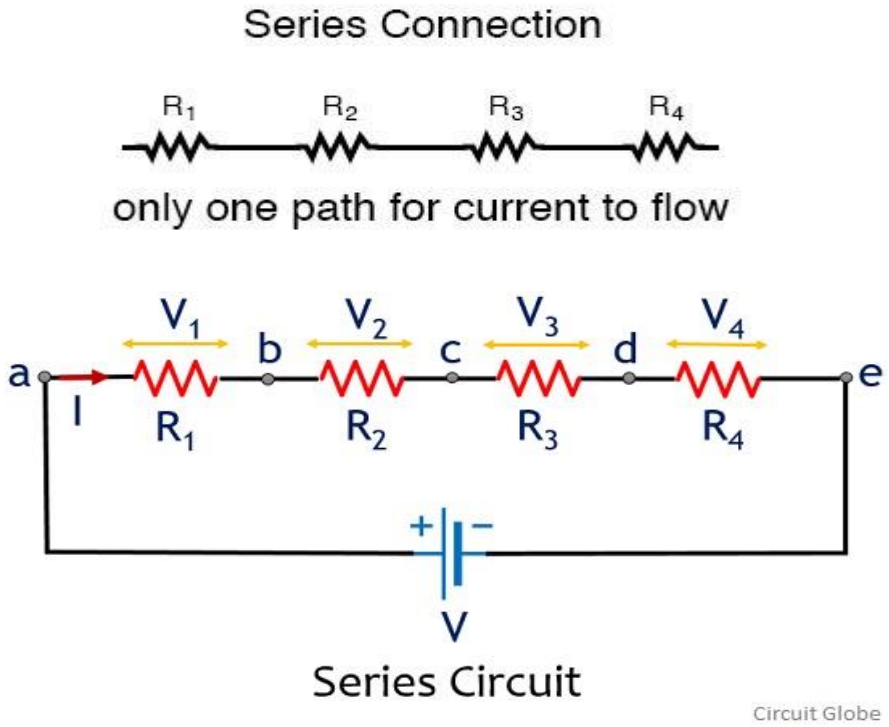
C. 80 mW

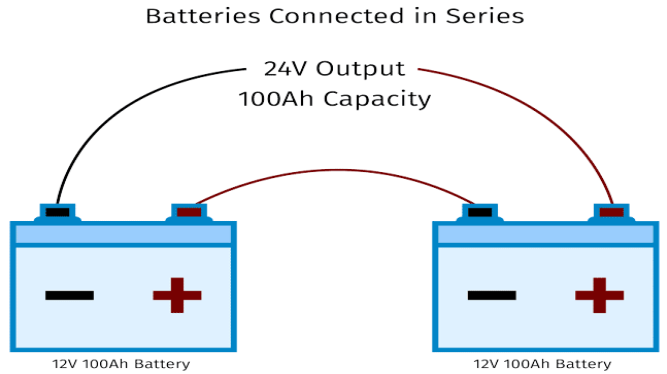
D. 90 mW

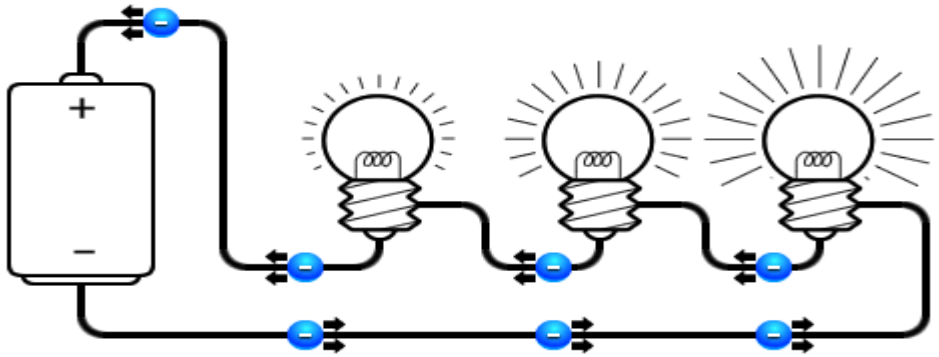


Series Connection

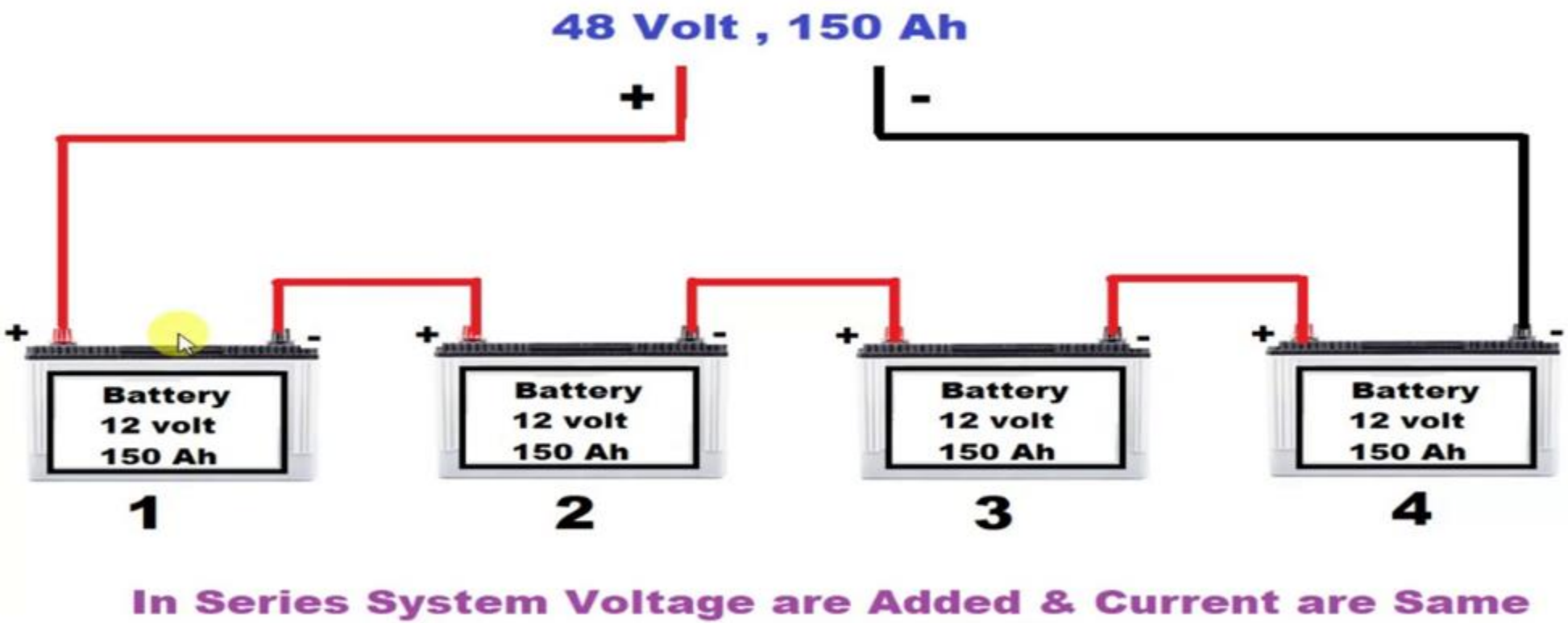
- **SERIES CONNECTION:** Two or more elements are in series if they exclusively share a single node and consequently carry the same current.





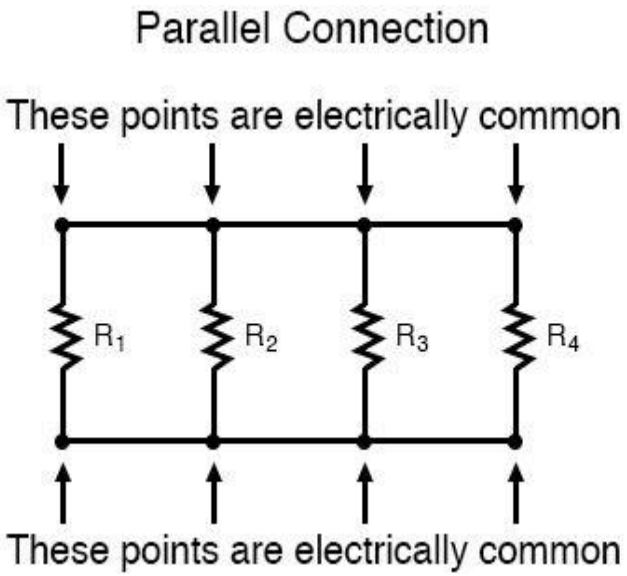


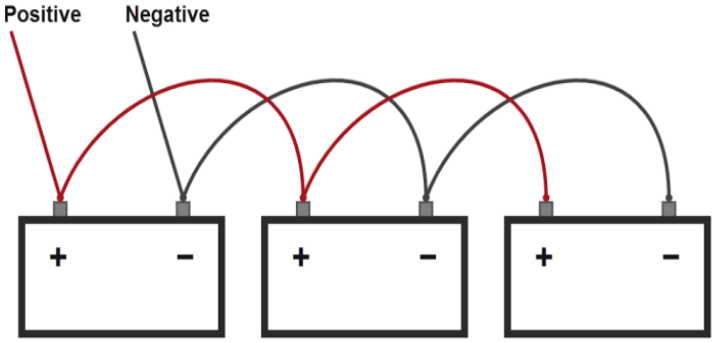
Point to Remember for Series Circuits

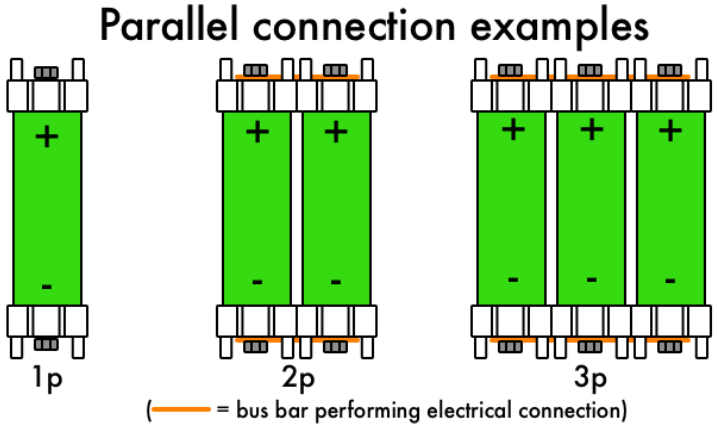


Parallel Connection

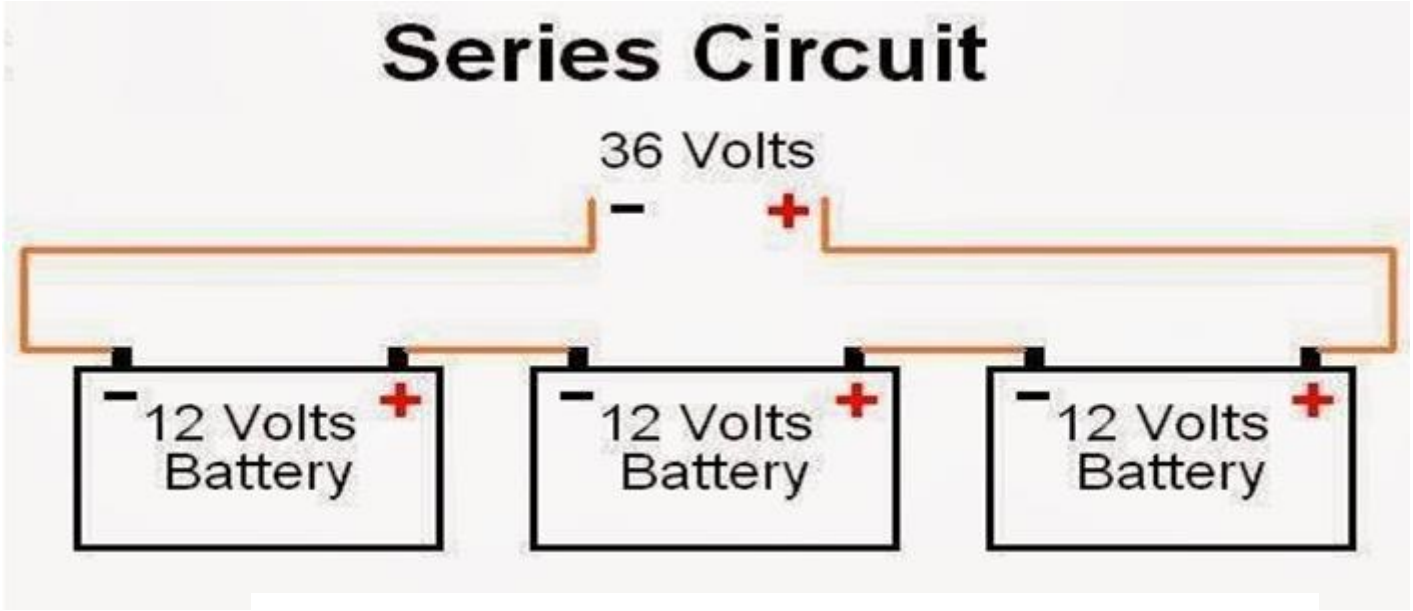
- PARALLEL CONNECTION: Two or more elements are in parallel if they are connected to the same two nodes and consequently have the same voltage across them

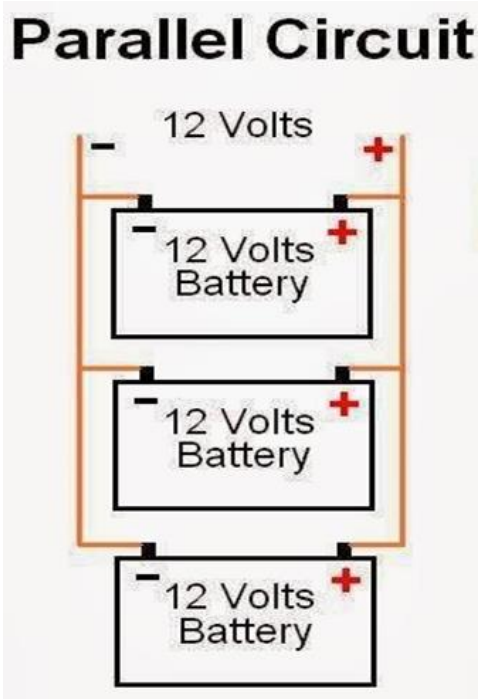


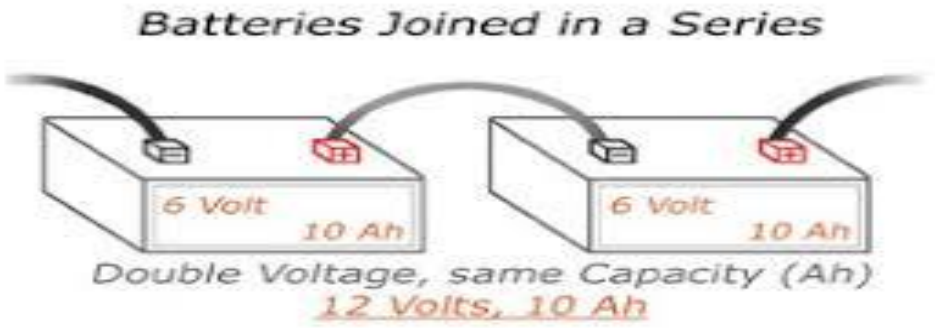


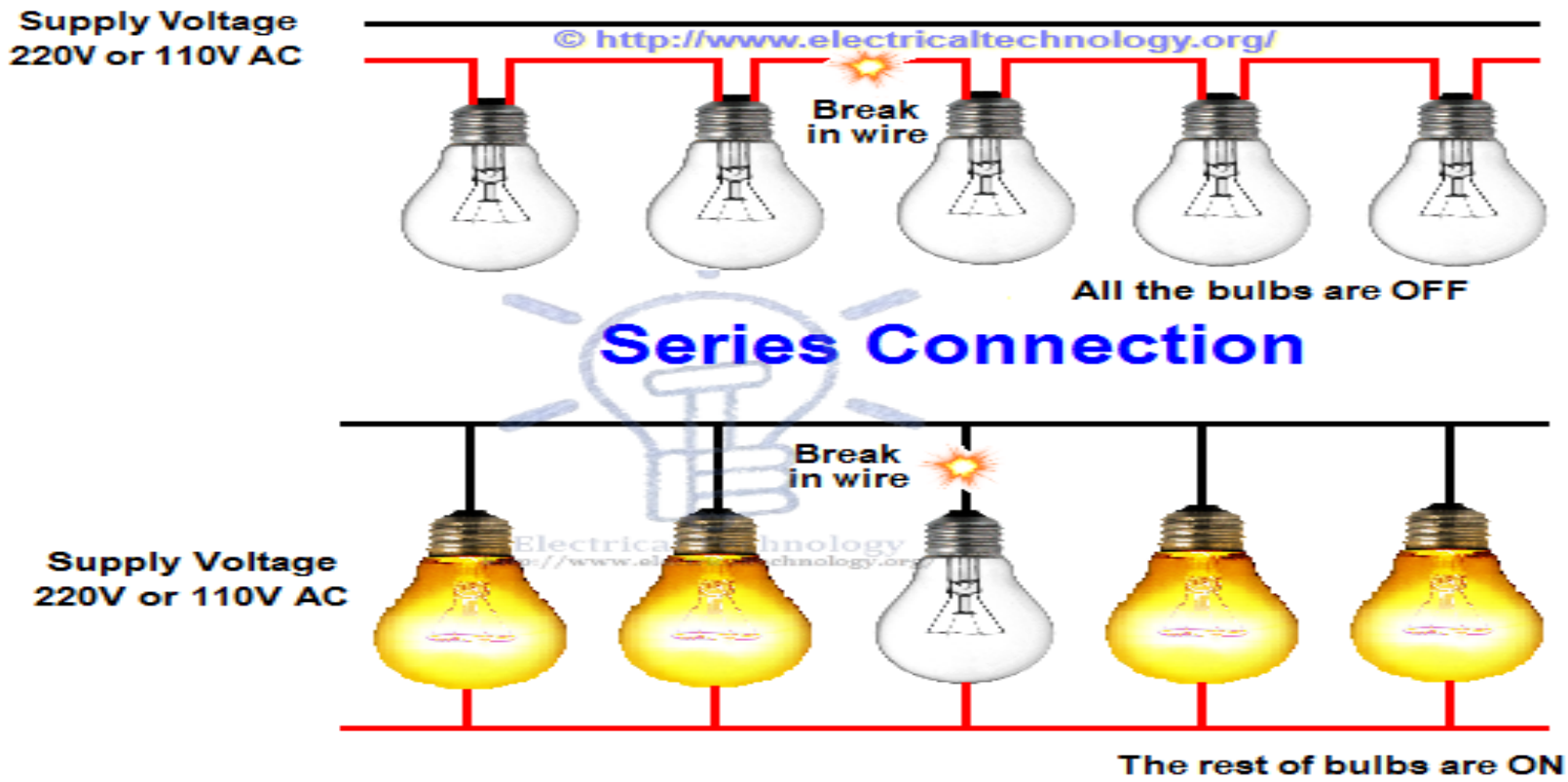


Battery Voltage In Series And Parallel









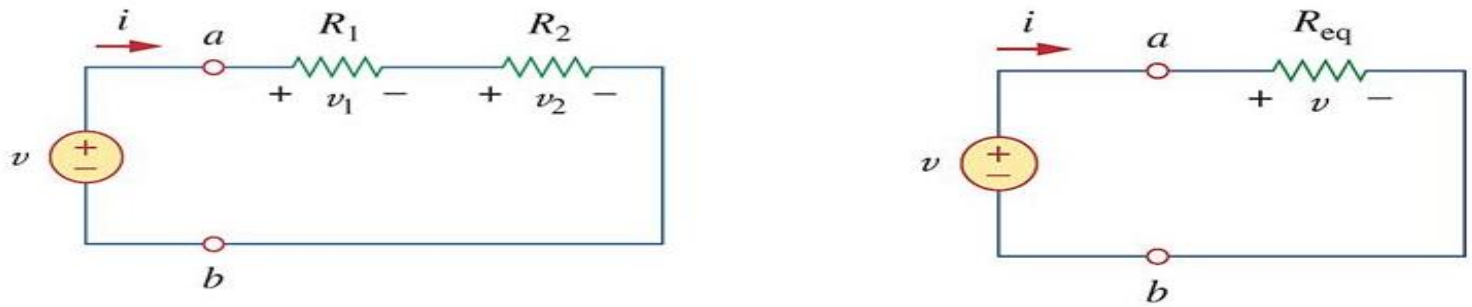
Why Parallel Connection is Preferred over Series Connection?

RESISTORS IN SERIES

Series: Two or more elements are in series if they are cascaded or connected sequentially and consequently carry the same current.

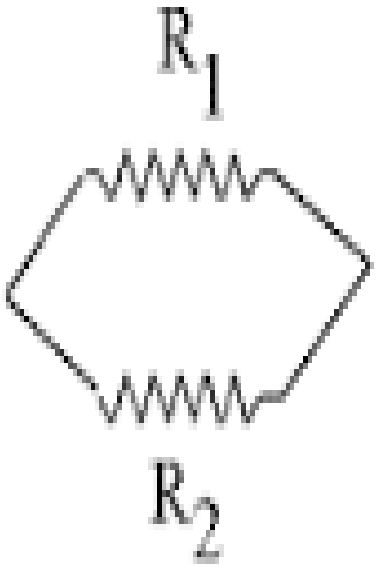
The equivalent resistance of any number of resistors connected in a series is the sum of the individual resistances

$$R_{eq} = R_1 + R_2 + \cdots + R_N = \sum_{n=1}^{N} R_n$$



Note: Resistors in series behave as a single resistor whose resistance is equal to the sum of the resistances of the individual resistors.

Resistors in Parallel



$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2}$$

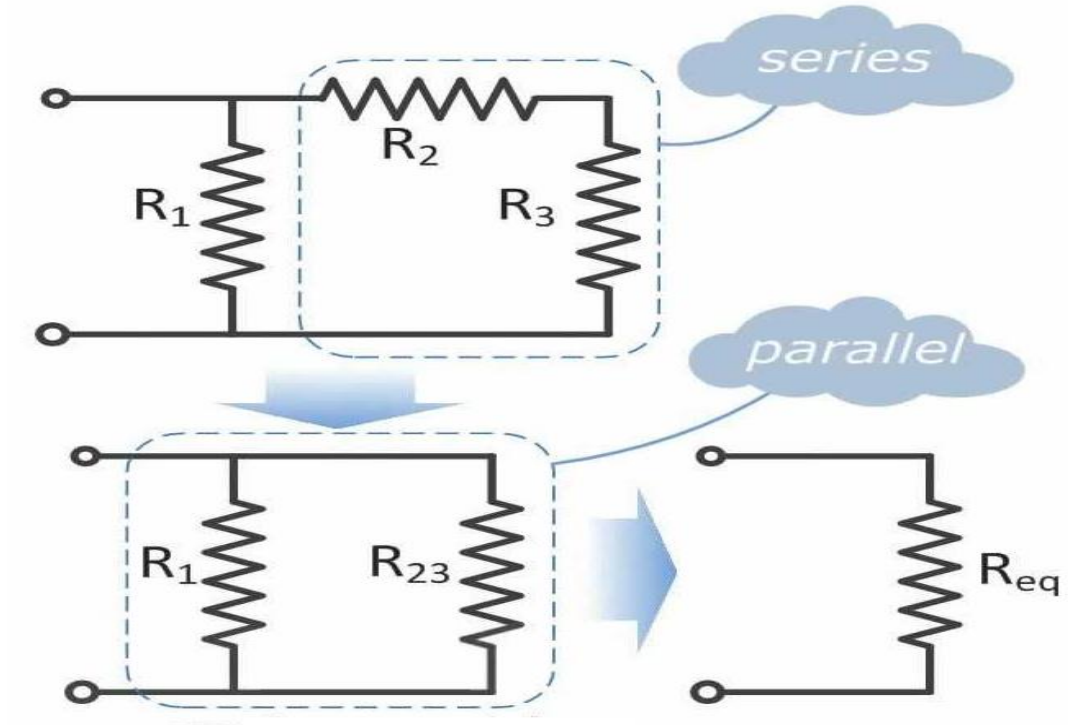
$$\frac{1}{R_t} = \frac{R_2 + R_1}{R_1 R_2}$$

$$R_t = \frac{R_1 R_2}{R_2 + R_1}$$

The equivalent of two parallel resistor is equal to their product divided by their sum .

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}$$

How to find Equivalent Resistance for Series-Parallel Combinations



$$R_{23} = R_2 + R_3$$

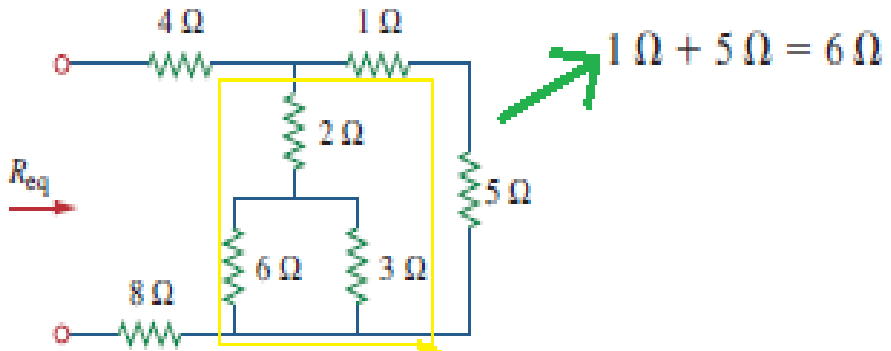
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_{23}}$$

$$R_{eq} = \frac{R_1 \cdot R_{23}}{R_1 + R_{23}}$$

$$R_{eq} = \frac{R_1(R_2 + R_3)}{R_1 + R_2 + R_3}$$

Example: To find R_{eq}

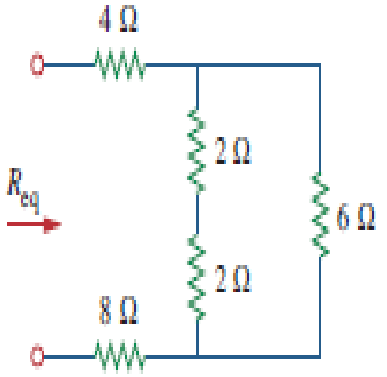
Find R_{eq} for the circuit shown in Fig.



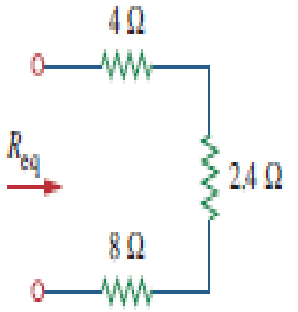
$1\,\Omega + 5\,\Omega = 6\,\Omega$

$2\,\Omega + 2\,\Omega = 4\,\Omega$

$$6\,\Omega \parallel 3\Omega = \frac{6 \times 3}{6 + 3} = 2\,\Omega$$



$$4\,\Omega \parallel 6\,\Omega = \frac{4 \times 6}{4 + 6} = 2.4\,\Omega$$



$$R_{eq} = 4\,\Omega + 2.4\,\Omega + 8\,\Omega = 14.4\,\Omega$$

QUICK QUIZ (Poll 9)

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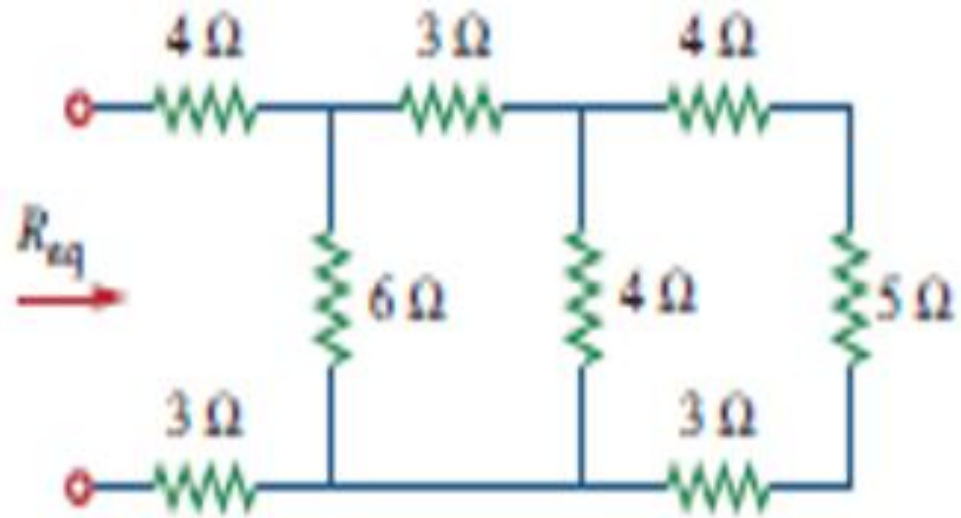
Find Equivalent Resistance in Ohms?

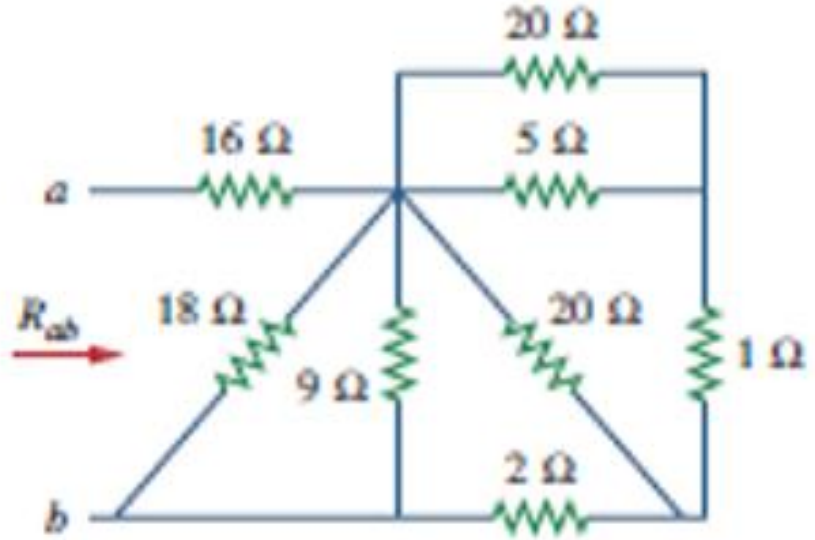
A. 5
B. 10
C. 15
D. 20



QUICK QUIZ (Poll 10)

Find Equivalent Resistance in Ohms?

A. 12
B. 17
C. 19
D. 29



Useful Links

- http://www.dynamicscience.com.au/tester/solutions1/electric/voltage.htm
- https://gfycat.com/directhauntinglamb
- https://www.youtube.com/watch?v=NfcgA1axPLo