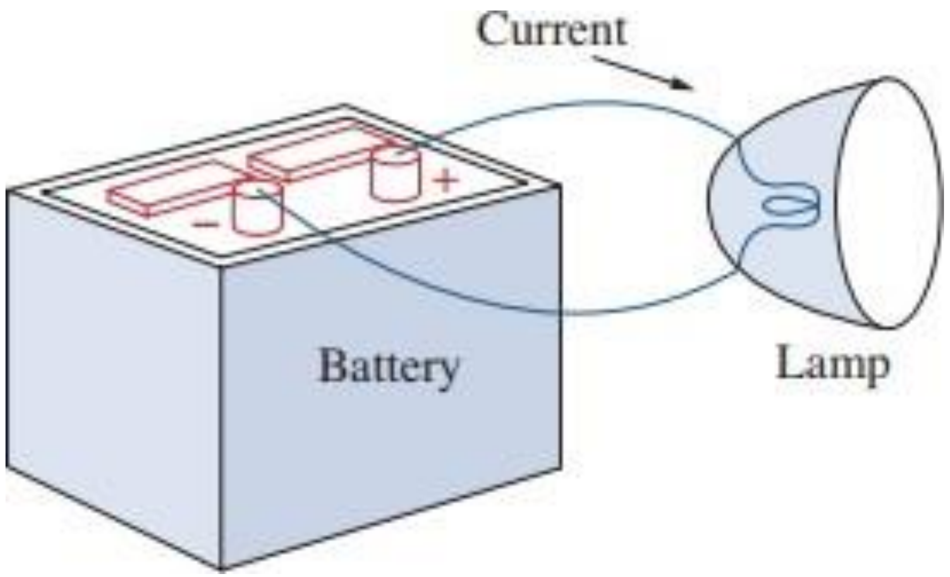
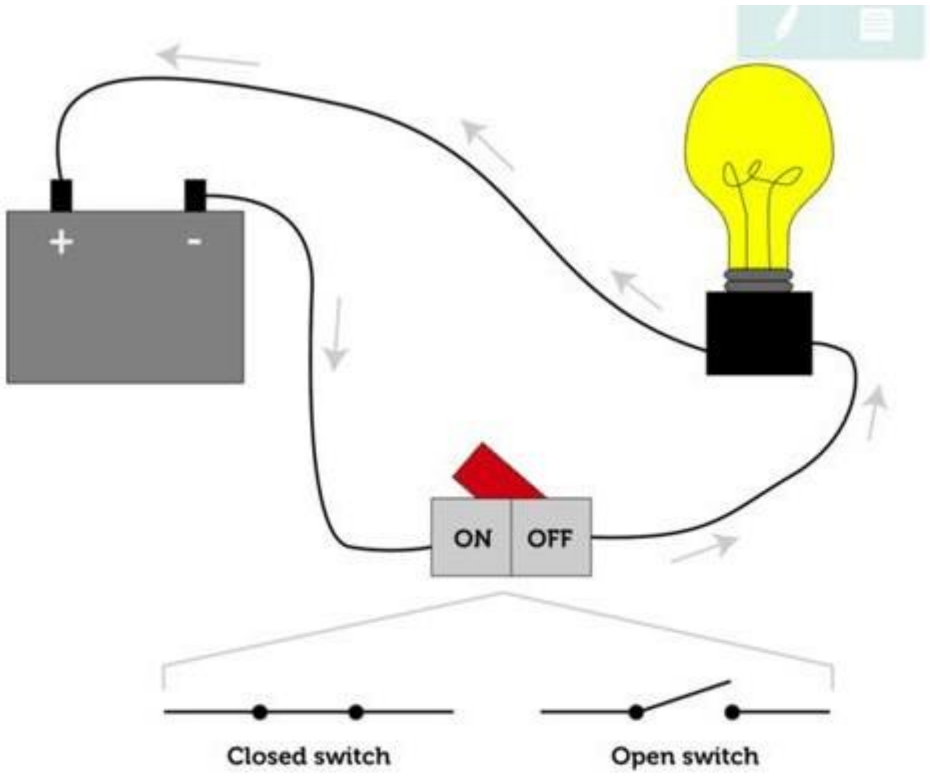
UNIT 1:
DC CIRCUITS

Electrical Circuit





Charge and Current

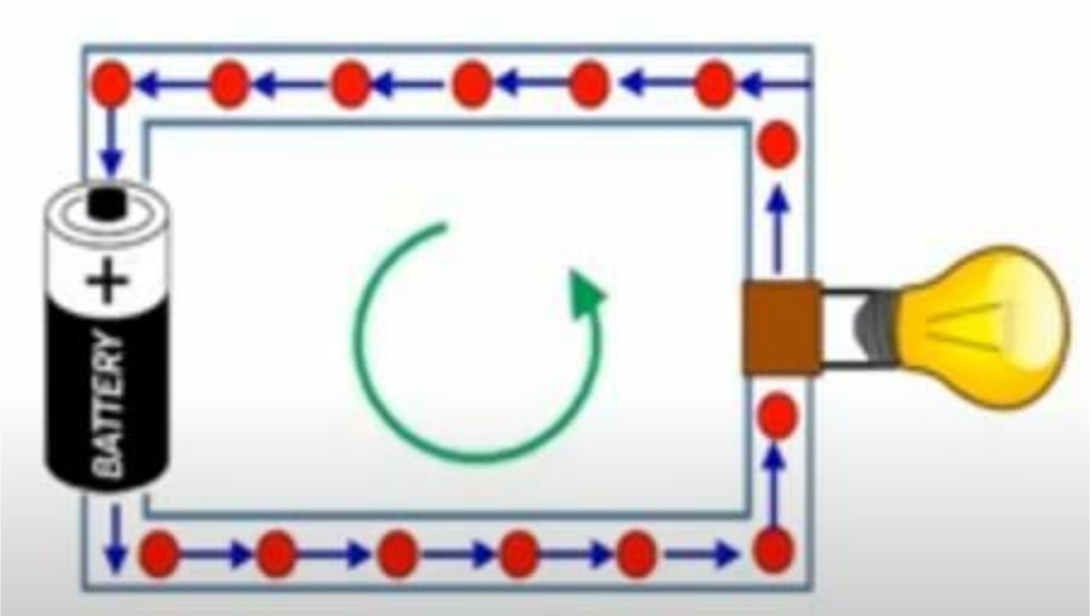
Fundamental electric-charge-carrying particles are electrons (-ve Charge) and protons (+ve Charge)

- **Charge:** Charge is an electrical property of the atomic particles of a matter.

  Electronic Charge = 1.602×10^{-19}

  S.I Unit: Coulomb (C)

  Symbol: Q



- **Current:** Rate of flow of charge through a conducting path.

OR

Continuous flow of electrons in an electrical circuit.

S.I Unit: Ampere (A)

Symbol: I

Charge and Current

- Mathematically,

$$I = \frac{dQ}{dt} \ or \ Q = \int_{t_0}^{t} I.dt$$

Or, in simple terms:

$$I = \frac{Q}{T}$$

So, 1 Ampere = 1 coulomb/ 1 second.

QUICK QUIZ (Poll 1)

1 Coulomb is same as:

A. Watt /sec

B. Ampere/sec

C. Joule-sec

D. Ampere-sec

QUICK QUIZ (Poll 1)

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1 Coulomb is same as:

A. Watt /sec
B. Ampere/sec
C. Joule-sec
D. Ampere-sec

QUICK QUIZ (Poll 2)

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The total charge entering the terminal is 5 $sin\ 4\pi t\ mC$. Calculate current at t= 0.5 sec.:

A. 31.2 A

B. 31.2 mA

C. 62.8 mA

D. 62.8 A

QUICK QUIZ (Poll 2)

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The total charge entering the terminal is $5 \; sin \; 4\pi t \; mC$. Calculate current at t= 0.5 sec.:

A. 31.2 A

B. 31.2 mA

C. **62.8 mA**

D. 62.8 A

QUICK QUIZ (Poll 3)

The total charge entering the terminal is $5\text{t } sin\ 4\pi t\ mC$. Calculate current at t= 0.5 sec.:

A. 31.2 A

B. 31.2 mA

C. 62.8 mA

D. 62.8 A

QUICK QUIZ (Poll 3)

The total charge entering the terminal is $5t\ sin\ 4\pi t\ mC$. Calculate current at t= 0.5 sec.:

A. 31.2 A

B. 31.2 mA

C. 62.8 mA

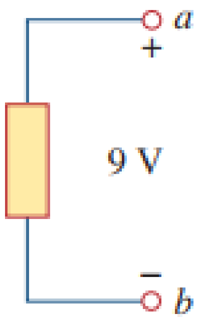
D. 62.8 A

Voltage

- It is the energy (Work) required to move a unit charge through an element.

S.I Unit: Volt (V)

Symbol: V



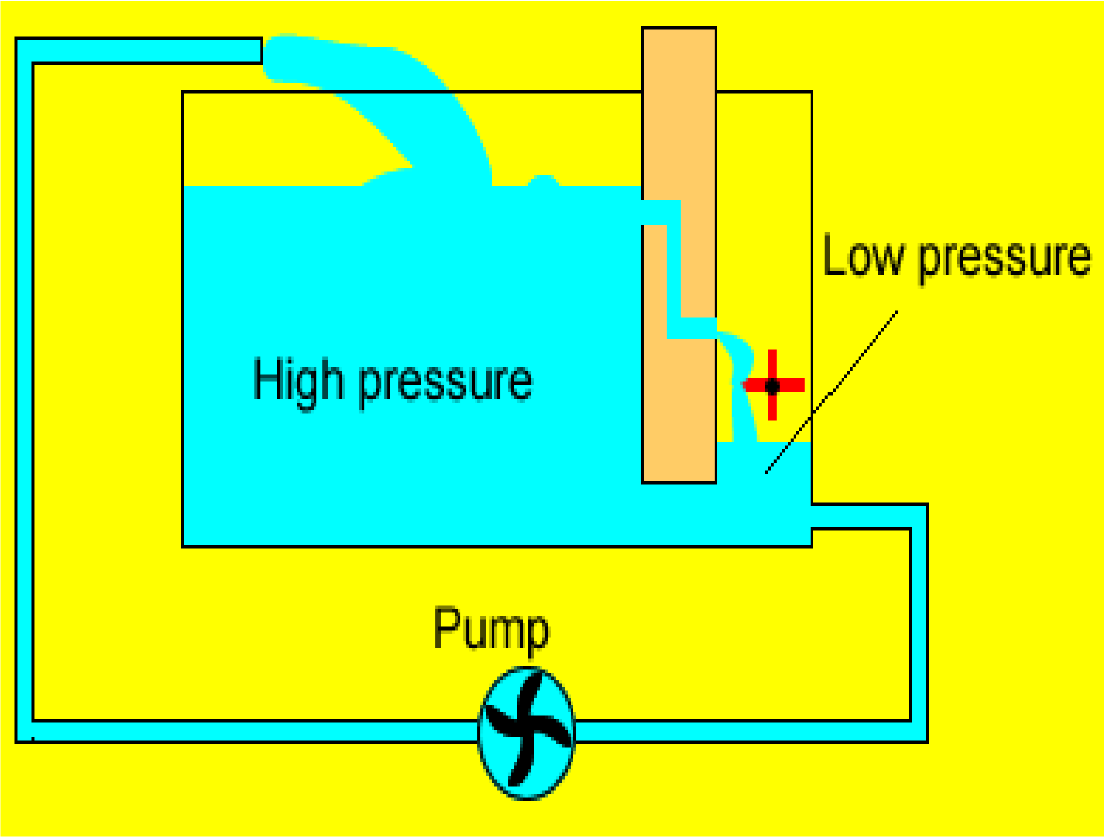
(a)

$$v_{ab} = -v_{ba}$$

$$1 \text{ volt} = 1 \text{ joule/coulomb}$$

Mathematically

$$V = \frac{dW}{dq}$$



Power and Energy

- **Power:** Rate at which the work is done.

OR

Time rate of absorbing or supplying energy

S.I Unit: Watts (W)

Symbol: P

Mathematically,

$$P = \frac{dW}{dt} = \frac{dW}{dq} \times \frac{dq}{dt}$$

Implies,

$$\boxed{P = V.I}$$

Power and Energy

- Energy: Capacity of doing work.

  S.I Unit: Joules(J)

  Symbol: E

QUICK QUIZ (Poll 4)

Calculate the current ratings of 100 Watt incandescent bulb and 15 Watt LED lamp operated with the domestic supply of 220 Volt?

A. Bulb = 0.068 A and LED = 0.45 A

B. Bulb = 0.45 A and LED = 0.068 A

C. Bulb =0.50 A and LED = 0.068 A

D. Bulb = 0.50 and LED = 0.68 A

QUICK QUIZ (Poll 4)

Calculate the current ratings of 100 Watt incandescent bulb and 15 Watt LED lamp operated with the domestic supply of 220 Volt?

A. Bulb = 0.068 A and LED = 0.45 A

B. Bulb = 0.45 A and LED = 0.068 A

C. Bulb =0.50 A and LED = 0.068 A

D. Bulb = 0.50 and LED = 0.68 A

QUICK QUIZ (Poll 5)

From the previous question, it can be inferred that:

A. LED consumes 5 times more current than Bulb.

B. Bulb consumes 5 times more current than LED.

C. LED consumes 6.6 times more current than Bulb.

D. Bulb consumes 6.6 times more current than LED.

QUICK QUIZ (Poll 5)

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From the previous question, it can be inferred that:

A. LED consumes 5 times more current than Bulb.

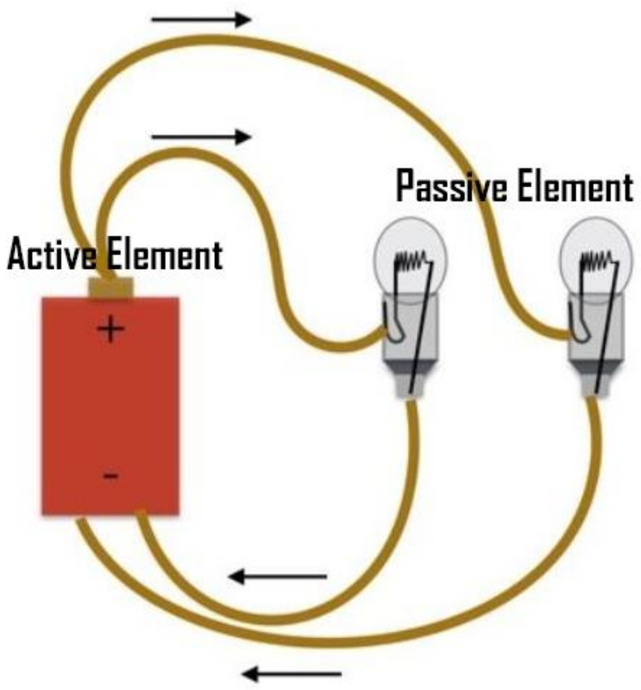
B. Bulb consumes 5 times more current than LED.

C. LED consumes 6.6 times more current than Bulb.

D. Bulb consumes 6.6 times more current than LED.

Network Components

Active	Passive
Battery Transistor, Op-amp, Diode VS and CS Generators	Resistance (R) Capacitance (C) Inductance (L) Transformers

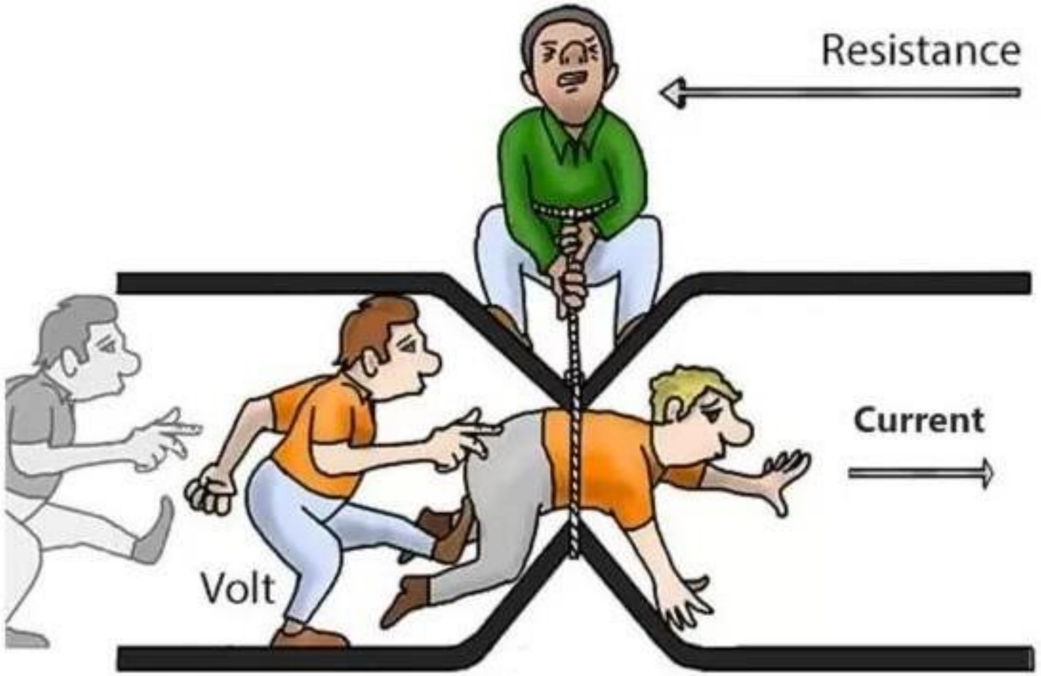


Resistance

- Resistance: It is an opposition to the flow of current.

    S.I Unit: Ohm (Ω)

    Symbol: R



Capacitance

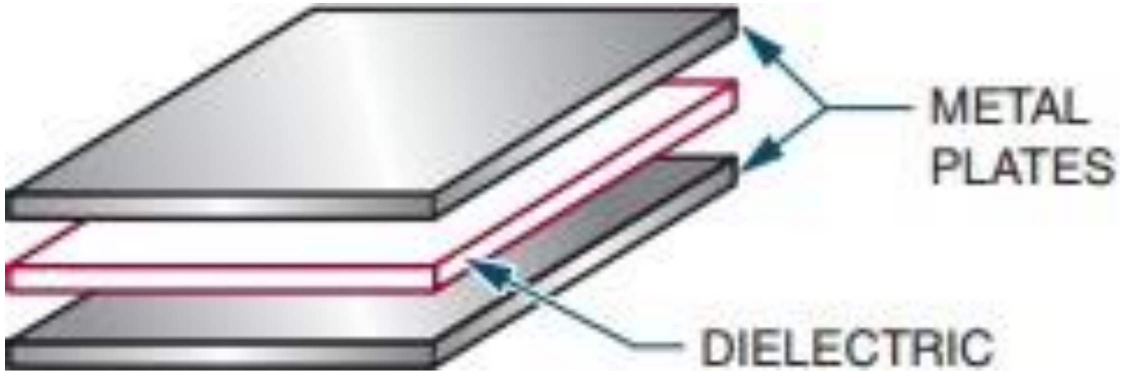
- Capacitance is the ability of a device to store electrical energy in an electrostatic field.
- A capacitor is a device that ***stores energy in the form of an electrical field***.
- A capacitor is made of two conductors separated by a dielectric.

S.I Unit: Farad (F)

Symbol: C

Two important Properties:

1. ***No current flows through the capacitor, if the voltage remains constant.***
2. Voltage across a capacitor cannot change instantaneously.



Inductance

- Inductance is the characteristic of an electrical conductor that opposes a change in current flow.
- An inductor is a device that ***stores energy in a magnetic field***.

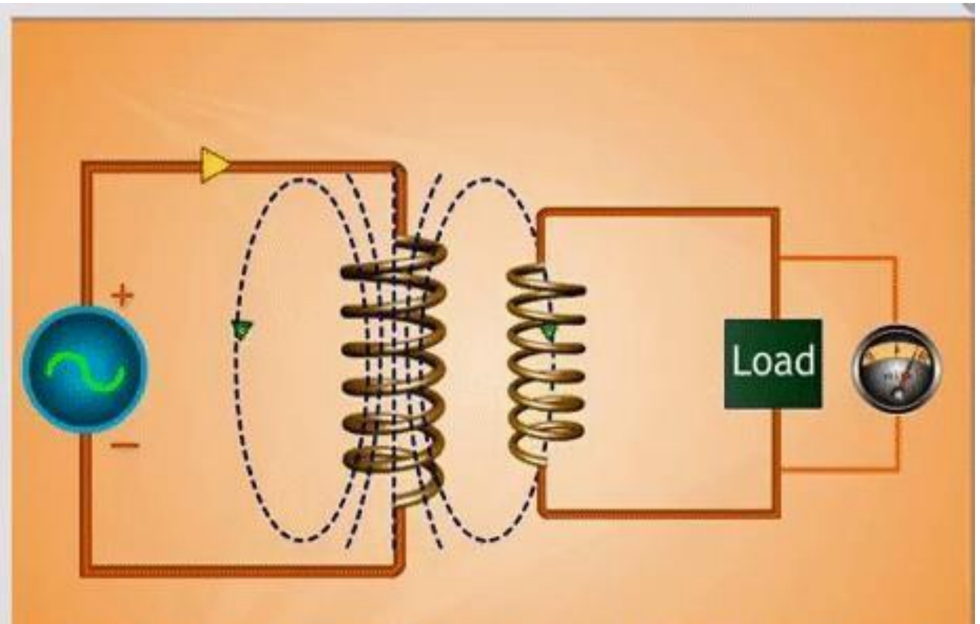
  - When a current flows through a conductor, magnetic field builds up around the conductor. This field contains energy and is the foundation for inductance.

S.I Unit: Henry (H)

Symbol: L

Two important Properties:

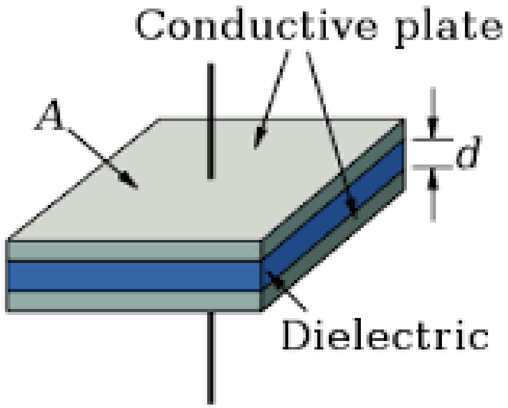
1. No voltage appears across an inductor, if the current through it remains constant.
2. The current through an inductor cannot change instantaneously.



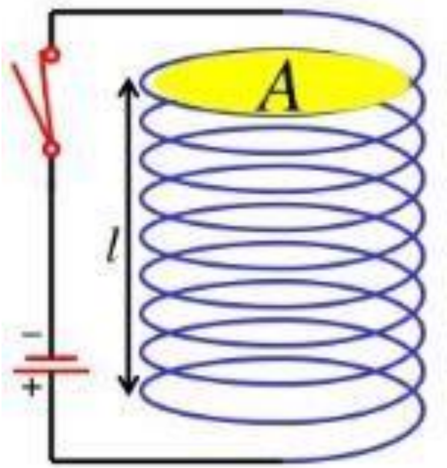
Flux links with second inductor which induces current in it

Capacitance and Inductance

- $Q = CV$
- $I = \frac{dQ}{dt} = \frac{d\,CV}{dt} = C\,\frac{dV}{dt}$
- $E = \frac{1}{2}CV^{\,2}$
- $C = \frac{A\epsilon}{d}$



- $V = L\,\frac{dI}{d}$
- $E = \frac{1}{2}LI^2$
- $L = \frac{\mu\,N^2 A}{l_{(\text{length of coil})}}$



QUICK QUIZ (Poll 6)

Identify the passive element

A. Battery

B. Transformer

C. Transistor

D. OP-amp

QUICK QUIZ (Poll 6)

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Identify the passive element

A. Battery
B. Transformer
C. Transistor
D. OP-amp

QUICK QUIZ (Poll 7)

Find the value of capacitance if the value of voltage increases linearly from 0 to 100 V in 0.1 s causing a current flow of 5 mA?

A. 10 μF

B. 5 F

C. 10 F

D. 5 μF

QUICK QUIZ (Poll 7)

Find the value of capacitance if the value of voltage increases linearly from 0 to 100 V in 0.1 s causing a current flow of 5 mA?

A. 10 μF

B. 5 F

C. 10 F

D. 5 μF

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"

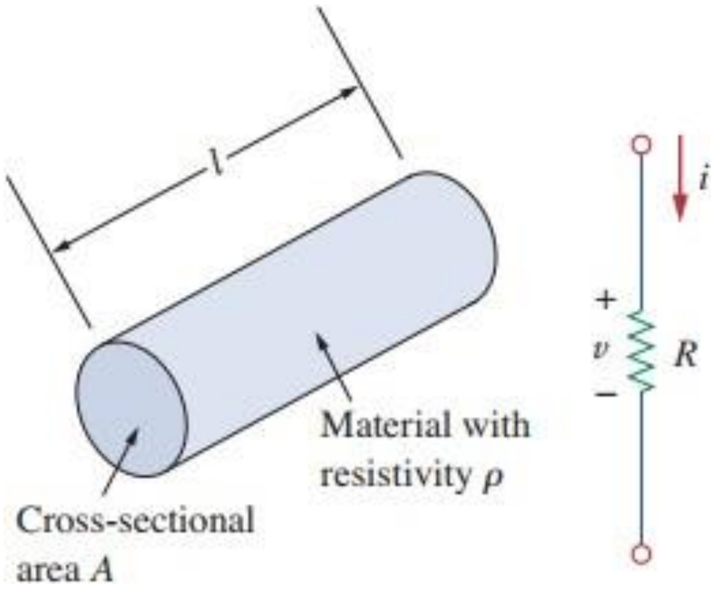
Mathematically,

$$I \propto V$$

Or,

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

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



Resistivity Table

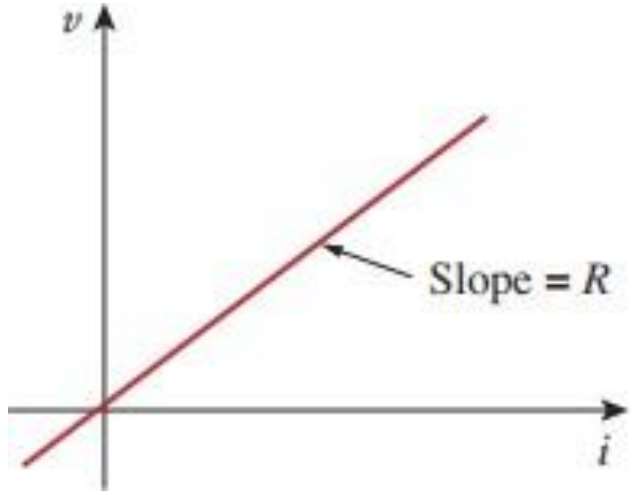
Material	Resistivity ($\Omega \cdot m$)	Usage
Silver	1.64×10^{-8}	Conductor
Copper	1.72×10^{-8}	Conductor
Aluminum	2.8×10^{-8}	Conductor
Gold	2.45×10^{-8}	Conductor
Carbon	4×10^{-5}	Semiconductor
Germanium	47×10^{-2}	Semiconductor
Silicon	6.4×10^{2}	Semiconductor
Paper	10^{10}	Insulator
Mica	5×10^{11}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

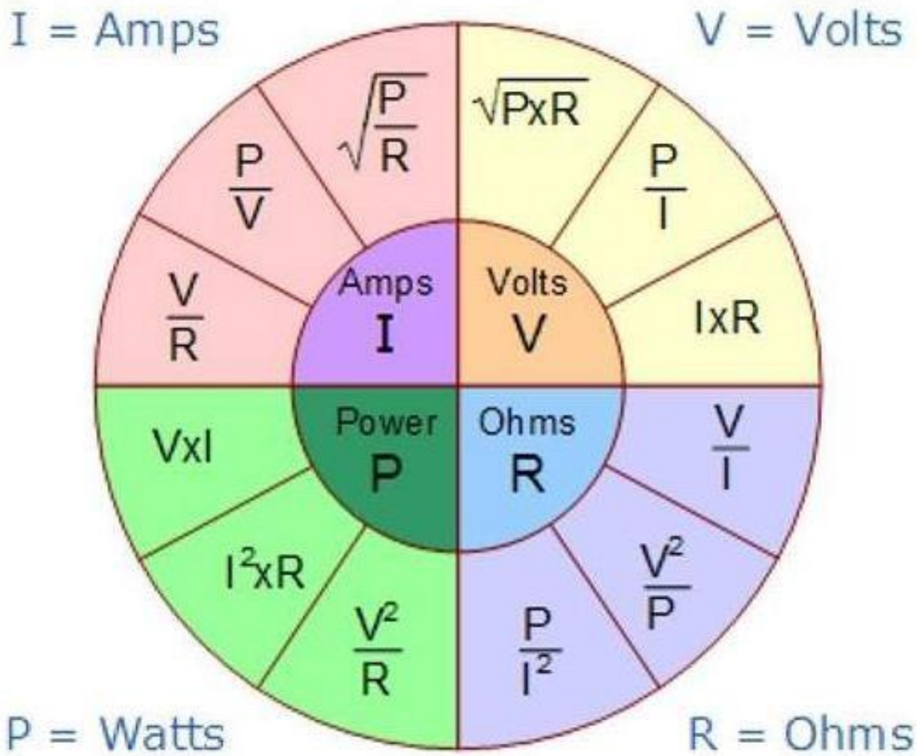
Conductance

- 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: ℧, the inverted omega.

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

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



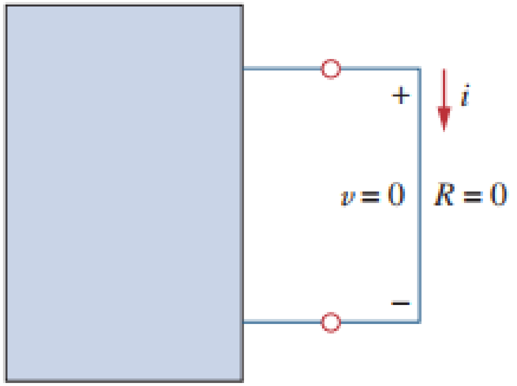


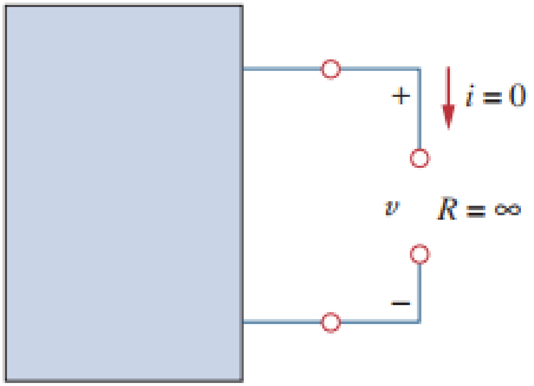
Ohm's Law Pie Chart (Source: Electronics-Tutorials.ws)

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)





Current follows the least resistive path

Applications of Ohm's Law

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

$$\boxed{v = iR}$$

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

$$I=V/R$$

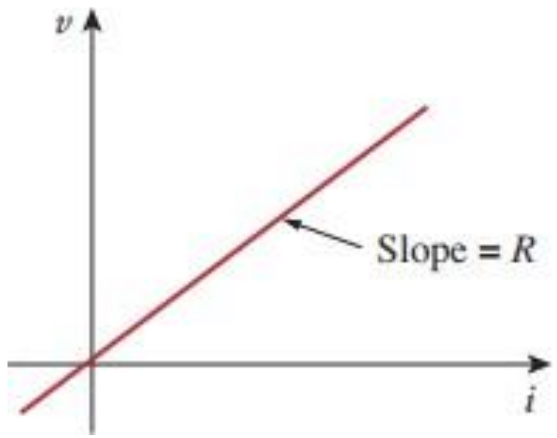
$$R = \rho\frac{\ell}{A}$$

Applications of Ohm's Law

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 current 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 8)

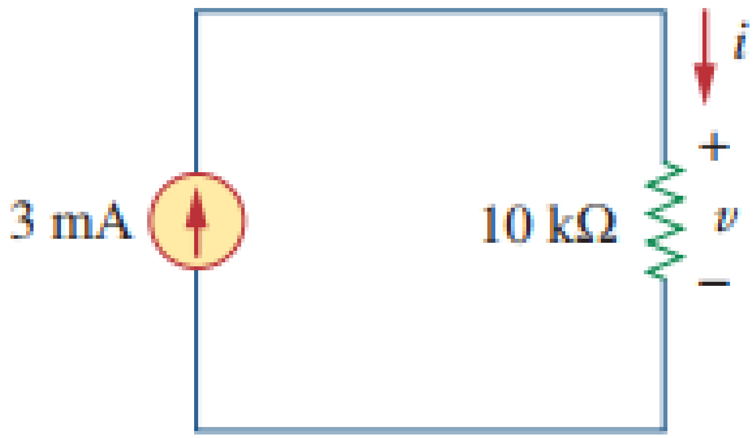
The voltage and the conductance of the given circuit is:

A. 30 V, 10 µS

B. 30 mV, 100 µS

C. 30 V, 100 µS

D. 30 mV, 10 µS



QUICK QUIZ (Poll 8)

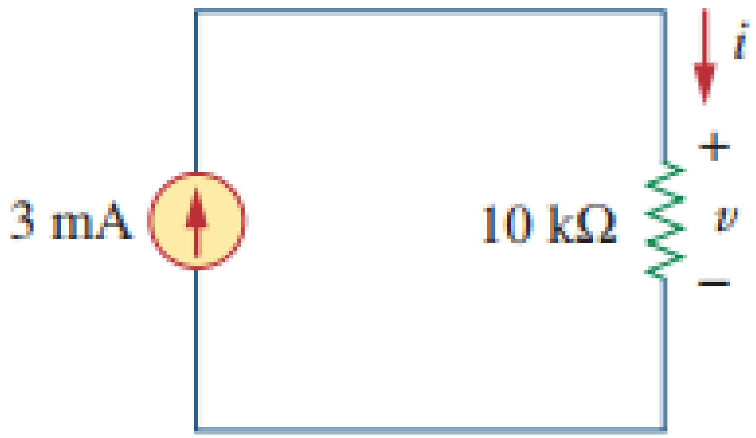
The voltage and the conductance of the given circuit is:

A. 30 V, 10 µS

B. 30 mV, 100 µS

C. **30 V, 100 µS**

D. 30 mV, 10 µS



QUICK QUIZ (Poll 9)

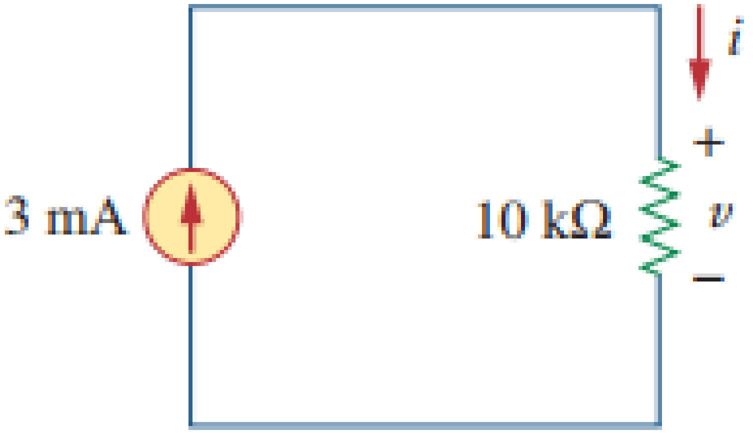
The power of the given circuit is:

A. 60 mW

B. 70 mW

C. 80 mW

D. 90 mW



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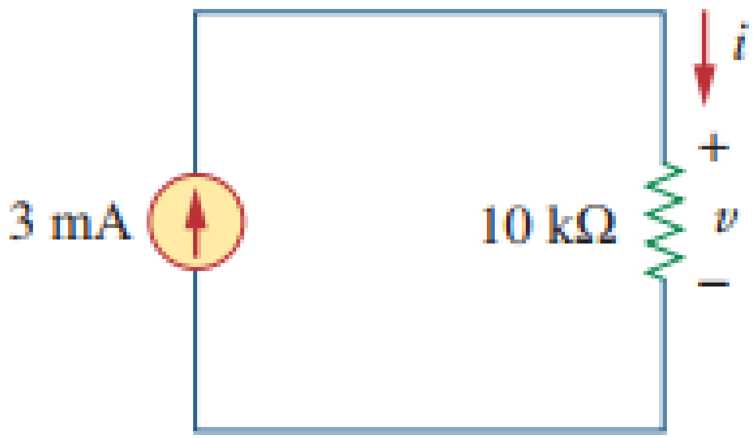
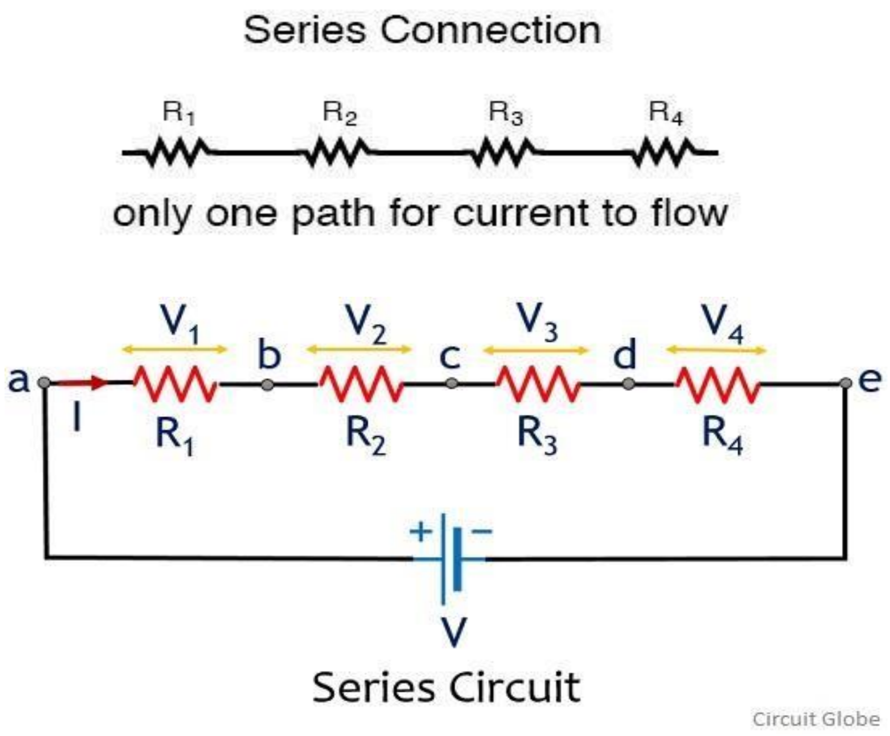
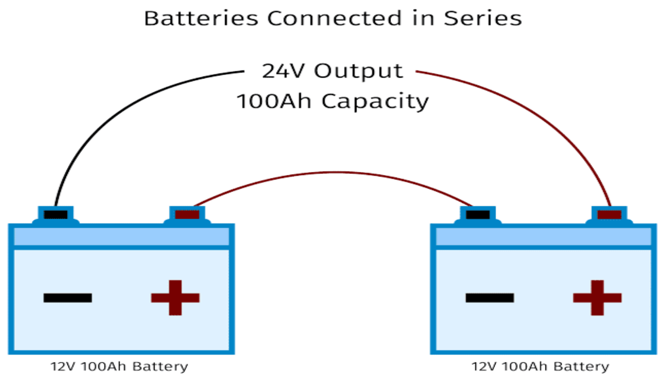
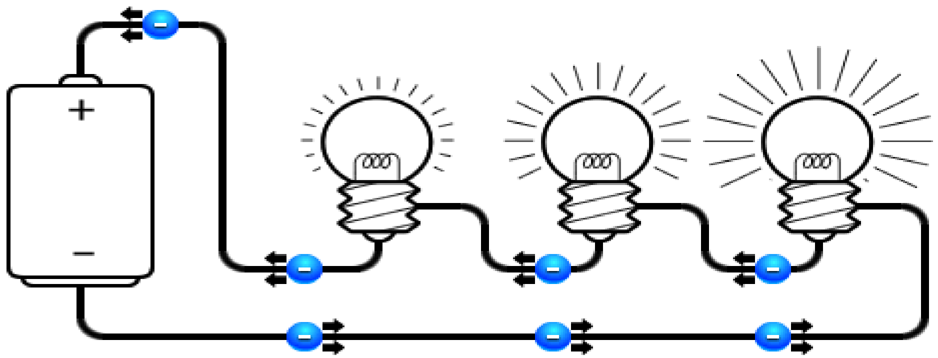


Series Connection

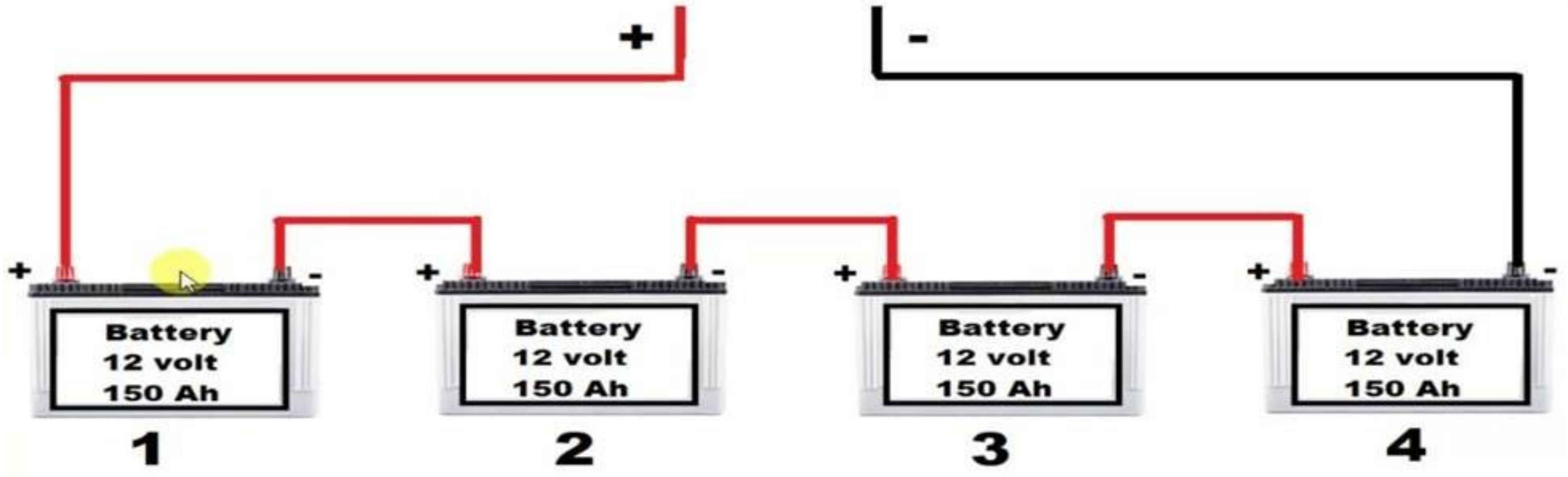
- **SERIES CONNECTION:** Two or more elements are in series if they exclusively share a single node and consequently carry the same current.



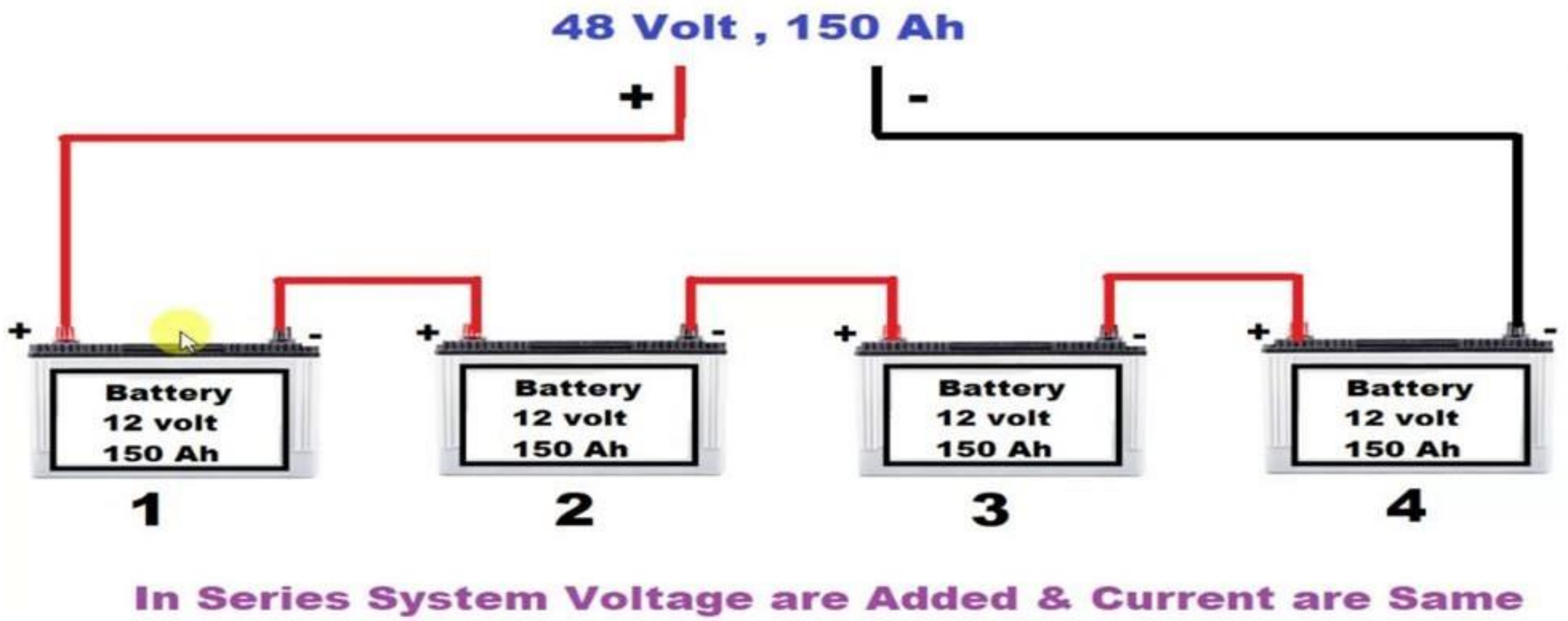




Point to Remember for Series Circuits

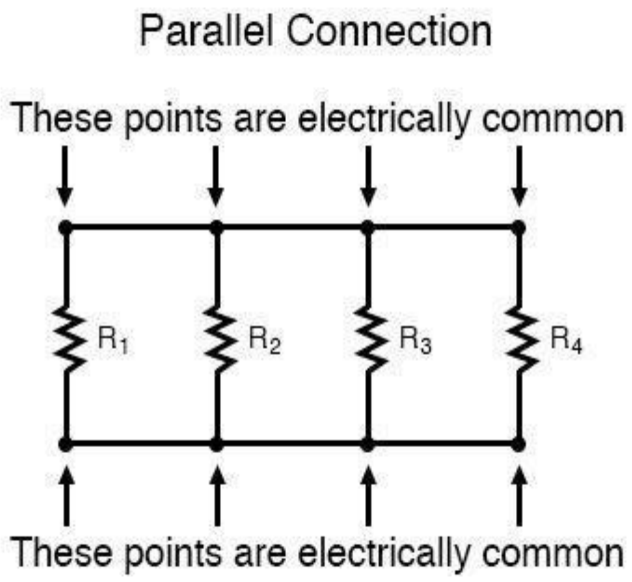


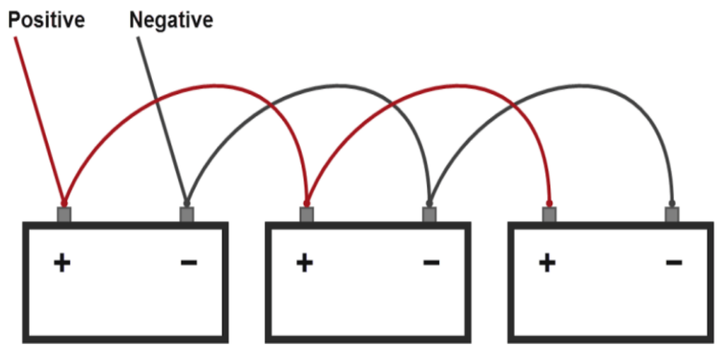
Point to Remember for Series Circuits

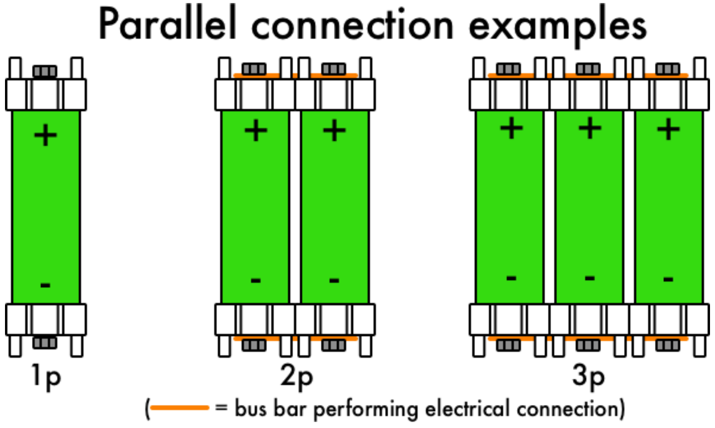


Parallel Connection

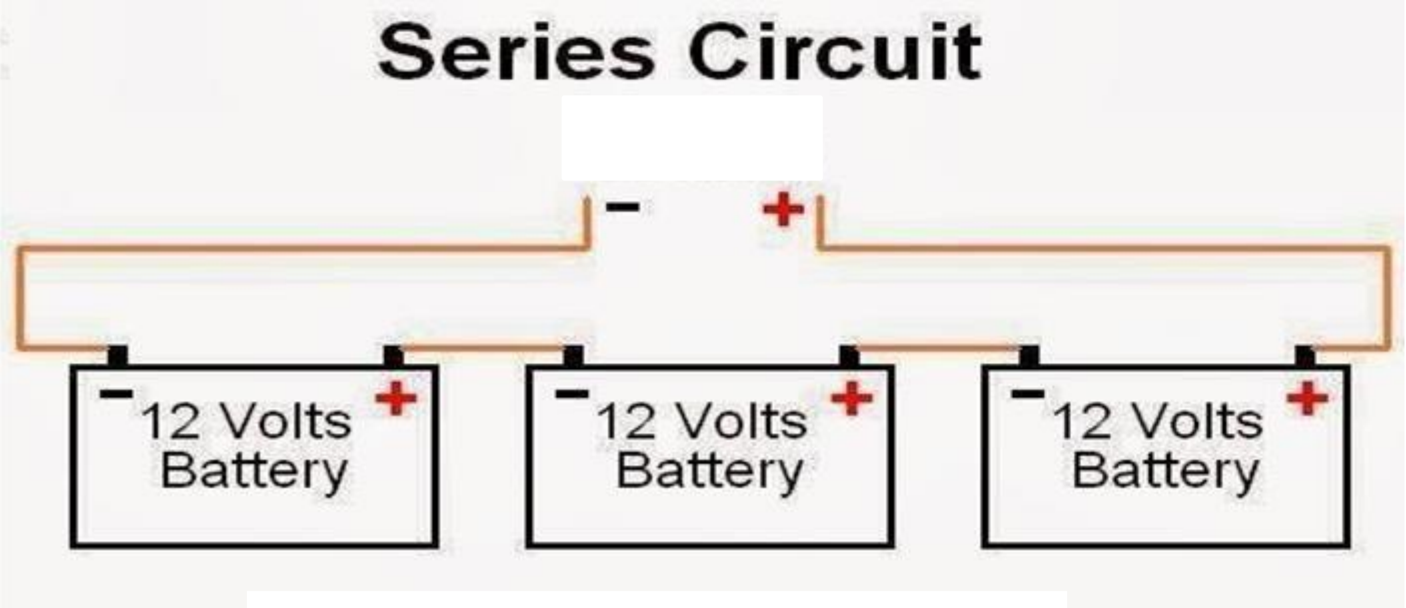
- PARALLEL CONNECTION: Two or more elements are in parallel if they are connected to the same two nodes and consequently have the same voltage across them

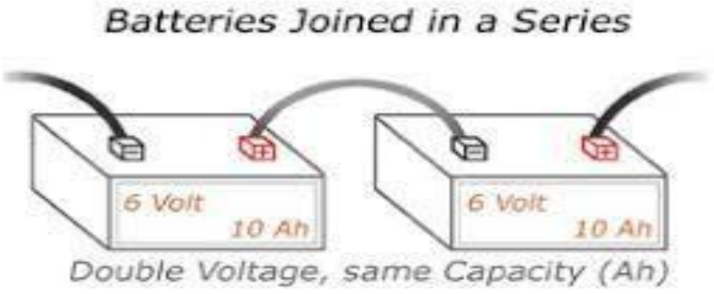


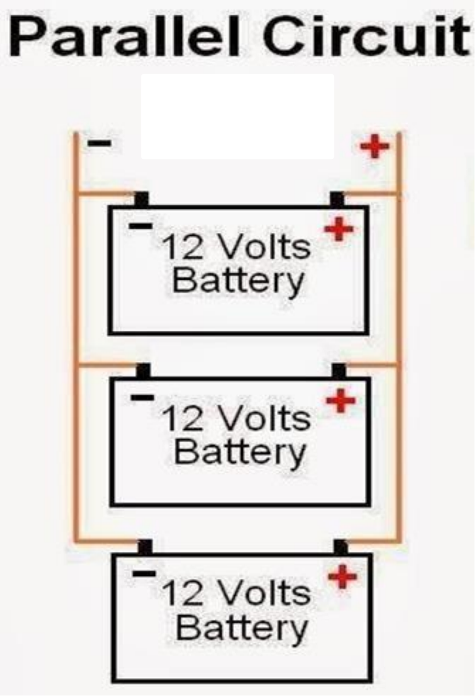




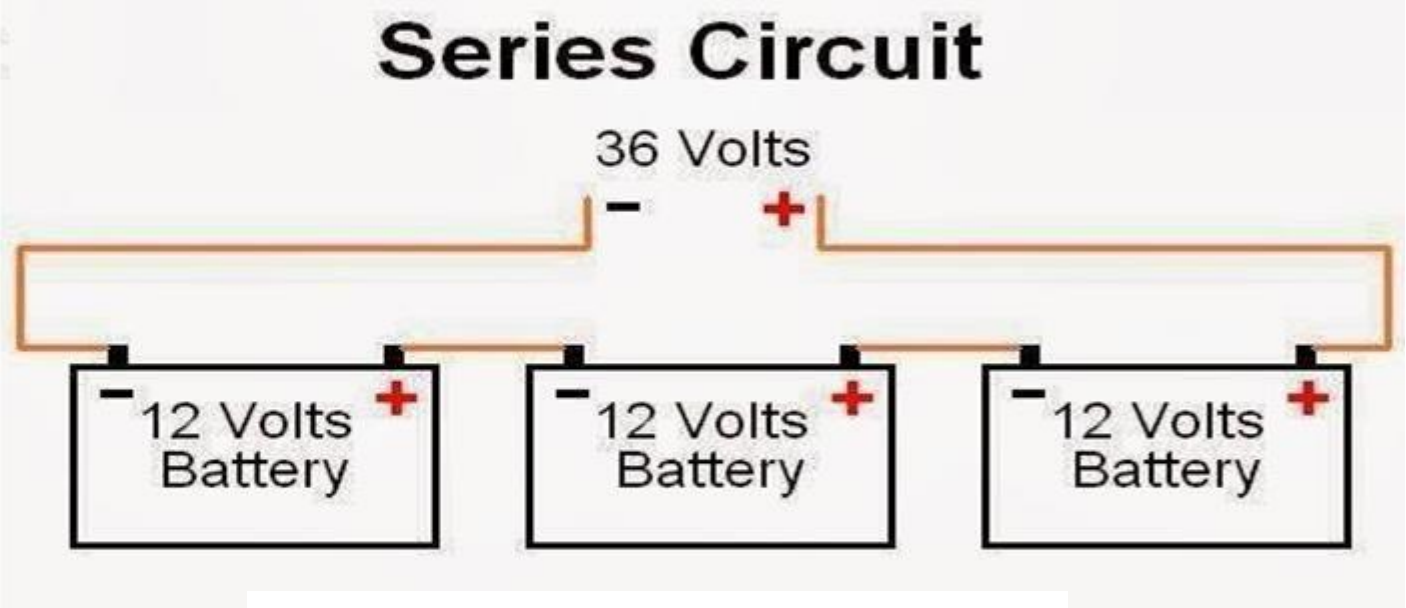
Battery Voltage In Series And Parallel

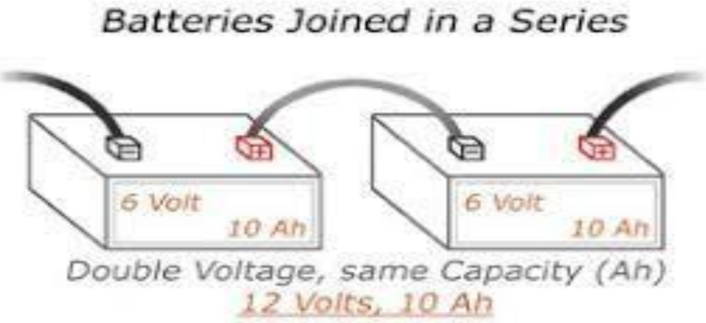


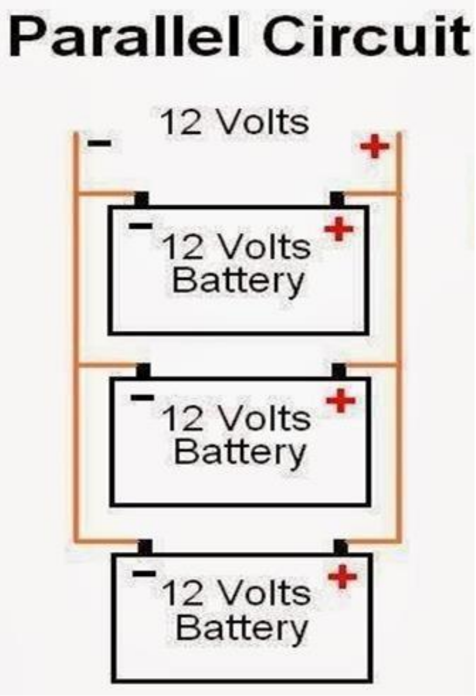




Battery Voltage In Series And Parallel







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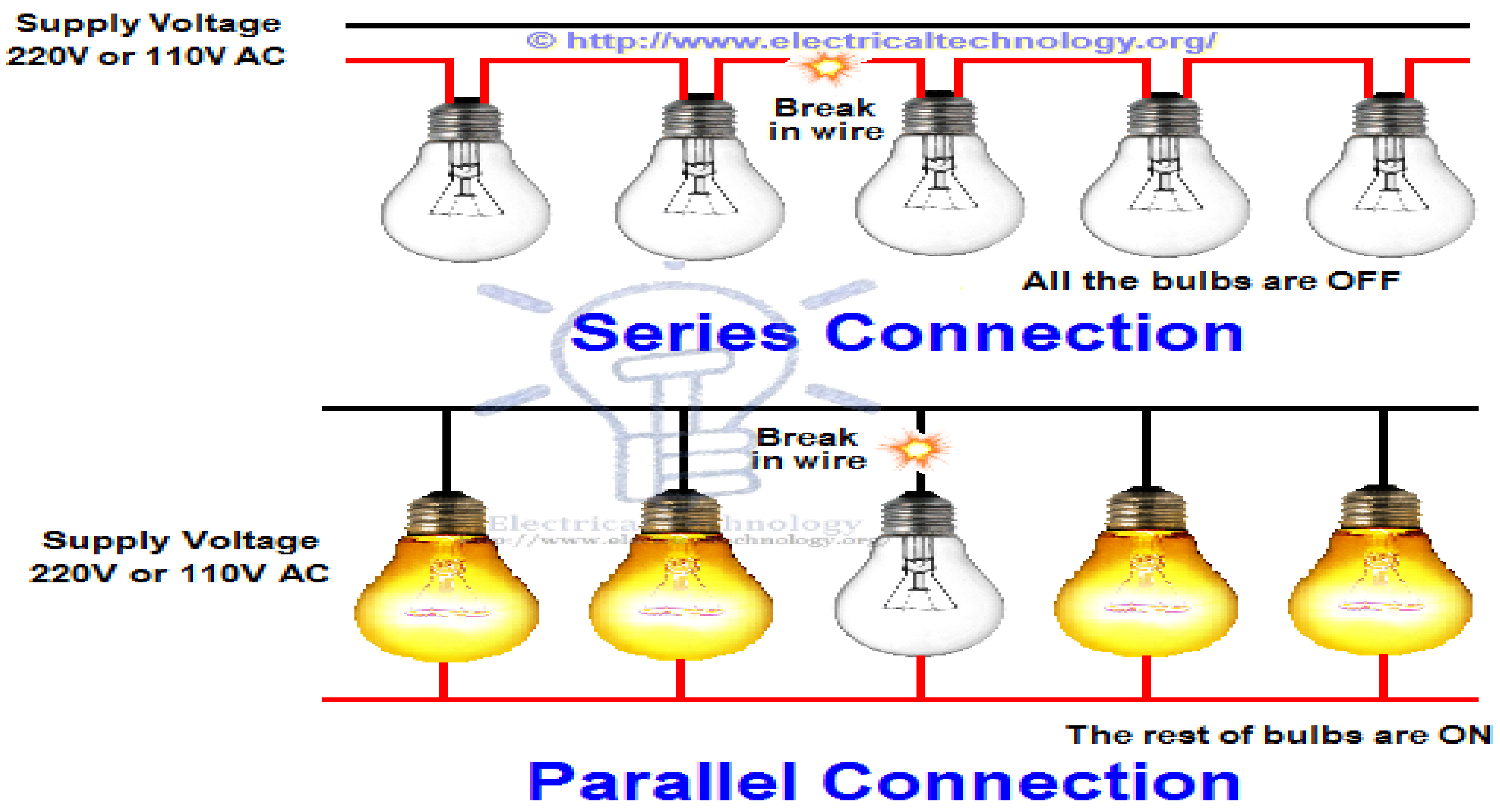


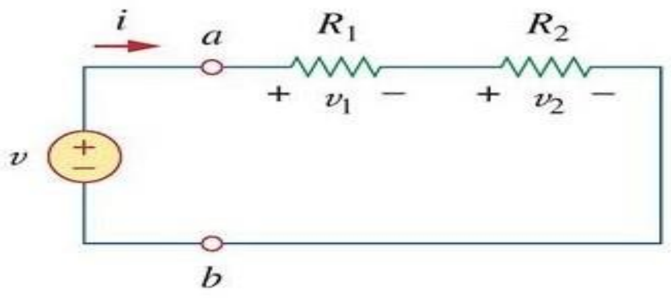
Why Parallel Connection is Preferred over Series Connection?

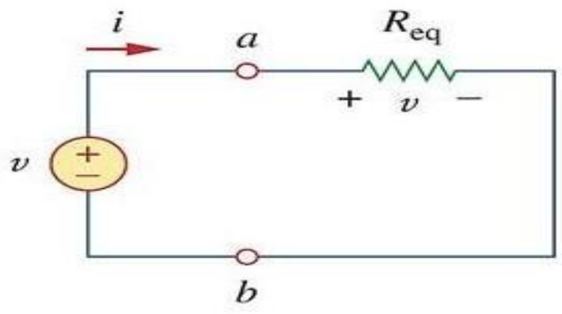
RESISTORS IN SERIES

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

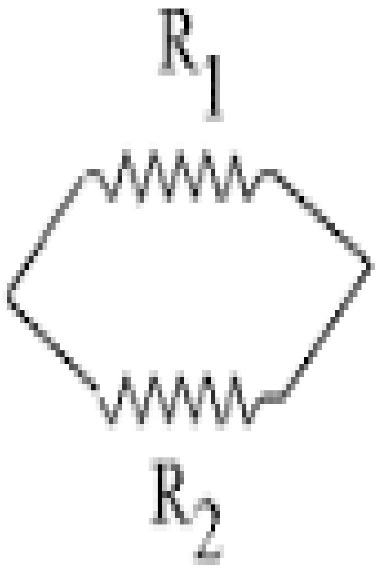
$$R_{eq} = R_1 + R_2 + \cdots + R_N = \sum_{n=1}^{N} R_n$$





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



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

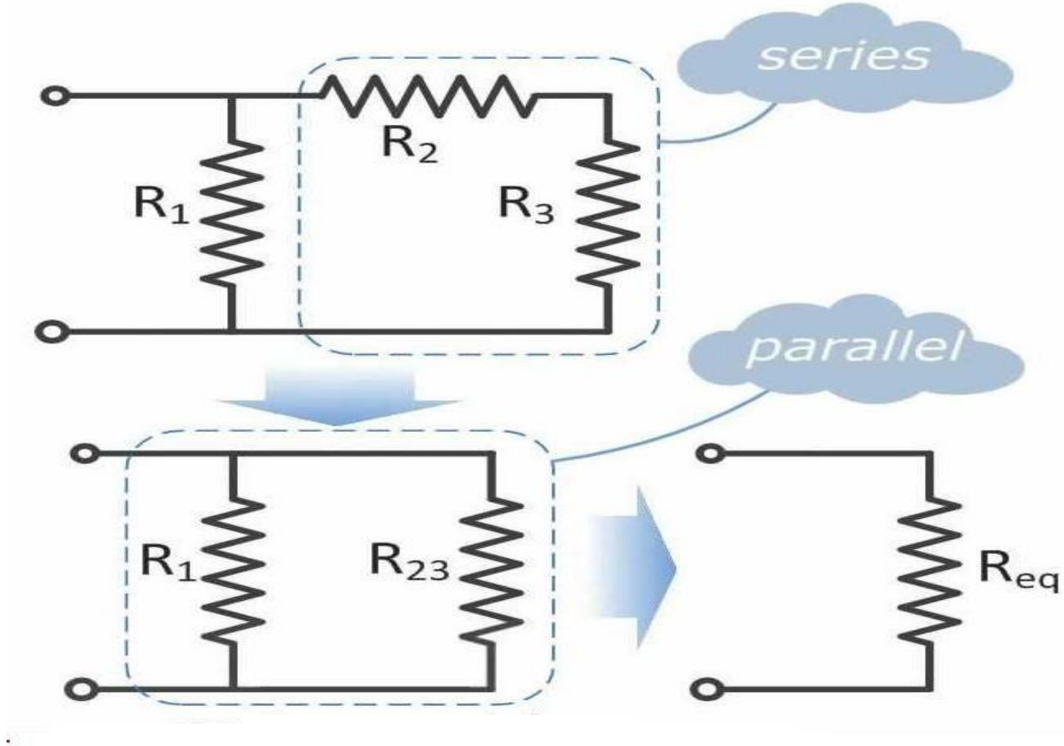
$$\frac{1}{R_t} = \frac{R_2 + R_1}{R_1 R_2}$$

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

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

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

How to find Equivalent Resistance for Series-Parallel Combinations



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

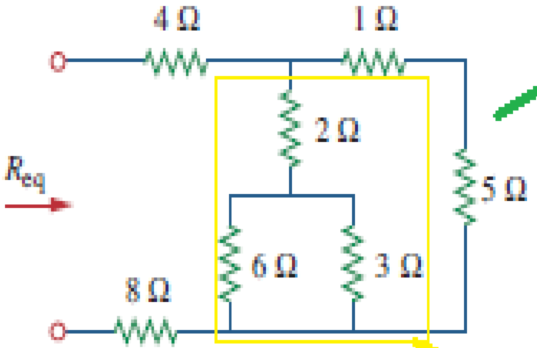
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_{23}}$$

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

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

Example: To find R_{eq}

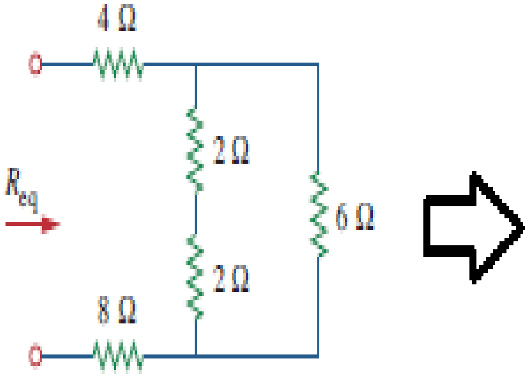
Find R_{eq} for the circuit shown in Fig.



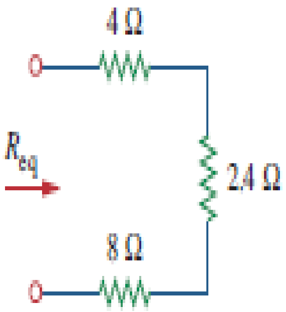
$1\ \Omega + 5\ \Omega = 6\ \Omega$

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

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



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

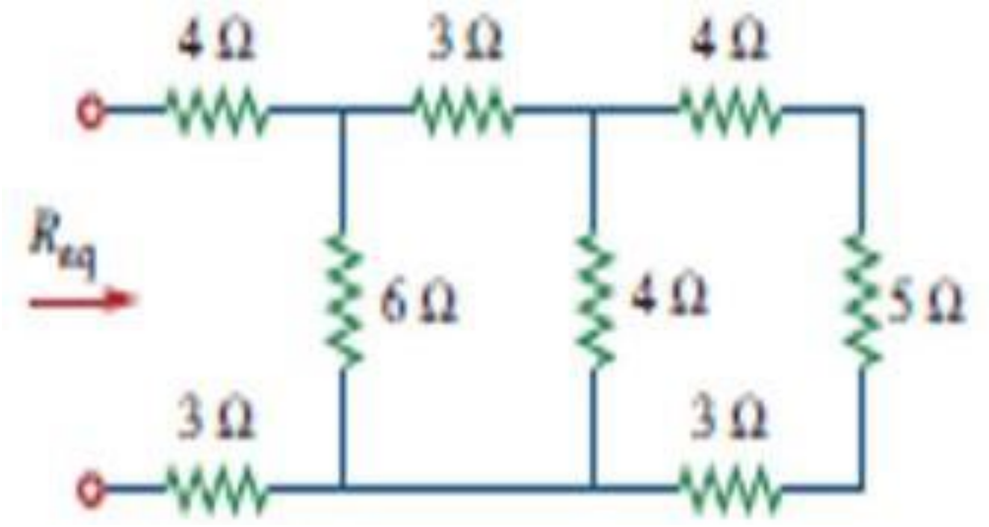


$$R_{eq} = 4\ \Omega + 2.4\ \Omega + 8\ \Omega = 14.4\ \Omega$$

QUICK QUIZ (Poll 10)

Find Equivalent Resistance in Ohms?

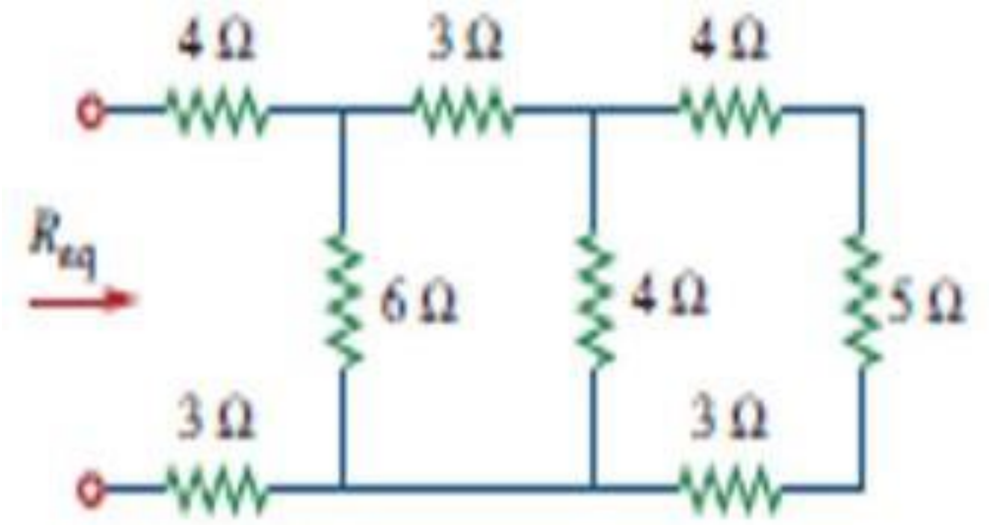
A. 5
B. 10
C. 15
D. 20



QUICK QUIZ (Poll 10)

Find Equivalent Resistance in Ohms?

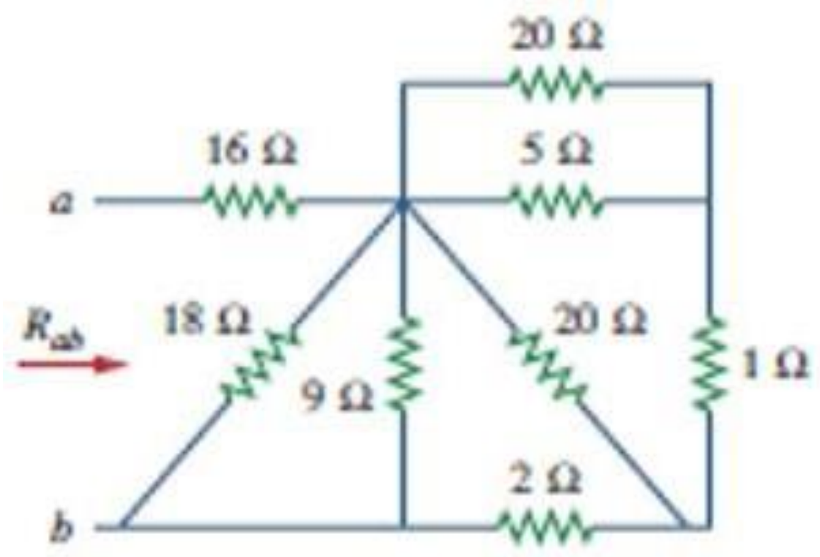
A. 5
B. 10
C. 15
D. 20



QUICK QUIZ (Poll 11)

Find Equivalent Resistance in Ohms?

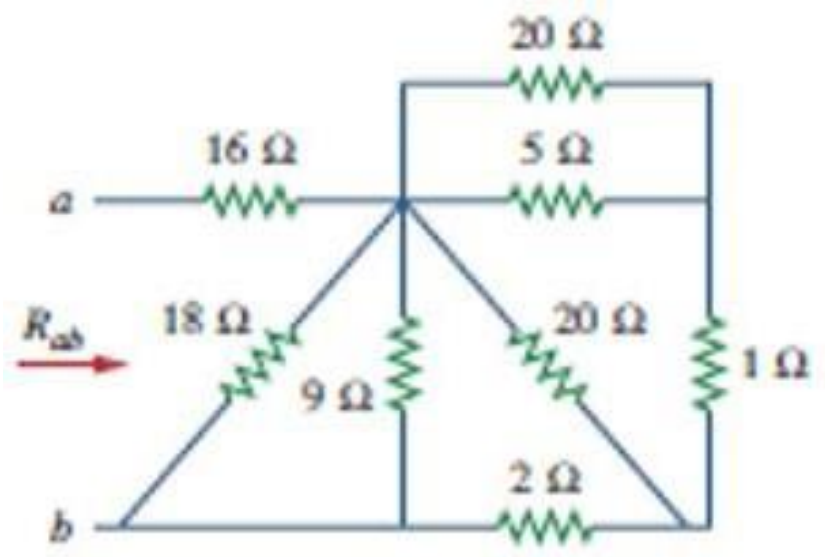
A. 12
B. 17
C. 19
D. 29



QUICK QUIZ (Poll 11)

Find Equivalent Resistance in Ohms?

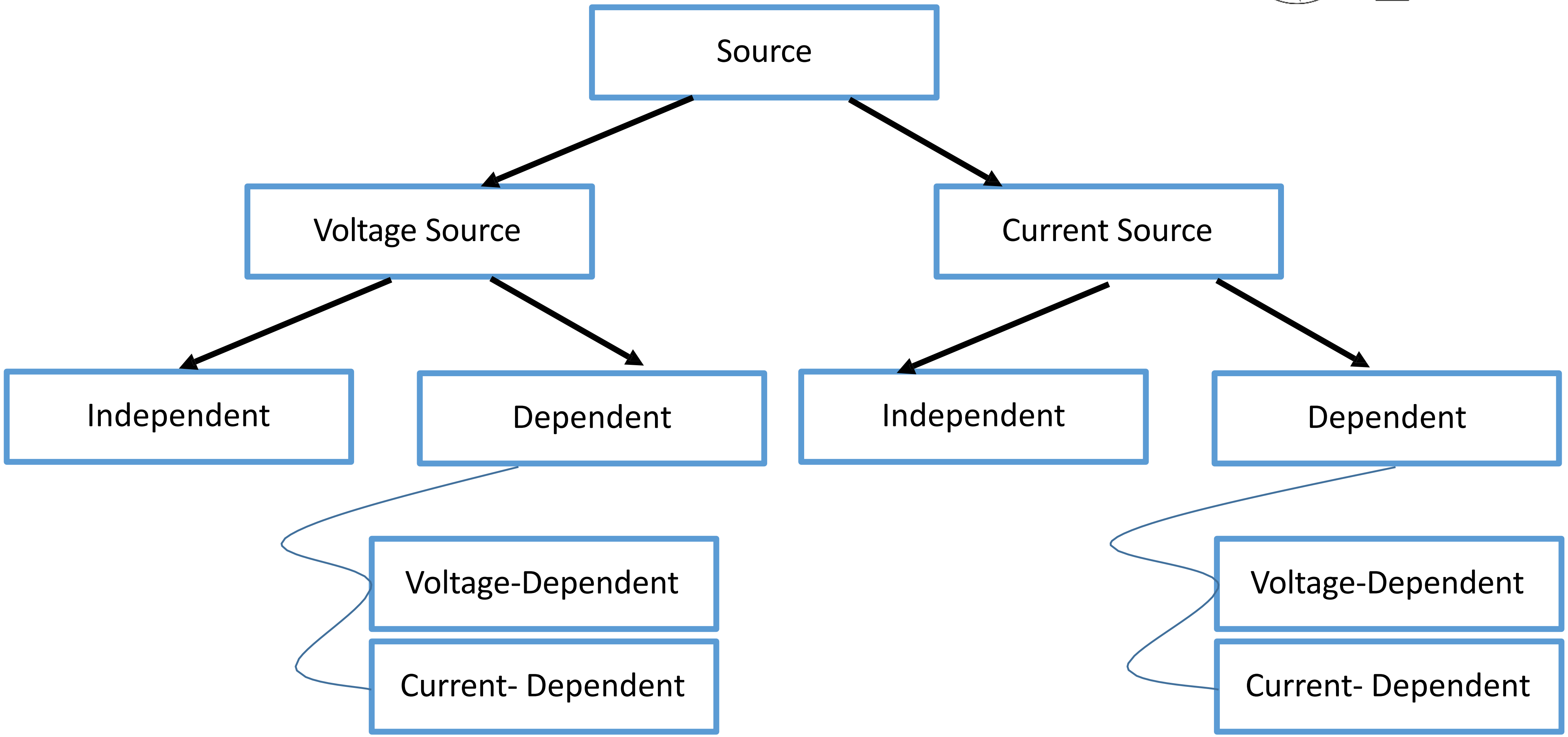
A. 12
B. 17
C. **19**
D. 29



DC CIRCUITS

Lecture 3

Energy Sources



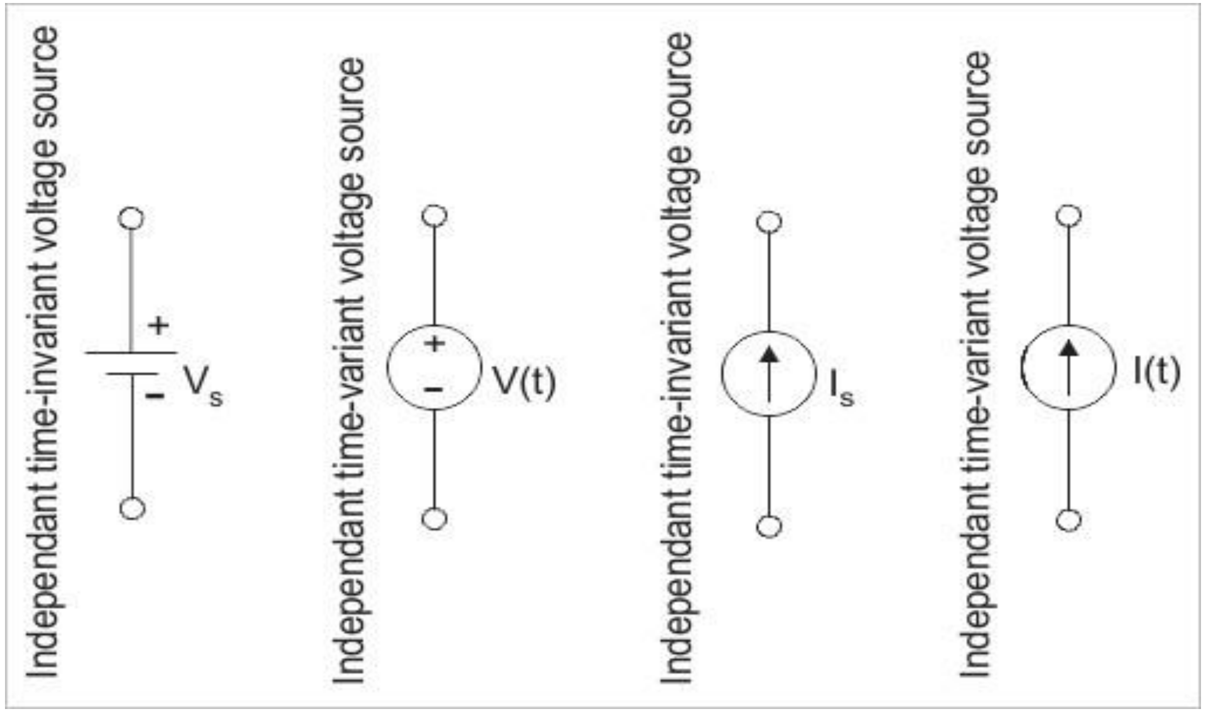
Independent and Dependent Sources

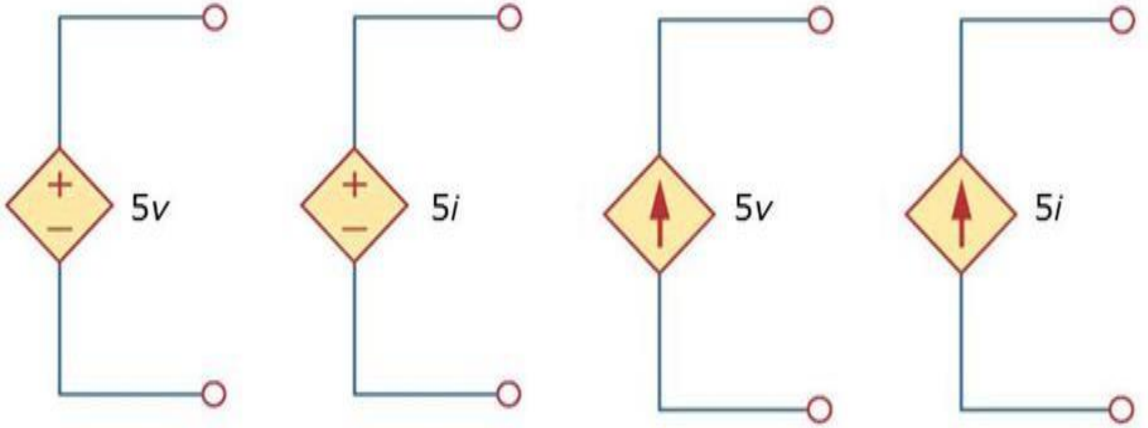
- Independent sources are those which does not depend on any other quantity in the circuit. They are two terminal devices and has a constant value, i.e. the voltage across the two terminals remains constant irrespective of all circuit conditions. The Independent sources are represented by a circular shape.

- Dependent or Controlled sources are those whose output voltage or current is NOT fixed but depends on the voltage or current in another part of the circuit. When the strength of voltage or current changes in the source for any change in the connected network, they are called dependent sources. The dependent sources are represented by a diamond shape.

Independent and Dependent Sources

- Independent
- Dependent





Voltage-controlled voltage source

Current-controlled voltage source

Voltage-controlled current source

Current-controlled current source

Ideal and Practical Voltage Source

Ideal is one where internal resistance does NOT exist

NOTE

1. For a voltage source, internal resistance must be ZERO.
2. For a current source, internal resistance must be INFINITY.

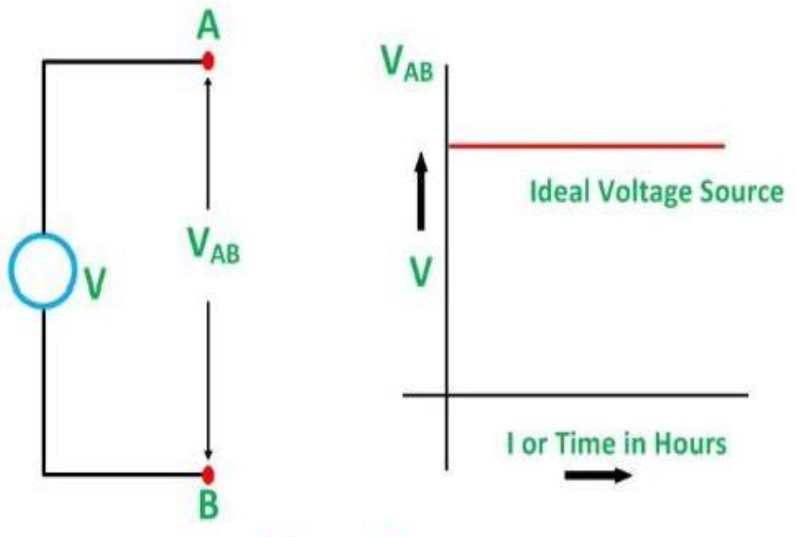


Figure A

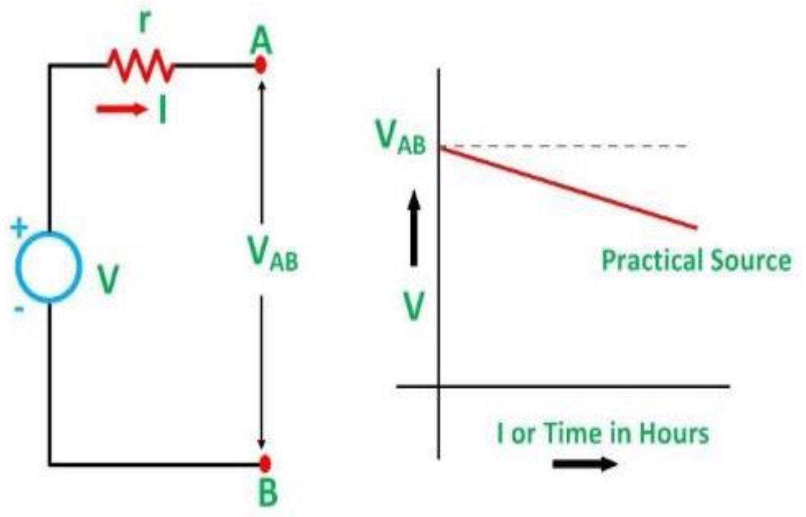


Figure B

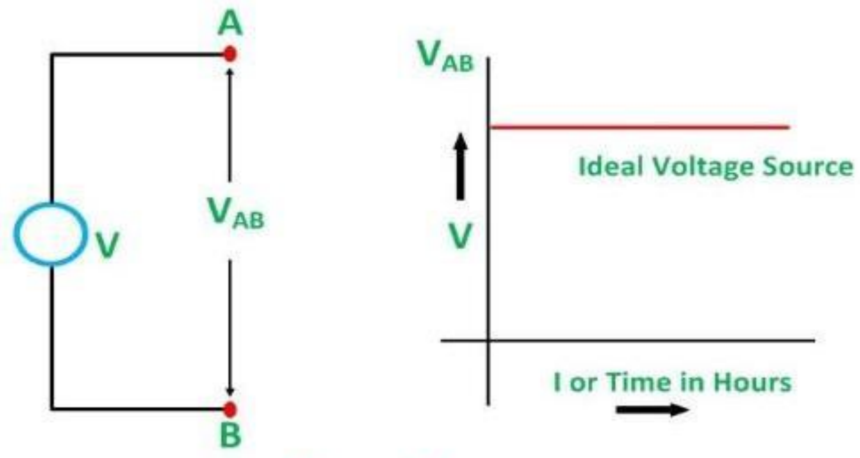


Figure A

The figure B shown below gives the circuit diagram and characteristics of Practical Voltage Source

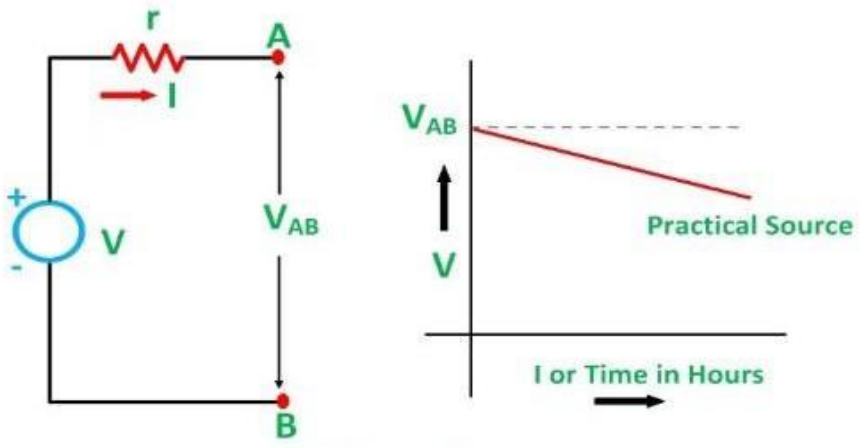


Figure B

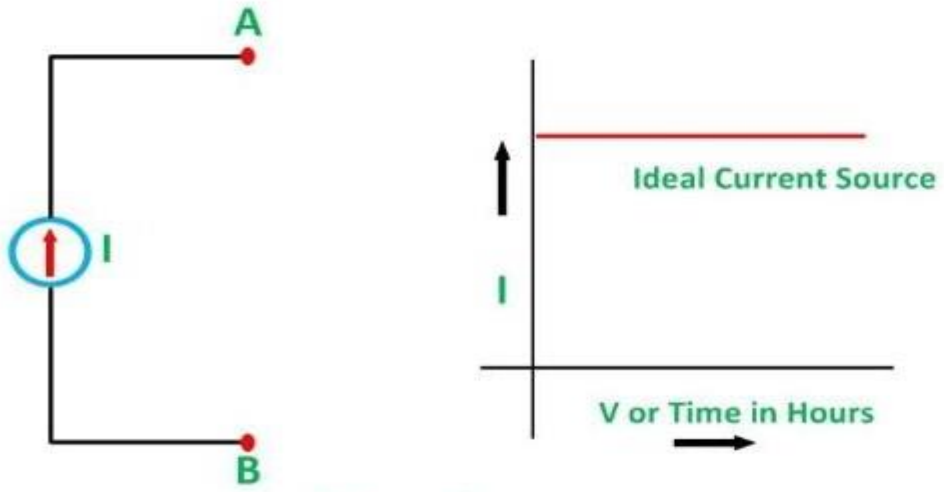


Figure C

Figure D shown below shows the characteristics of Practical Current Source.

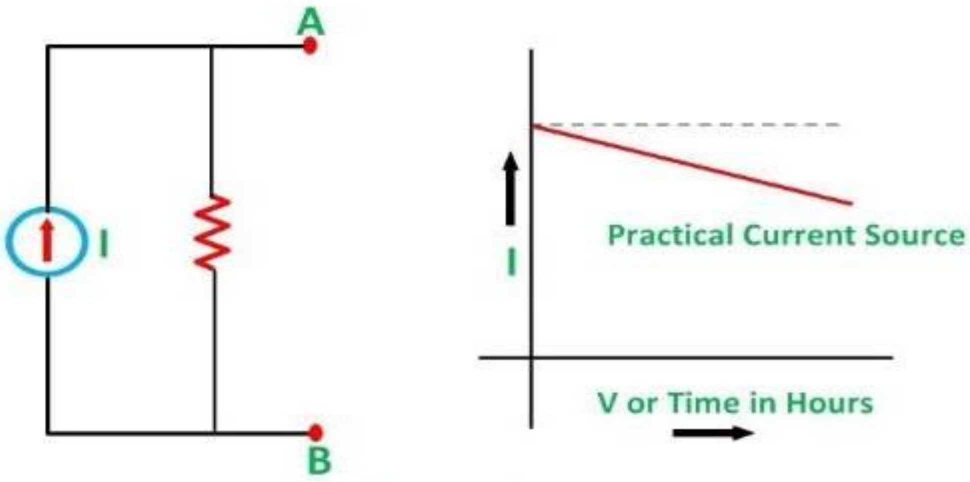


Figure D

QUICK QUIZ

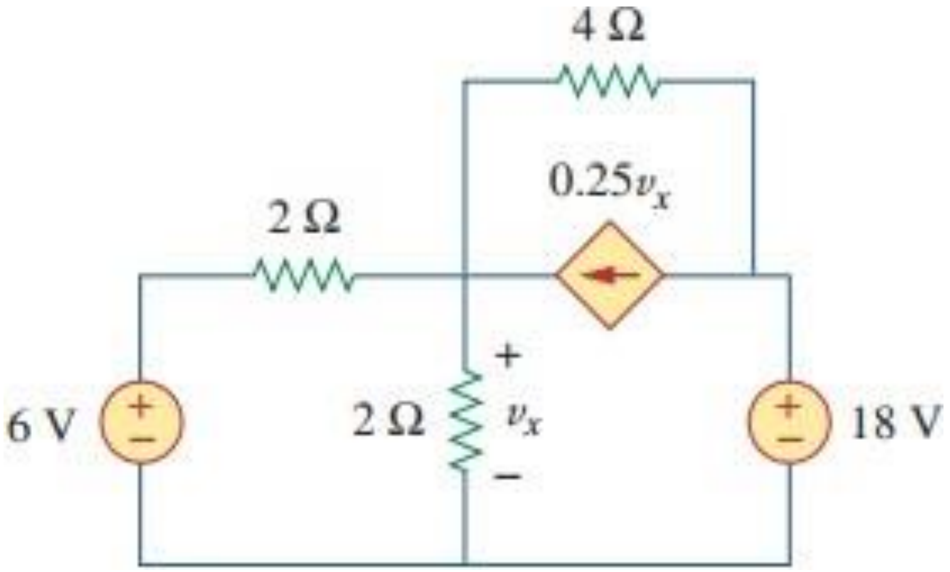
Identify the type of dependent source used in the network:

A. VCVS

B. CCCS

C. VCCS

D. CCVS



QUICK QUIZ

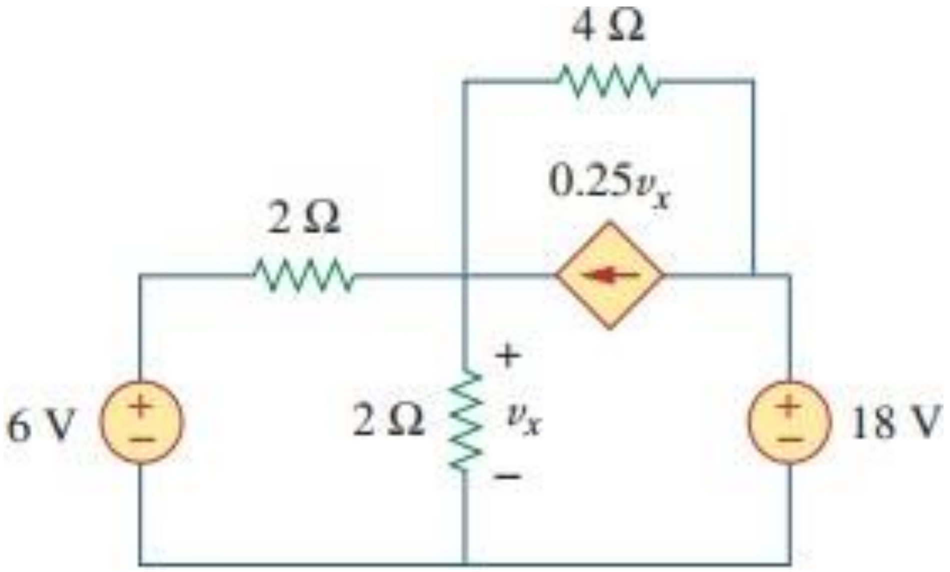
Identify the type of dependent source used in the network:

A. VCVS

B. CCCS

C. VCCS

D. CCVS



Fundamental Laws of Electric Circuit

Node: Circuit point where ends (terminals) of two or more circuit elements meet

Path: Traversal through elements from one node to another

Branch: Path between two adjoining nodes

Loop: Closed path starting and ending at the same node without going through the same node more than once

Mesh: Loop that does not contain any other loop within it.

Junction: Node where three or more circuit elements (branches) meets

Kirchhoff’s Law

- Ohm’s law by itself is not sufficient to analyze circuits.
- However, when it is coupled with Kirchhoff’s two laws, we have a sufficient, powerful set of tools for analyzing a large variety of electric circuits.
- These laws are:

1. Kirchhoff’s Current Law (KCL)
2. Kirchhoff’s Voltage Law (KVL)

Kirchhoff's Current Law (KCL)

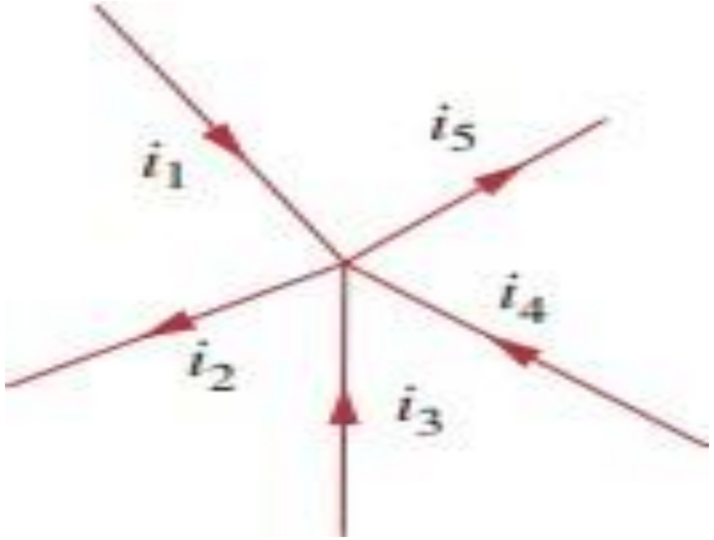
- It states that:

"the algebraic sum of currents entering a node is zero".

OR

" Sum of currents entering a node = Sum of currents leaving a node "

- Based on Law of Conservation of Charge.
- Mathematically, $\sum I = 0$



QUICK QUIZ (Poll 1)

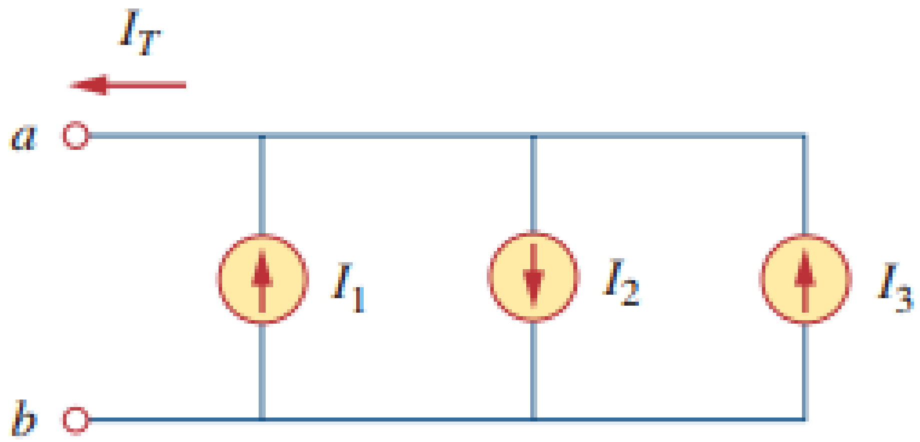
KCL equation for the given network is:

A. $I_1 + I_2 + I_3$

B. $I_1 + I_2 - I_3$

C. $I_1 - I_2 + I_3$

D. $-I_1 - I_2 + I_3$



QUICK QUIZ (Poll 1)

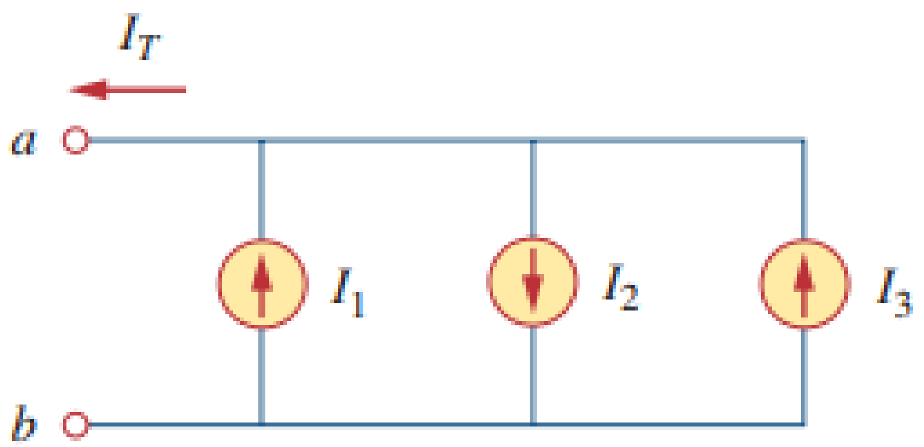
KCL equation for the given network is:

A. $I_1 + I_2 + I_3$

B. $I_1 + I_2 - I_3$

C. $I_1 - I_2 + I_3$

D. $-I_1 - I_2 + I_3$



Kirchhoff's Voltage Law (KVL)

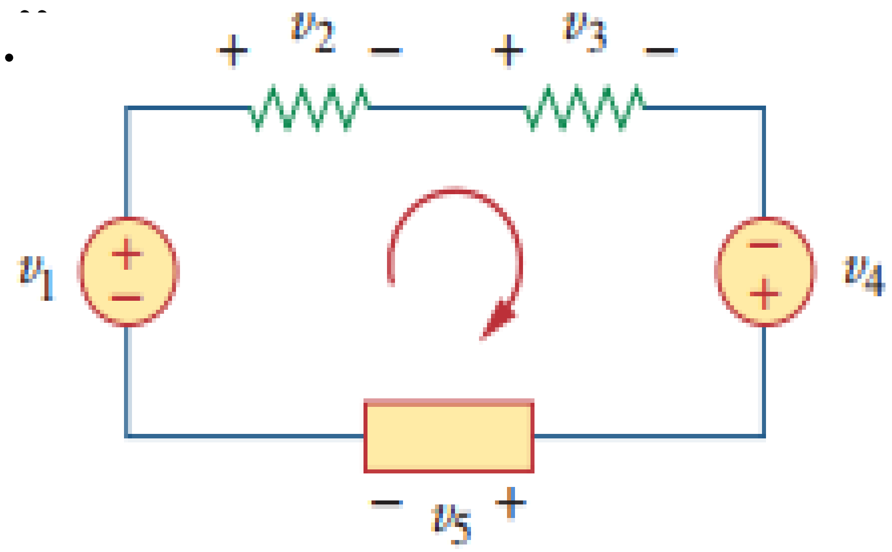
- It states that:

"algebraic sum of all voltages around a closed path (or loop) is zero."

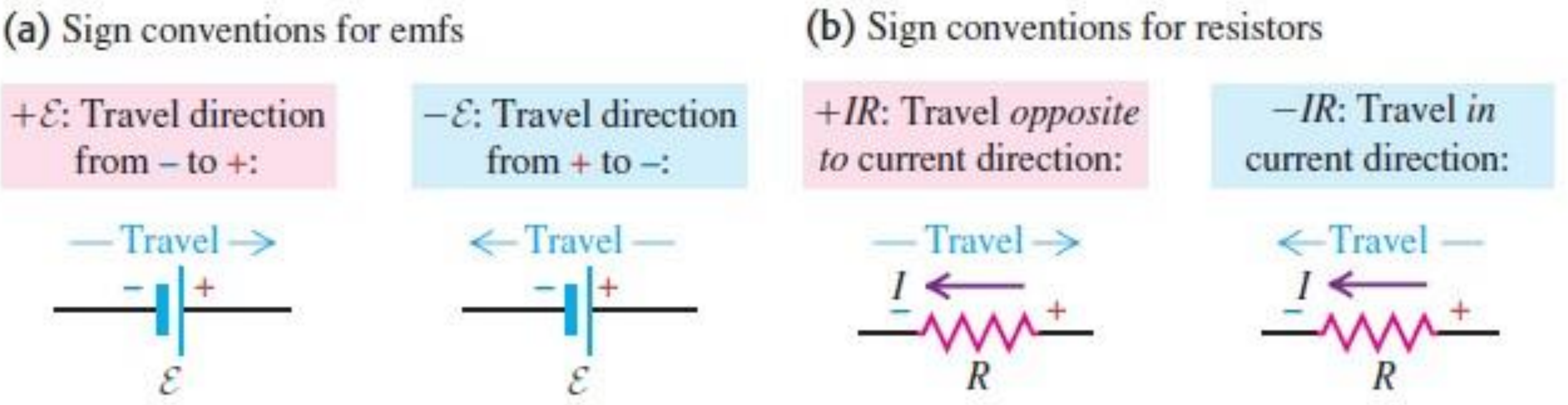
OR

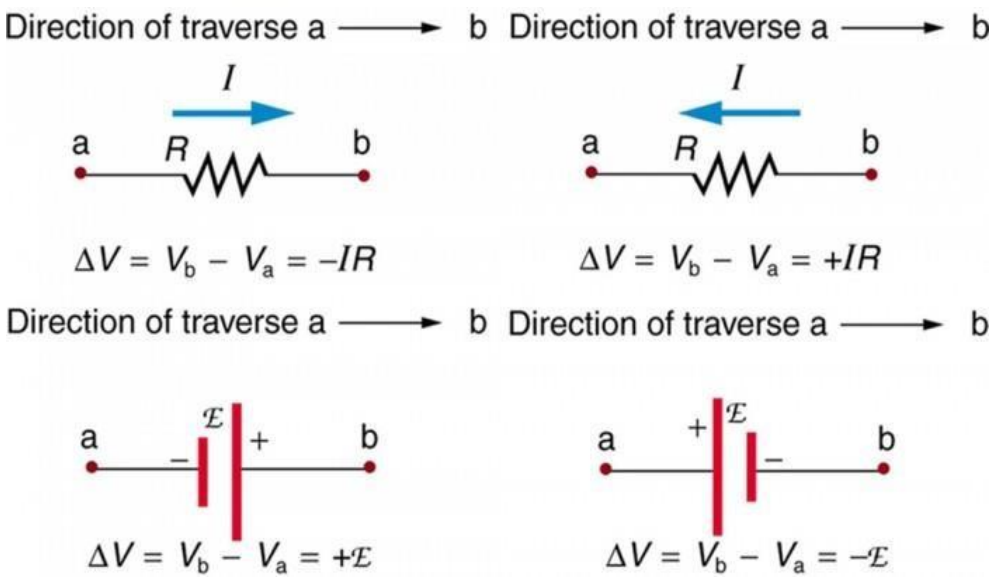
" Sum of voltage drops = Sum of voltage rises."

- Based on Law of Conservation of Energy
- Mathematically, $\sum V = 0$



Sign Convention for KVL





Let us Recall!

- Taking Clockwise direction (Def. 1):

$$+V_1 - V_2 - V_3 + V_4 - V_5 = 0$$

- Taking Anti-clockwise direction(Def. 1):

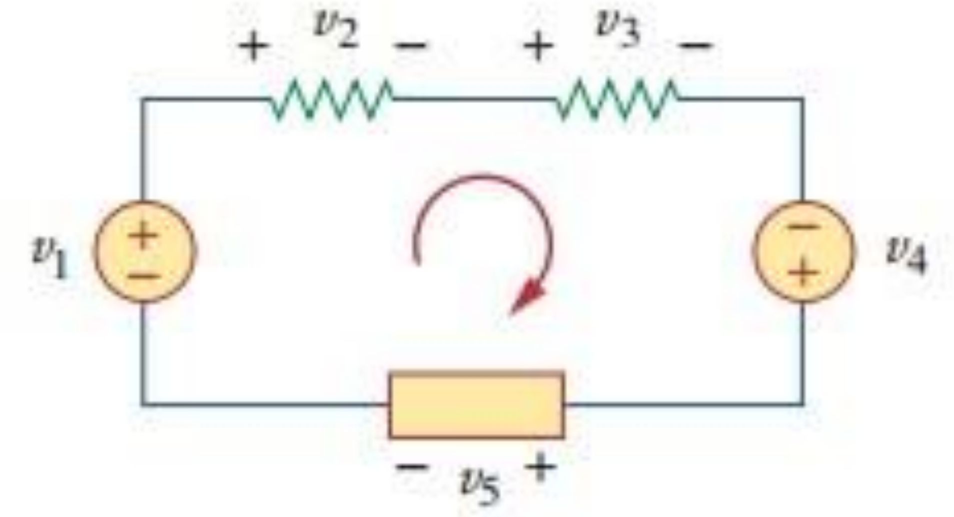
$$-V_4 + V_3 + V_2 - V_1 + V_5 = 0$$

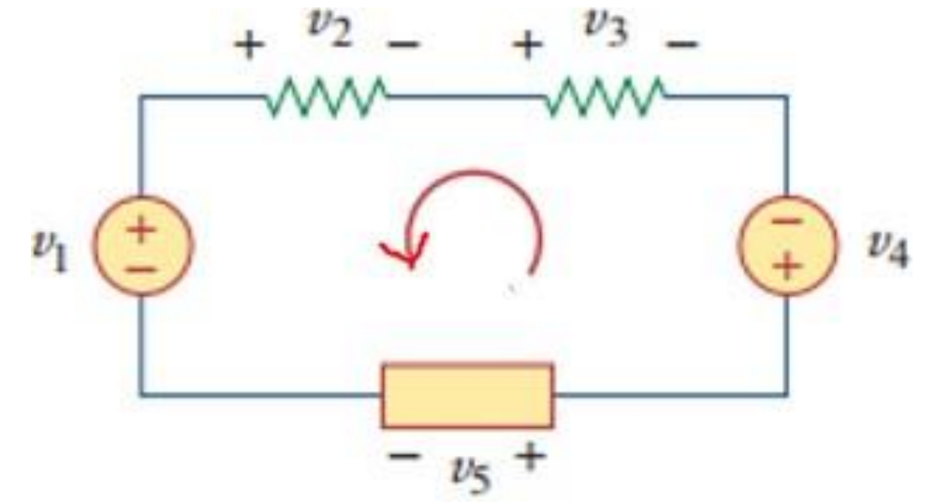
- Voltage rise = Voltage drop

$$+V_1 + V_4 = V_2 + V_3 + V_5$$

- What we can Say

$$-V_1 + V_2 + V_3 - V_4 + V_5$$





QUICK QUIZ (Poll 2)

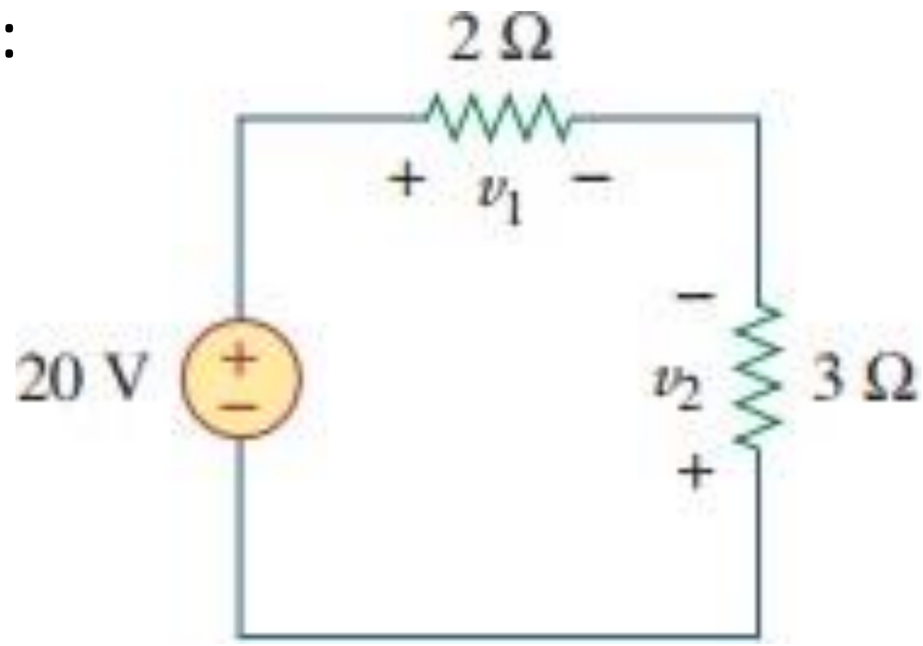
Find voltages V_1 and V_2 in the given circuit:

A. $V_1 = 16\,V\ and\ V_2 = 12\,V$

B. $V_1 = 16\,V\ and\ V_2 = -8\,V$

C. $V_1 = 8\,V\ and\ V_2 = -12\,V$

D. $V_1 = -12\,V\ and\ V_2 = 8\,V$



QUICK QUIZ (Poll 2)

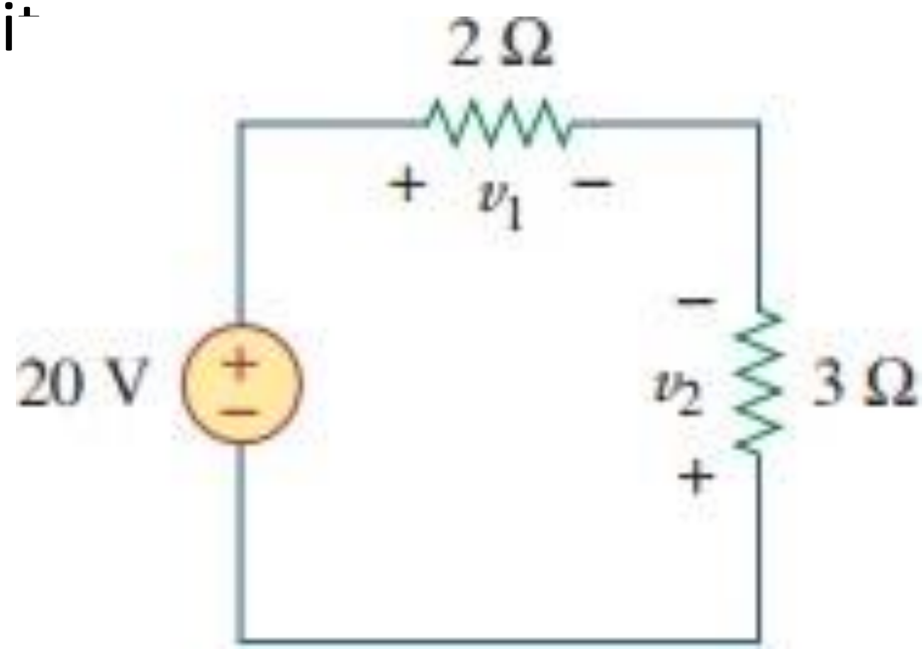
Find voltages V_1 and V_2 in the given circui

A. $V_1 = 16\,V\ and\ V_2 = 12\,V$

B. $V_1 = 16\,V\ and\ V_2 = -8\,V$

C. $V_1 = 8\,V\ and\ V_2 = -12\,V$

D. $V_1 = -12\,V\ and\ V_2 = 8\,V$



Voltage Division Rule

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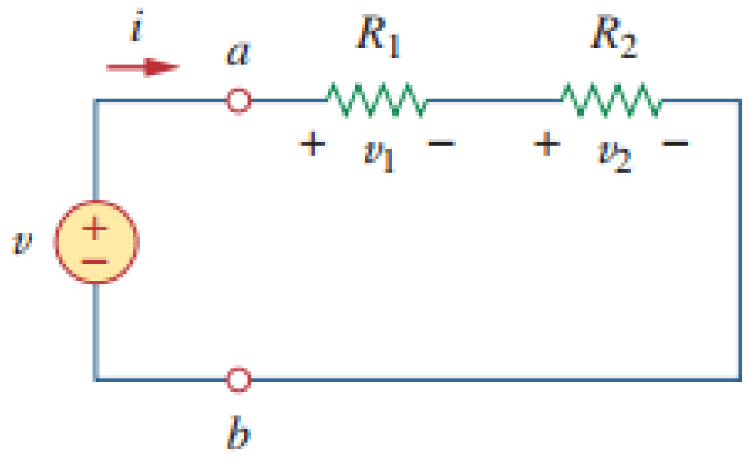
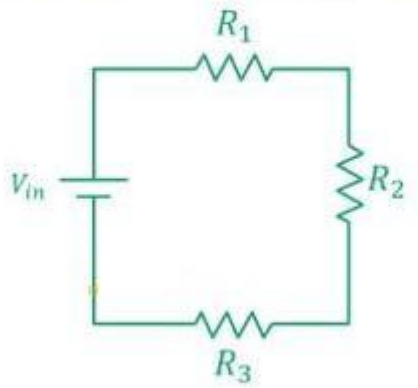
- The important relations are:

$$v_1 = \frac{R_1}{R_1 + R_2} v, \qquad v_2 = \frac{R_2}{R_1 + R_2} v$$



VOLTAGE DIVISION RULE FOR 3- RESISTORS



$$V_1 = \frac{R_1}{R_1 + R_2 + R_3} \cdot V_{in}$$

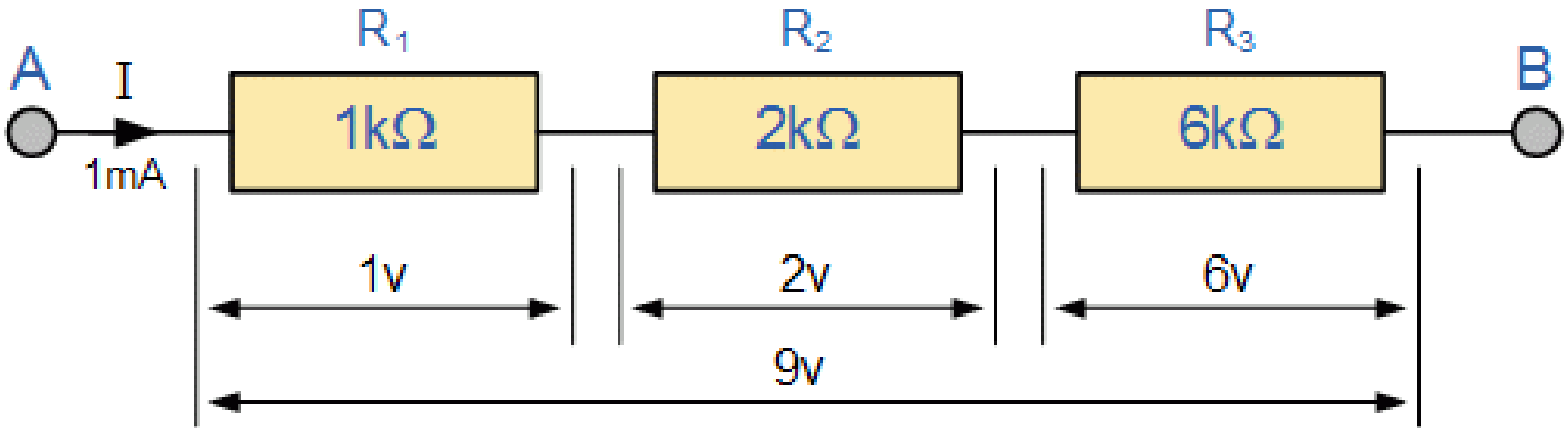
$$V_2 = \frac{R_2}{R_1 + R_2 + R_3} \cdot V_{in}$$

$$V_3 = \frac{R_3}{R_1 + R_2 + R_3} \cdot V_{in}$$

Voltage Division Rule for N-Resistors

$$v_n = \frac{R_n}{R_1 + R_2 + \cdots + R_N} v$$

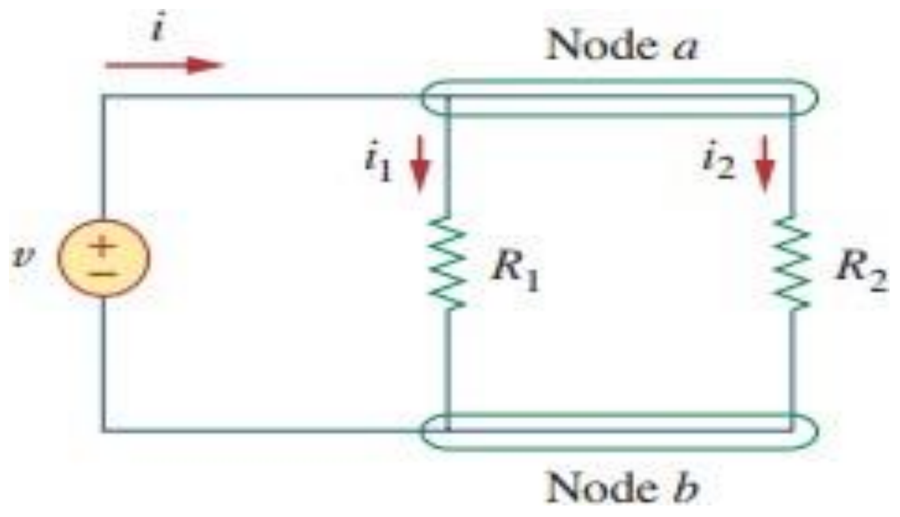
Example for Voltage Division Rule



Current Division Rule

- The important relations are:

$$i_1 = \frac{R_2\, i}{R_1 + R_2}, \qquad i_2 = \frac{R_1\, i}{R_1 + R_2}$$



QUICK QUIZ (Poll 3)

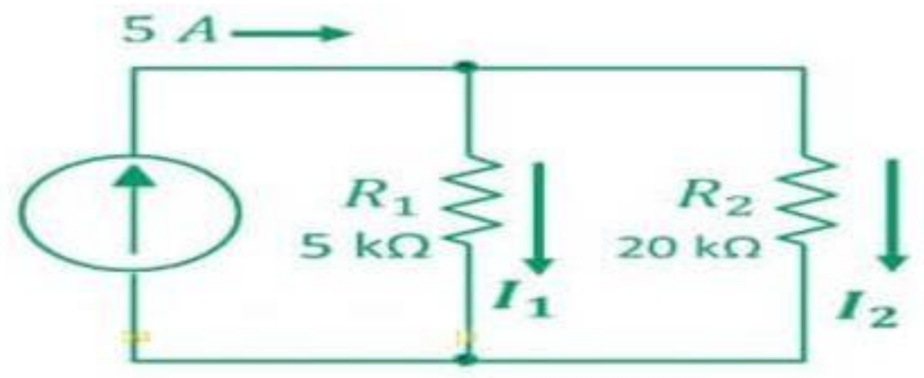
Find current across two resistors?

A. $I_1 = 4\ A\ and\ I_2 = 16\ A$

B. $I_1 = -2\ A\ and\ I_2 = 1\ A$

C. $I_1 = 4\ A\ and\ I_2 = 1\ A$

D. $I_1 = 1\ A\ and\ I_2 = 4\ A$



QUICK QUIZ (Poll 3)

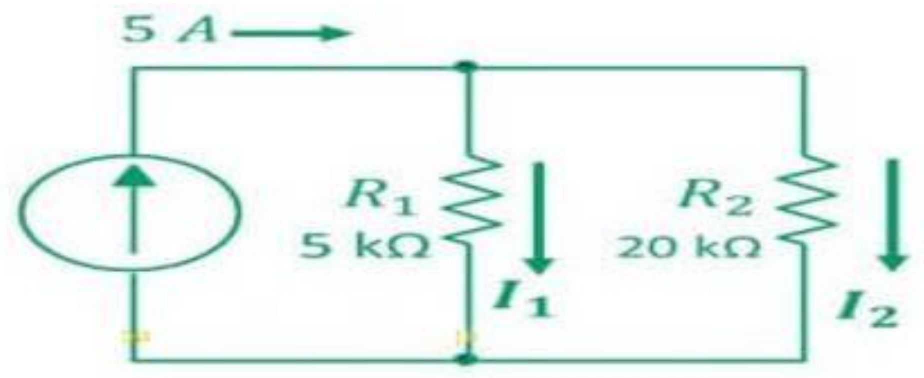
Find current across two resistors?

A. $I_1 = 4\ A\ and\ I_2 = 16\ A$

B. $I_1 = -2\ A\ and\ I_2 = 1\ A$

C. $I_1 = 4\ A\ and\ I_2 = 1\ A$

D. $I_1 = 1\ A\ and\ I_2 = 4\ A$



Applications of Kirchhoff's Laws

- They can be used to analyze any electrical circuit.
- Computation of current and voltage of complex circuits.

Limitations of Kirchhoff's Laws

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- The limitation of Kirchhoff's both laws is that it works under the assumption that there is no fluctuating magnetic field in the closed loop and the current flows only through conductors and wires.

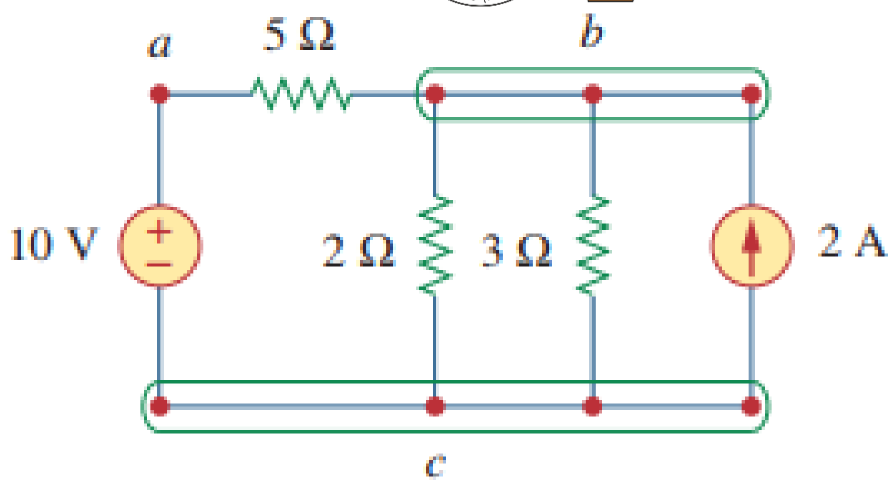
$$\frac{\partial \phi_B}{\partial t} = 0$$ Outside elements

$$\frac{\partial q}{\partial t} = 0$$ Inside elements

wires resistors sources

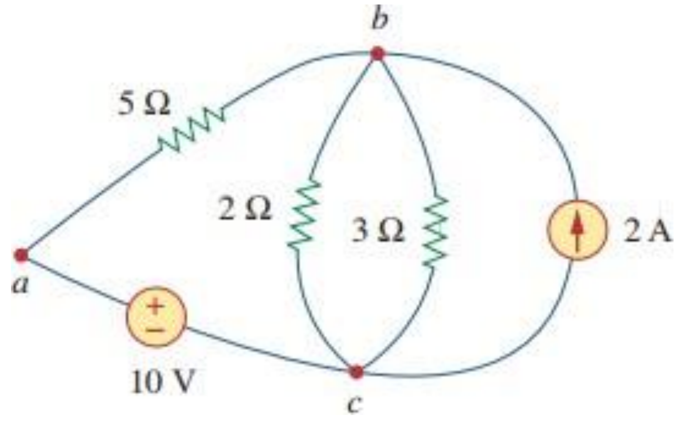
Nodes, Branches, and Loops

- A branch represents a single element such as a voltage source or a resistor.
- A node is the point of connection between two or more branches.
- A loop is any closed path in a circuit



NOTE:

- Two or more elements are in series if they exclusively share a single node and consequently carry the same current.
- Two or more elements are in parallel if they are connected to the same two nodes and consequently have the same voltage across them.



QUICK QUIZ (Poll 4)

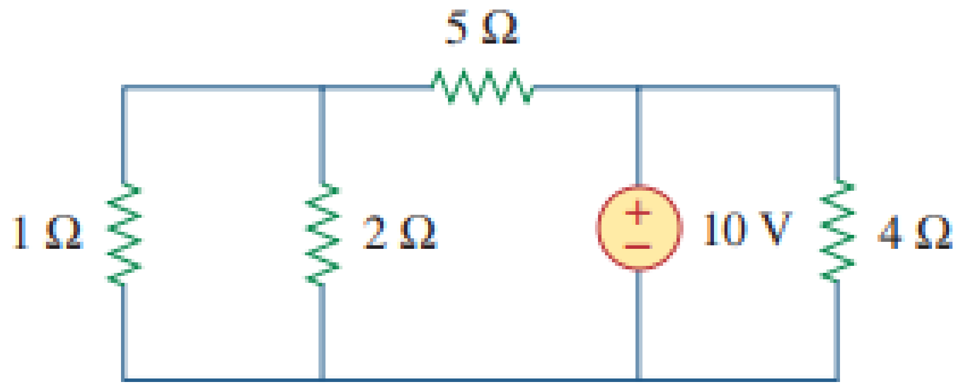
How many branches, nodes and independent loops are present in the given circuit?

A. b=3, n=5, l=6

B. b=5, n=3, l=6

C. b=5, n=3, l=3

D. b=3, n=5, l=3



QUICK QUIZ (Poll 4)

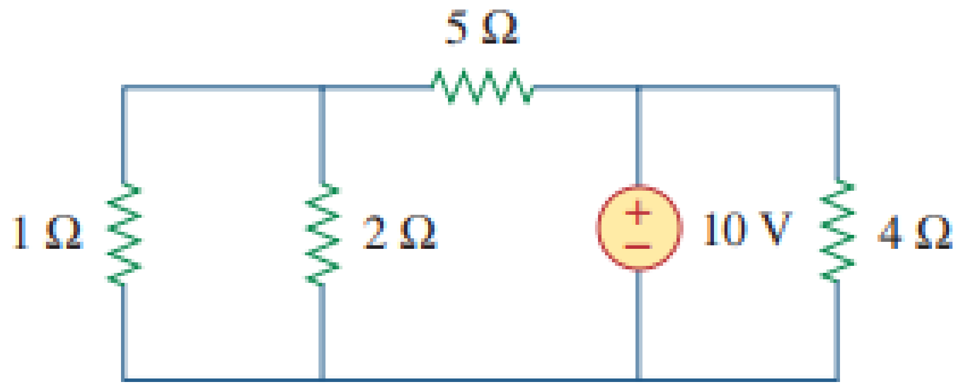
How many branches, nodes and independent loops are present in the given circuit?

A. b=3, n=5, l=6

B. b=5, n=3, l=6

C. b=5, n=3, l=3

D. b=3, n=5, l=3



UNIT 1: DC CIRCUITS

Lecture 4

Nodal Analysis

- Nodal analysis provides a general procedure for analyzing circuits using node voltages as the circuit variables.

- Choosing node voltages instead of element voltages as circuit variables is convenient and reduces the number of equations one must solve simultaneously.

- Applicable to nodes only.

- It is used to find the unknown node voltages.

- This Method is Application of KCL+Ohm's Law Only

Steps to Determine Node Voltages

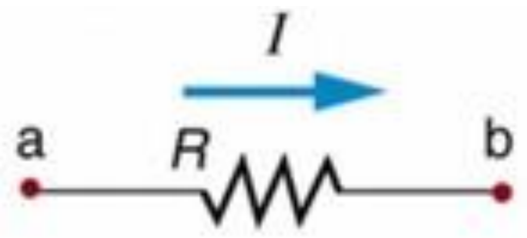
1. Select one nodes out of ‘n’ node as the reference node. Assign voltages to the remaining nodes. The voltages are referenced with respect to the reference node.

2. Apply KCL to each of the non-reference nodes. Use Ohm’s law to express the branch currents in terms of node voltages.

3. Solve the resulting simultaneous equations to obtain the unknown node voltages.

- The number of non-reference nodes is equal to the number of independent equations that we have to derive.

- Current flows from a higher potential to a lower potential in a resistor



$$i = \frac{v_{\text{higher}} - v_{\text{lower}}}{R}$$

QUICK QUIZ

For “N” number of nodes, the number of non-reference nodes is equal to:

A. $N + 1$

B. $N - 1$

C. 2N

D. $2N - 1$

QUICK QUIZ

For "N" number of nodes, the number of non-reference nodes is equal to:

A. $N + 1$

B. $N - 1$

C. 2N

D. 2N – 1

QUICK QUIZ

Nodal analysis, which is based on KCL is used to find unknown:

A. Current

B. Voltage

QUICK QUIZ

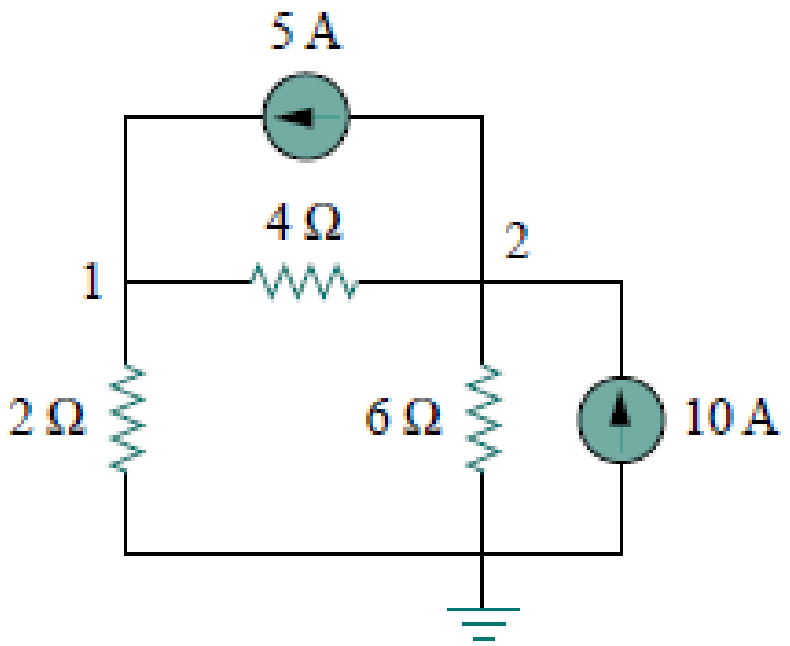
Nodal analysis, which is based on KCL is used to find unknown:

A. Current

B. Voltage

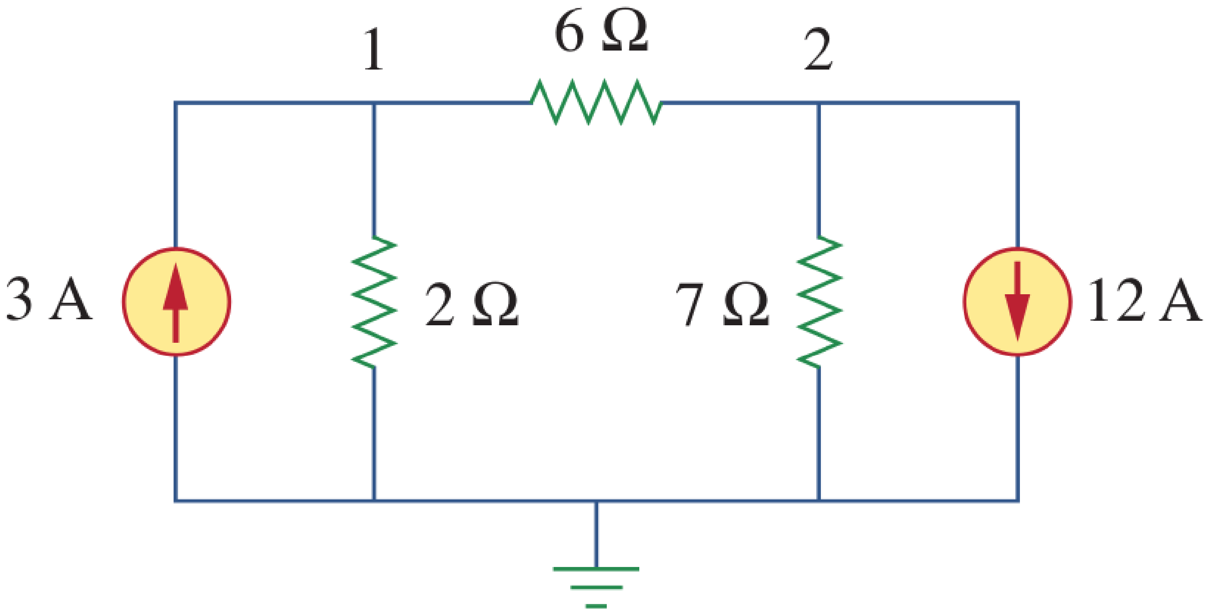
Example 1

- Obtain the node voltages in the given circuit?



Example 2

- Obtain the node voltages in the given circuit?



Mesh Analysis

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- Mesh analysis provides another general procedure for analyzing circuits, using mesh currents as the circuit variables.
- It is based on KVL.

RECALL!

- LOOP: A loop is a closed path with no node passed more than once.
- MESH: A mesh is a loop that does not contain any other loop within it.
- Mesh analysis is not quite as general as nodal analysis because it is only applicable to a circuit that is planar.
- **PLANAR CIRCUIT:** A planar circuit is one that can be drawn in a plane with no branches crossing one another; otherwise it is nonplanar.

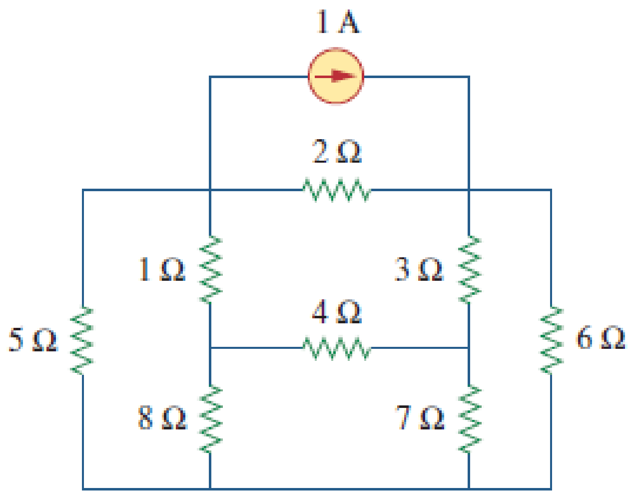
Steps to Determine Mesh Currents

1. Assign mesh currents to ‘n’ meshes

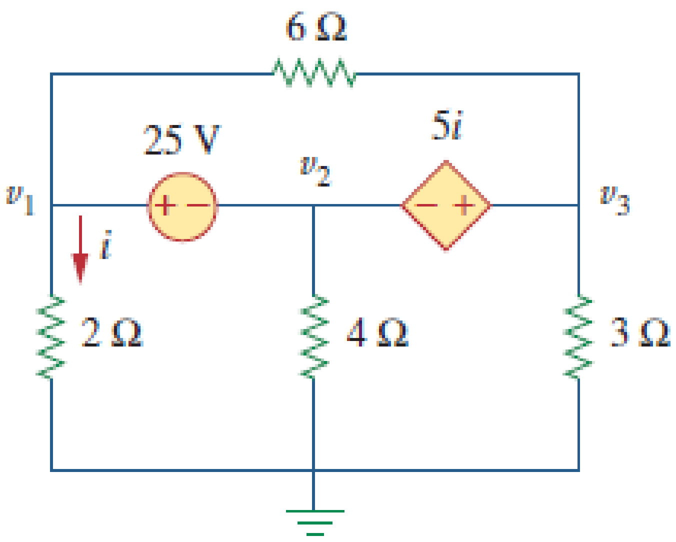
2. Apply KVL to each of the ‘n’ meshes.

3. Solve the resulting ‘n’ simultaneous equations to obtain the unknown mesh currents.

Examples of Planar Circuits



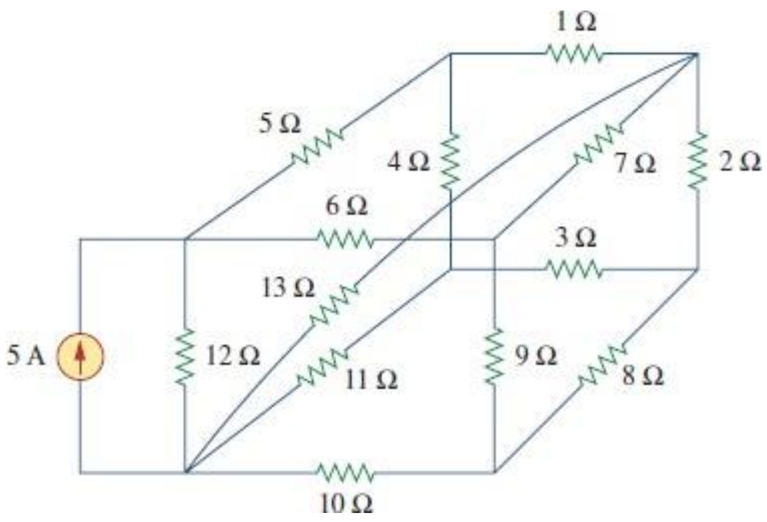
(b)

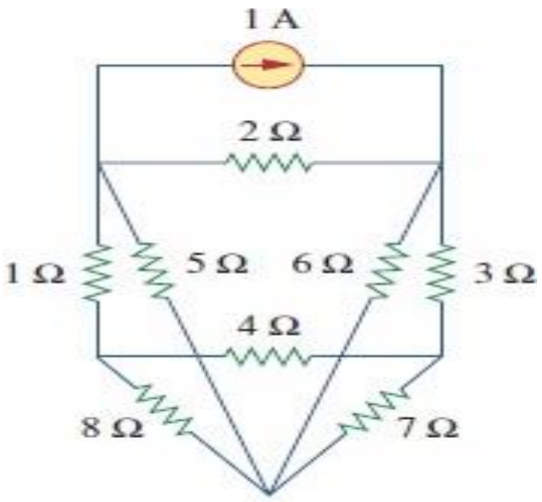


NOTE: A mesh is a loop which does not contain any other loops within it.

Mesh Analysis can be applied to meshes only inside the circuit, Not to LOOP.

Examples of Non-Planar Circuits





(a)

QUICK QUIZ

Mesh Analysis to applicable to______type networks.:

A. Planar and Loop
B. Non planar and mesh
C. Planar and mesh
D. Non planar and Loop

QUICK QUIZ

Mesh Analysis to applicable to______type networks.:

A. Planar and Loop
B. Non planar and mesh
C. Planar and mesh
D. Non planar and Loop

QUICK QUIZ

Mesh analysis, which is based on KVL is used to find unknown:

A. Current

B. Voltage

QUICK QUIZ

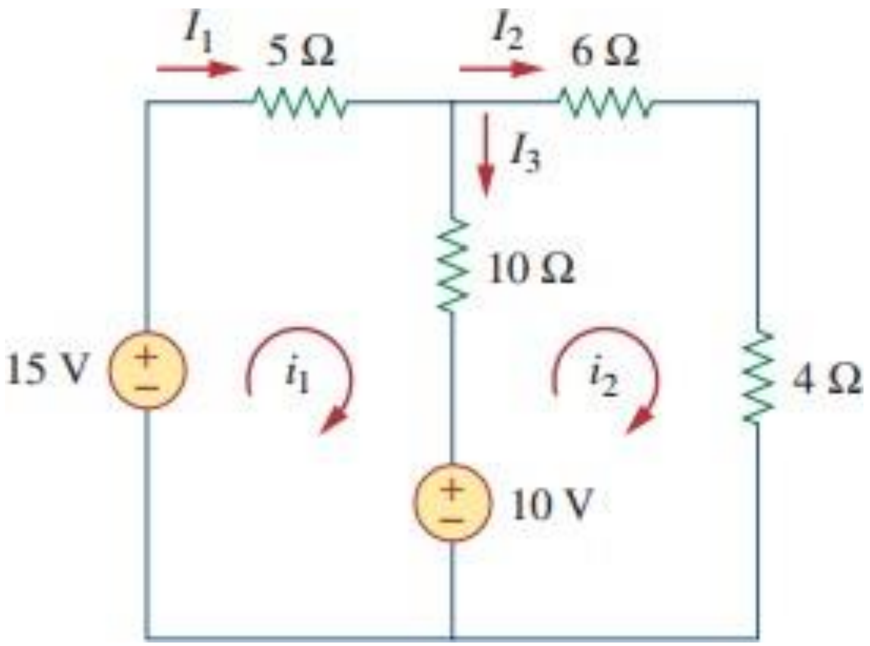
Mesh analysis, which is based on KVL is used to find unknown:

A. Current

B. Voltage

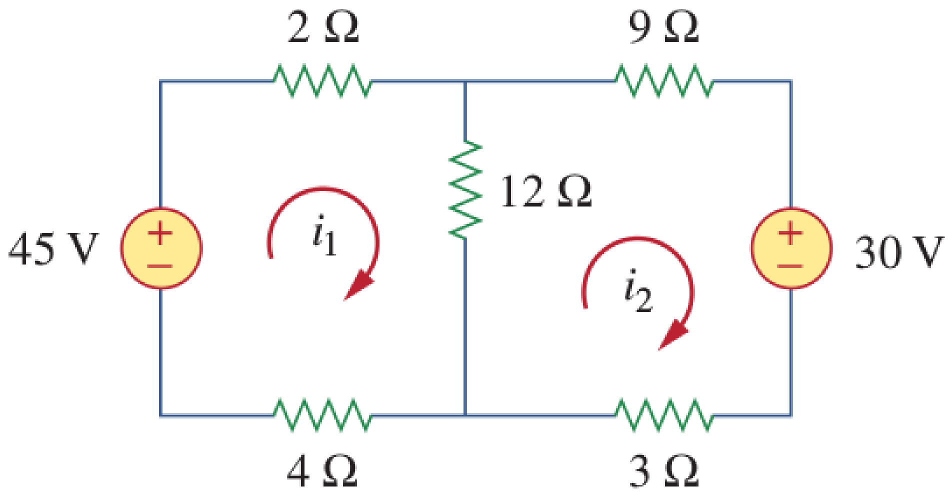
Example 1

- Obtain the mesh currents in the given circuit?



Example 2

- Obtain the mesh currents in the given circuit?



Thevenin's Theorem

- Thevenin's theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source V_{Th} in series with a resistor R_{Th}, where V_{Th} is the open-circuit voltage at the terminals and R_{Th} is the input or equivalent resistance at the terminals when the independent sources are turned off.

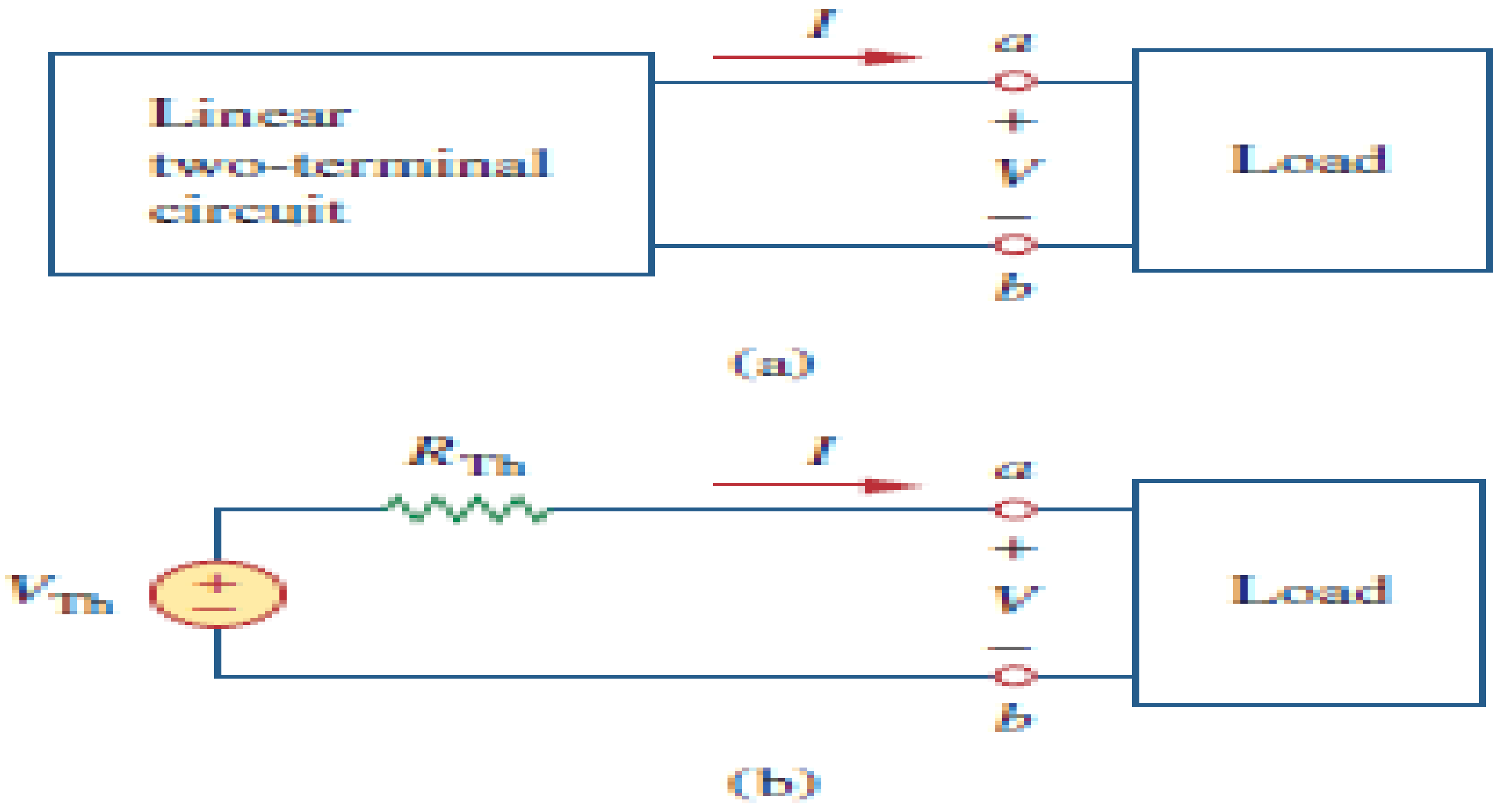
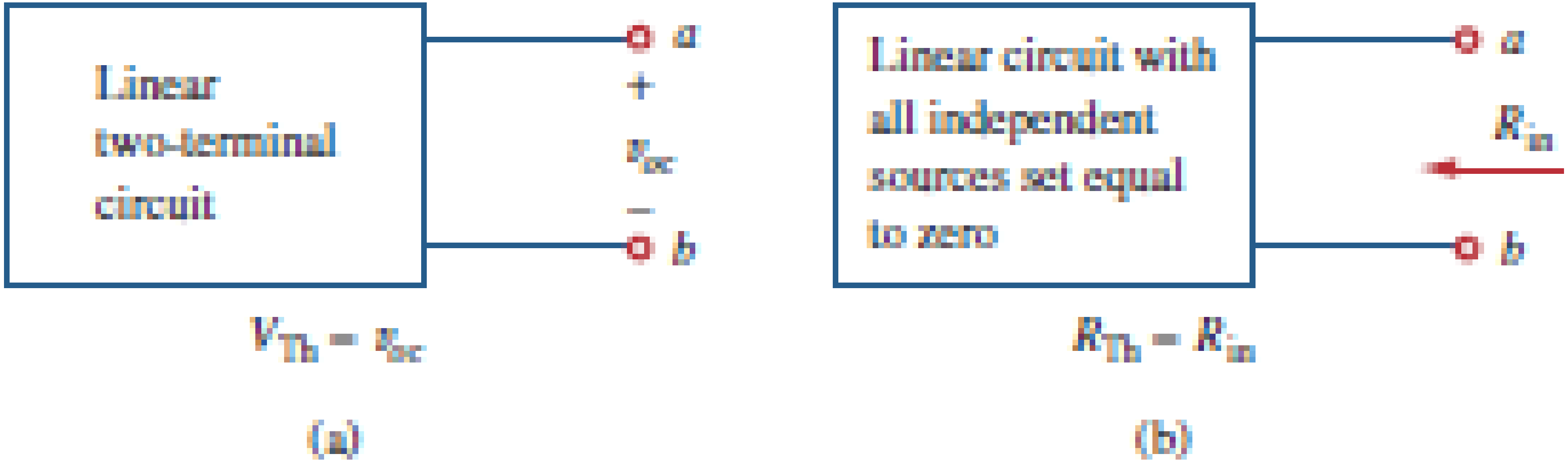


Figure 4.23
Replacing a linear two-terminal circuit by its Thevenin equivalent: (a) original circuit, (b) the Thevenin equivalent circuit.

$$V_{Th} = v_{oc} \tag{4.6}$$



Summary of Thevenin's Theorem

Step 1. Open the two terminals (remove any load) between which you want to find the Thevenin equivalent circuit.

Step 2. Determine the voltage (V_{TH}) across the two open terminals.

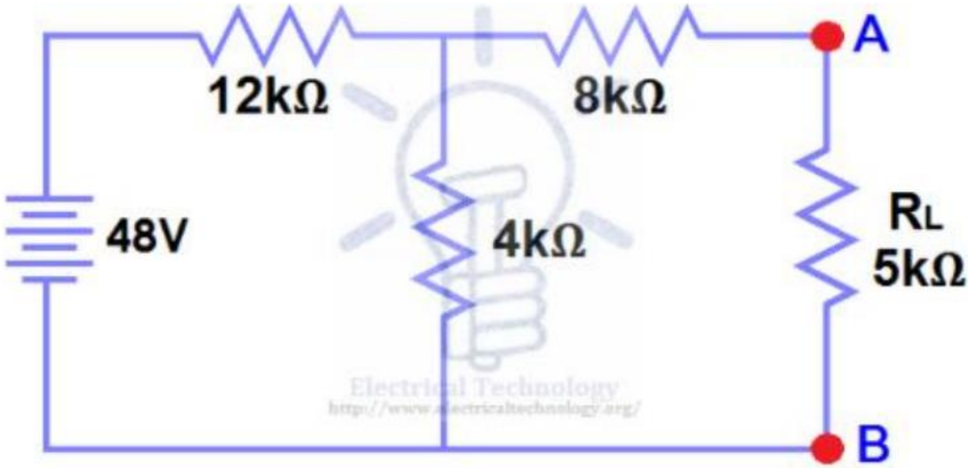
Step 3. Determine the resistance (R_{TH}) between the two open terminals with all sources replaced with their internal resistances (ideal voltage sources shorted and ideal current sources opened).

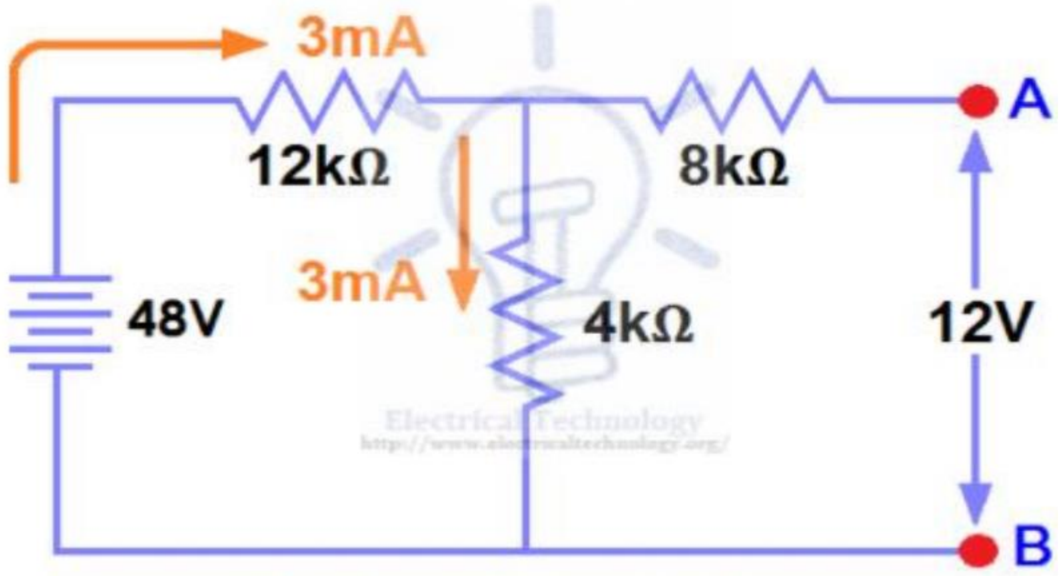
Step 4. Connect V_{TH} and R_{TH} in series to produce the complete Thevenin equivalent for the original circuit.

Step 5. Replace the load removed in Step 1 across the terminals of the Thevenin equivalent circuit. You can now calculate the load current and load voltage using only Ohm's law. They have the same value as the load current and load voltage in the original circuit.

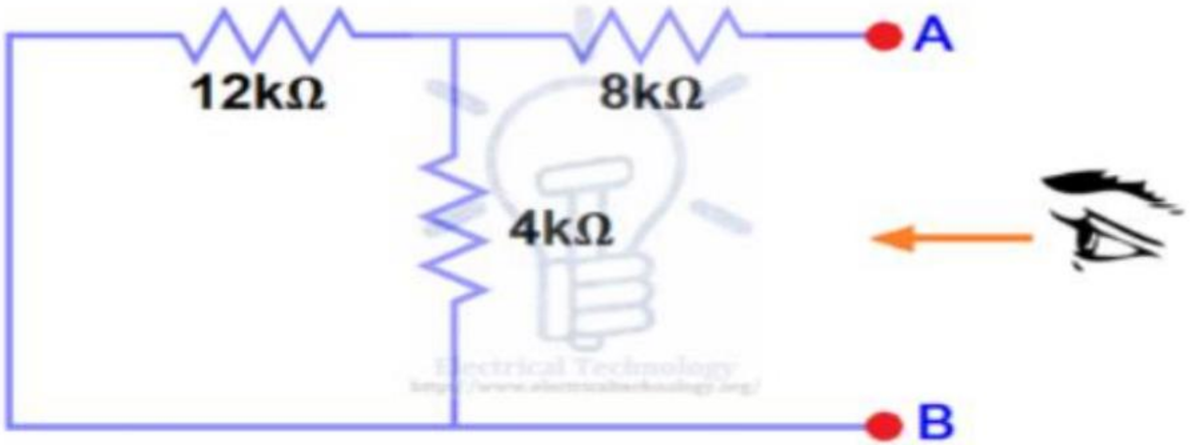
Find V_{TH}, R_{TH} and the load current I_L flowing through and load voltage across the load resistor in fig (1) *by using Thevenin's Theorem.*

V_{TH} = 12V



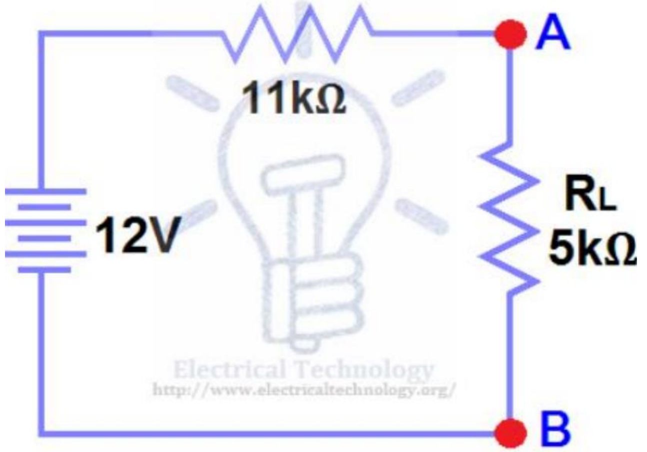


3mA x 4kΩ = 12V



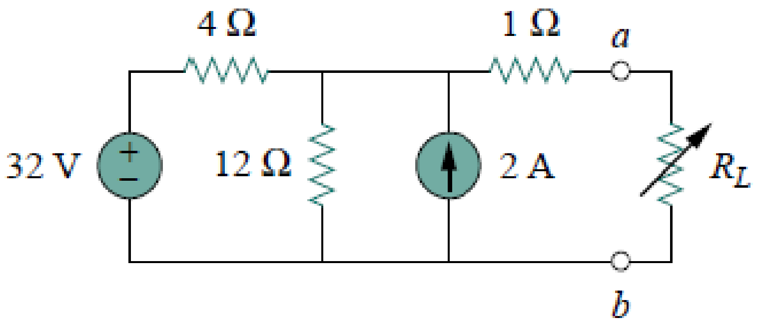
= 8kΩ + (4k Ω || 12kΩ) → = 8kΩ + 3kΩ

$\boxed{R_{TH} = 11k\Omega}$



Thevenin's equivalent circuit

MCQ



Find the Thevenin equivalent circuit, for the circuit shown in Fig. to the left of the terminals *a*-*b*, if RL=6 Ω.

(a) Rth= 4 ohm , Vth= 30 V

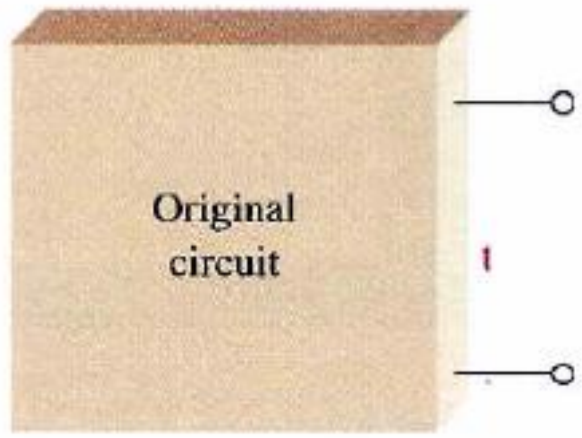
(b) Rth= 16 ohm , Vth= 30 V

(c) Rth= 17 ohm , Vth= 20 V

(d) Rth= 17 ohm , Vth= 30 V

Norton's Theorem

Like Thevenin's theorem, Norton's theorem provides a method of reducing a more complex circuit to a simpler equivalent form.



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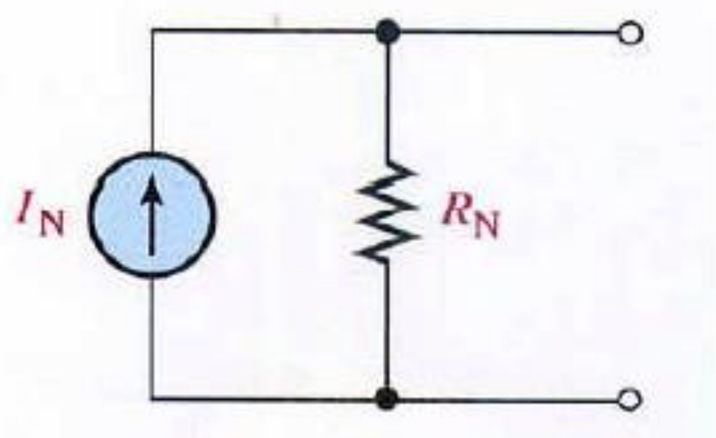


Norton's Theorem

IAL
TY

Summary of Norton's Theorem

Step 1. Short the two terminals between which you want to find the Norton equivalent circuit.

Step 2. Determine the current (I_N) through the shorted terminals.

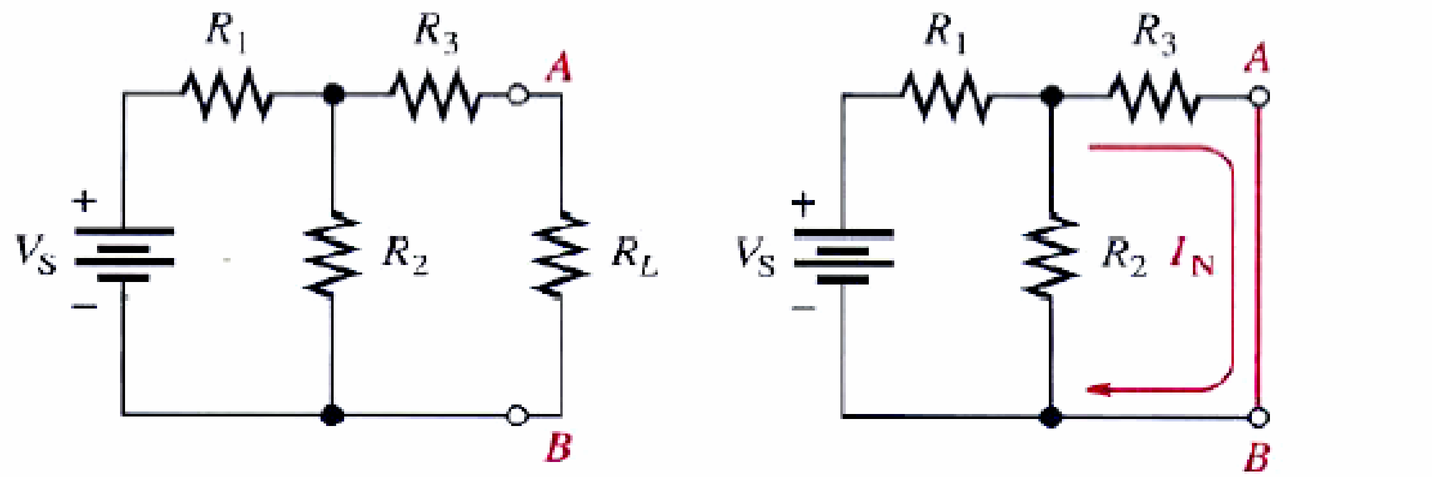
Step 3. Determine the resistance (R_N) between the two open terminals with all sources replaced with their internal resistances (ideal voltage sources shorted and ideal current sources opened). $R_N = R_{TH}$.

Step 4. Connect I_N and R_N in parallel to produce the complete Norton equivalent for the original circuit.

Norton's Theorem

Norton's Equivalent Current (I_N)

Norton's equivalent current (I_N) is the short-circuit current between two output terminals in a circuit.



(a) Original circuit

(b) Short the terminals to get I_N.

Find equivalent Norton Circuit across R?

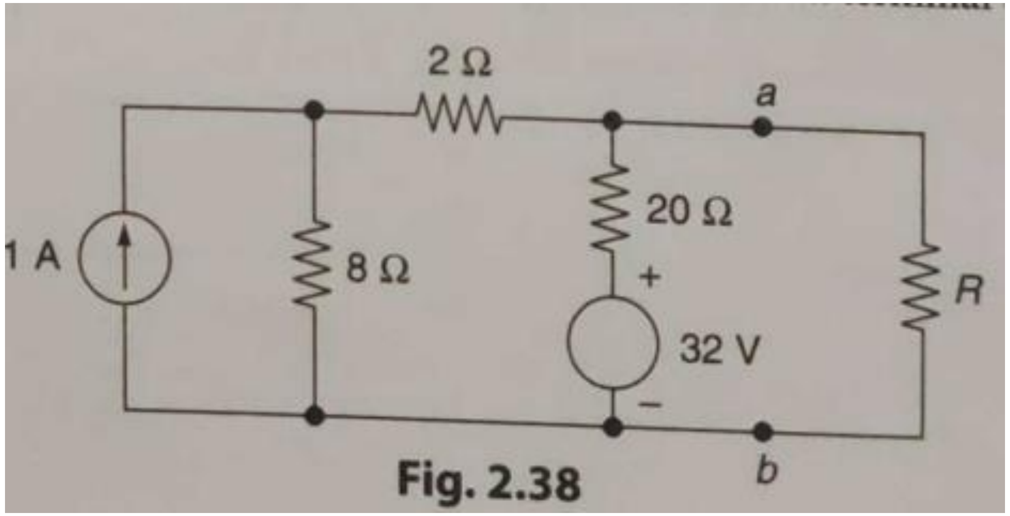
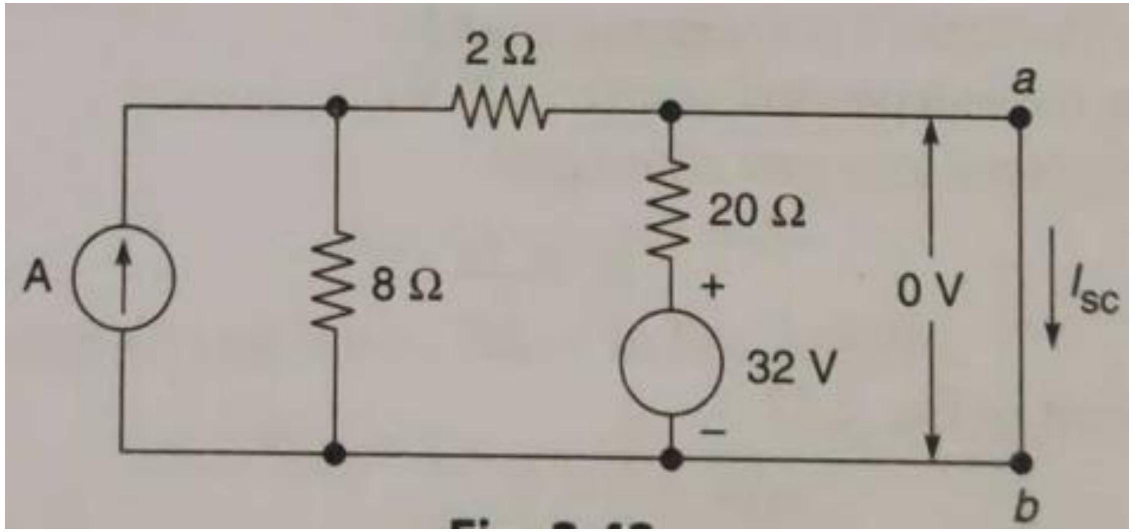
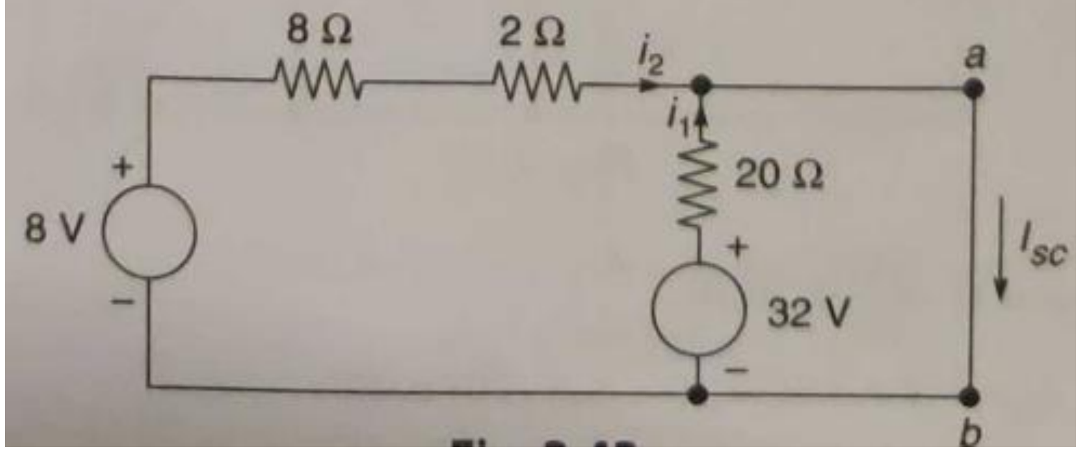


Fig. 2.38



$$I_{SC} = I_1 + I_2 = \frac{32}{20} + \frac{8}{10} = \frac{48}{20} = 2.4\text{ A}$$



Open-circuit 1 A source and short-circuit 32 V source.

$$R_0 = \frac{20 \times 10}{20 + 10} = \frac{20}{3}\ \Omega$$

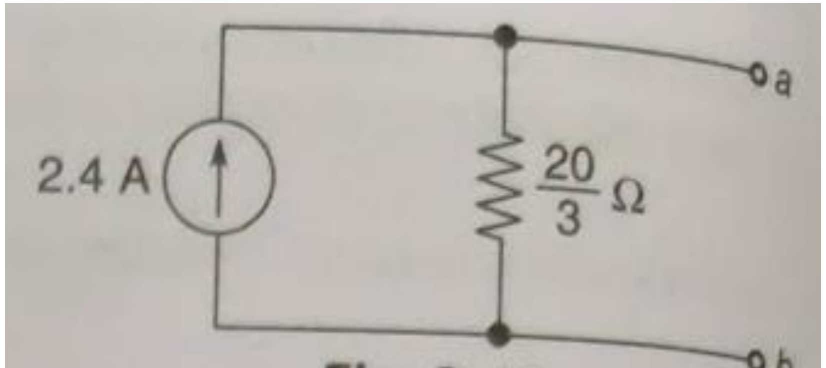
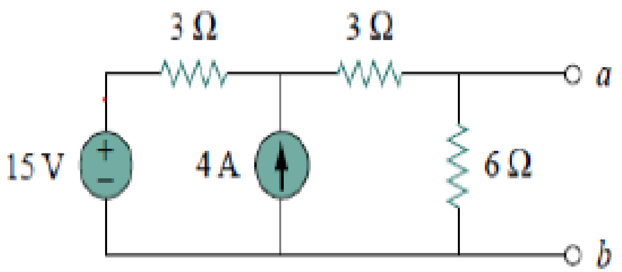


Fig. 2.44

HW: Find Current flowing in R and voltage across R if R=1000ohm

MCQ

Find the Norton equivalent circuit for the circuit in Fig



(a) *RN* = 3 Ω, *IN* = 4.5 A

(b) *RN* = 6 Ω, *IN* = 4.5 A

(c) *RN* = 3 Ω, *IN* = 1.5 A

(d) *RN* = 3 Ω, *IN* = 2.5 A

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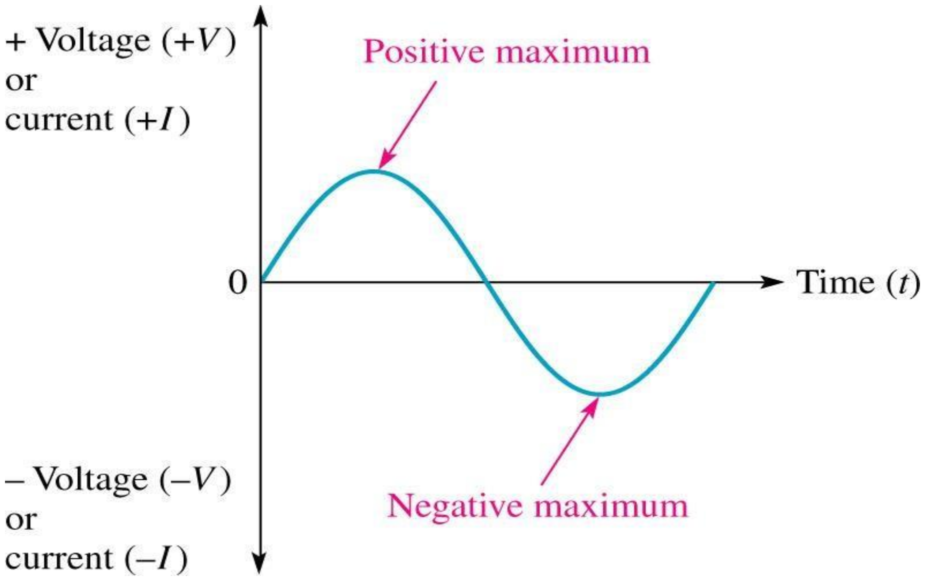
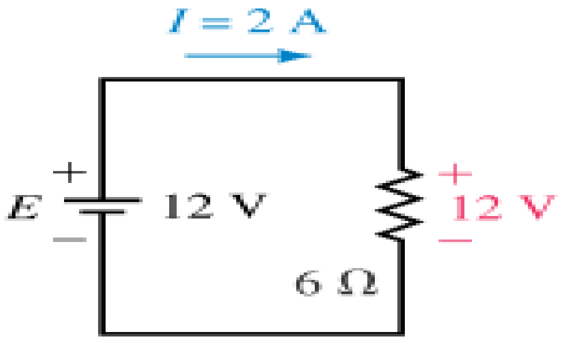
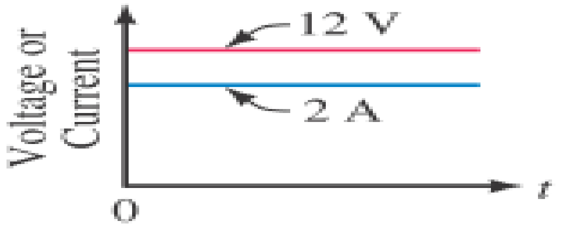
Fundamentals of A.C. circuits



AC Fundamentals

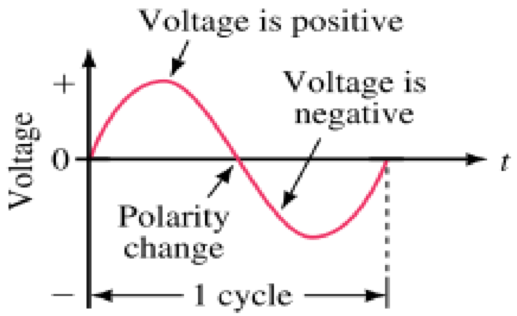
- Previously you learned that DC sources have fixed polarities and constant magnitudes and thus produce currents with constant value and unchanging direction



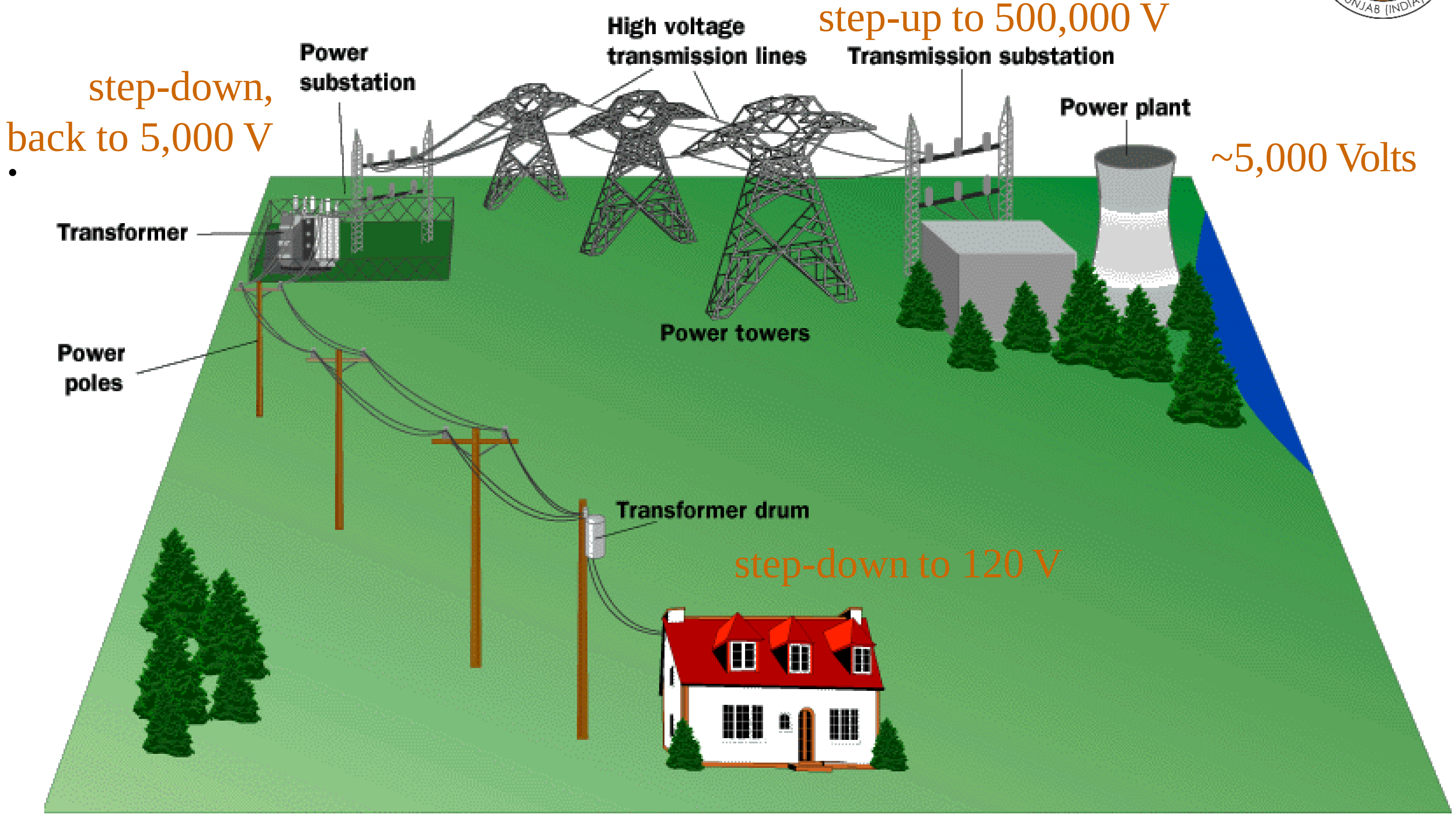


(b) Voltage and current versus time for dc

- In contrast, the voltages of ac sources alternate in polarity and vary in magnitude and thus produce currents that vary in magnitude and alternate in direction.

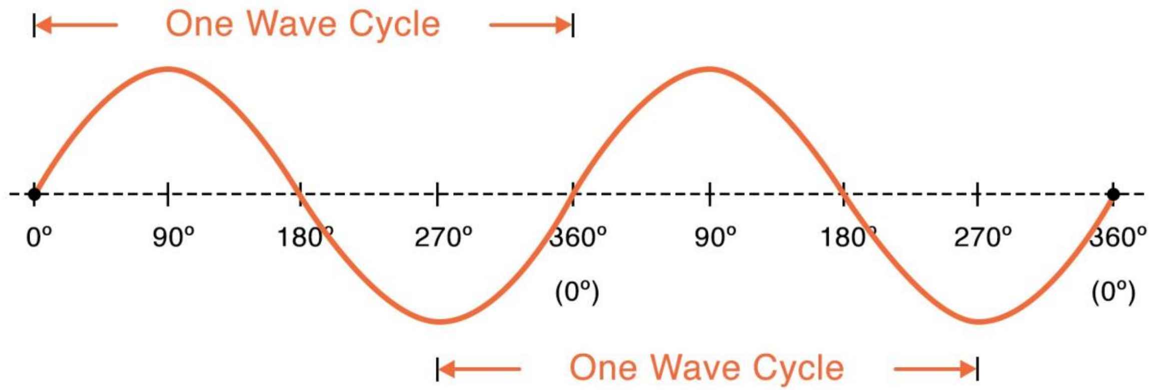


A way to provide high efficiency, safe low voltage



High Voltage Transmission Lines
Low Voltage to Consumers

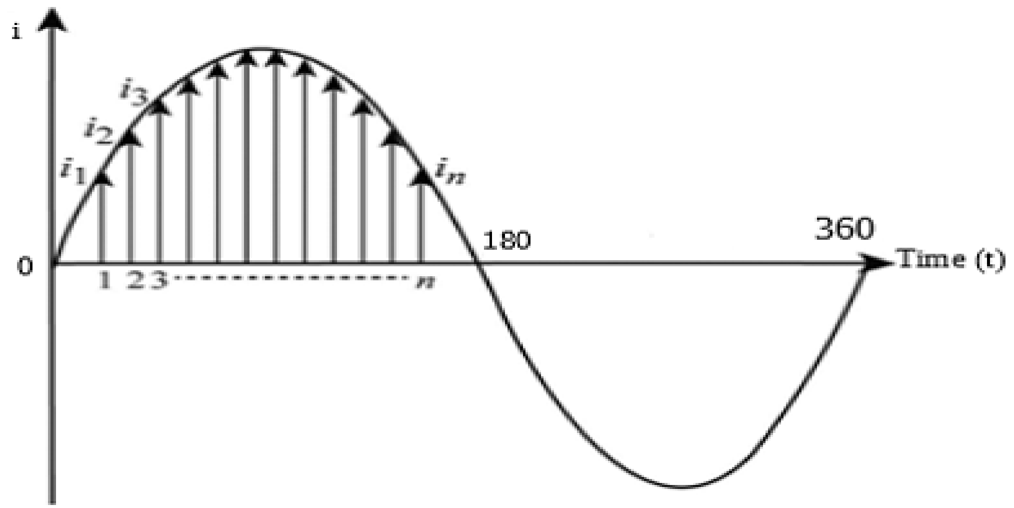
Alternating Current (AC) Parameters



Alternating Current is the current which constantly changes in amplitude and reverses direction at regular intervals,.
Due to this, alternating voltage and current have a number of properties associated with any such waveform

Frequency: The number of complete cycles that occurred in one second i.e. cycles per second
Unit: Herts (Hz)
Symbol: ‘f’
Time Period: Duration of time required for the quantity to complete one cycle.
Unit: seconds (s)
Symbol: ‘T’
Amplitude: Mathematically, the amplitude of the sine wave is the value of the sine wave at its peak (Max. +ve or –ve)

Cont…



Instantaneous Value: The value of an alternating voltage or current is the value of voltage or current at one particular instant

Average Value: The average of all the instantaneous values during one alternation. Since the voltage increases from zero to peak value and decreases back to zero during one alternation, the average value must be some value between those two limits

Peak Value: The maximum value of Voltage or current (for both positive or negative)

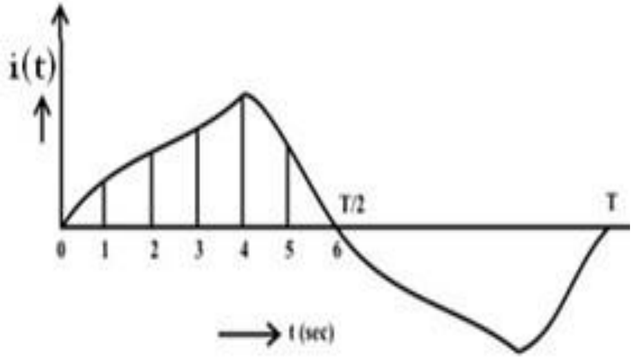
Periodic Voltage or Current Waveform

- Average value
  - The current waveform shown in Fig, is periodic in nature, with time period, T. It is positive for first half cycle, while it is negative for second half cycle.
  - The average value of the waveform, i(t) is defined as

$$I_{av} = \frac{\text{Area over half cycle}}{\text{Time period of half cycle}} = \frac{1}{T/2}\int_0^{T/2} i(t)\,dt = \frac{2}{T}\int_0^{T/2} i(t)\,dt$$

- In this case, only half cycle, or half of the time period, is to be used for computing the average value, as the average value of the waveform over full cycle is zero (0).
- If the half time period (T/2) is divided into 6 equal time intervals (ΔT)

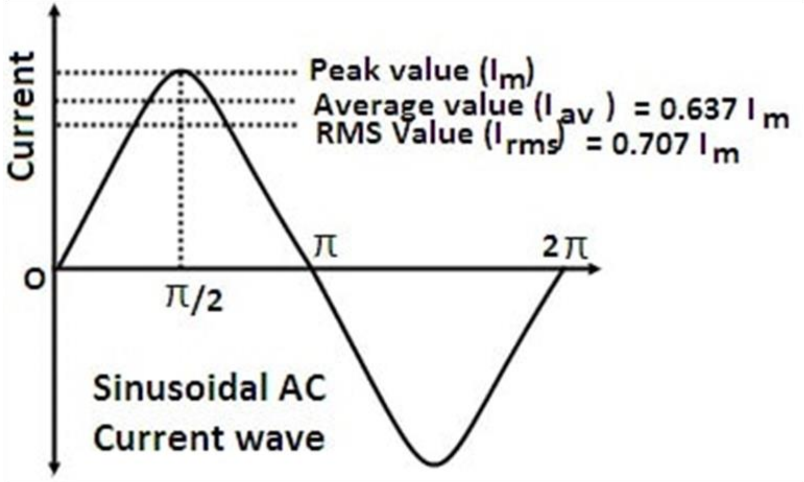
$$I_{av} = \frac{(i_1 + i_2 + i_3 + \cdots i_6)\Delta T}{6 \cdot \Delta T} = \frac{(i_1 + i_2 + i_3 + \cdots i_6)}{6}$$



Average Current (I_{avg})

Zero ?

$$Iavg = \frac{\int_0^{T/2} I_m \sin\omega t \; dt}{\int_0^{T/2} dt}$$



$$\boldsymbol{Iavg = \frac{2}{\pi} I_m}$$

$$\boldsymbol{Iavg = 0.637\, I_m}$$

Average Values of Sinusoidal Voltage Waveform

- The average value of sine wave over the complete cycle is zero.

- The half wave value of sinusoidal current is

$$I = I_{max} \; sin\,\omega t$$

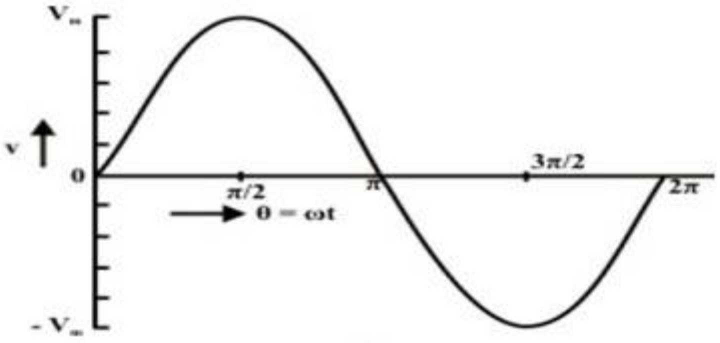
- For half cycle when ωt varies from 0 to π

$$I_{AV} = \frac{area\ of\ half\ cycle}{\pi}$$

$$I_{AV} = \frac{1}{\pi}\int_0^{\pi} i d(\omega t)$$

$$I_{AV} = \frac{1}{\pi}\int_0^{\pi} I_{max} \; sin\,\omega t \; d(\omega t)$$

$$I_{AV} = \frac{I_{max}}{\pi}[-cos\,\omega t] = \frac{2\ I_{max}}{\pi} = 0.637\, I_{max}$$



- Similarly

$$V_{AV} = \frac{2\ V_{max}}{\pi} = 0.637\, V_{max}$$

Root Mean Square (RMS) value

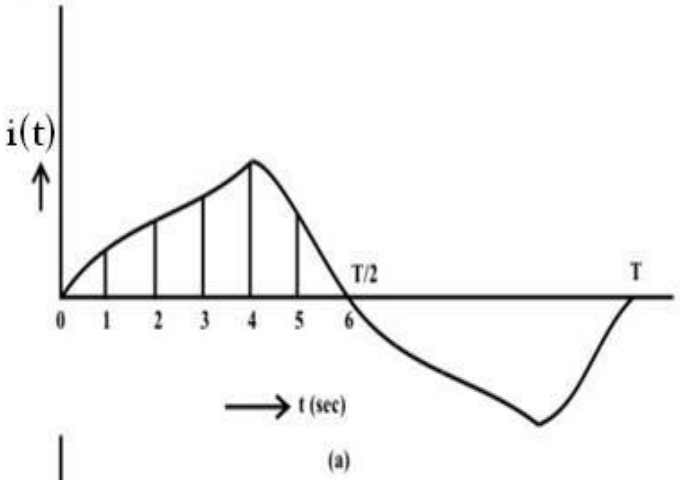
- For this current in half time period subdivided into 6 time intervals as given above, in the resistance R, the average value of energy dissipated is given by
  - Heat produce during interval = $I^2 R \frac{T}{n}$ joules

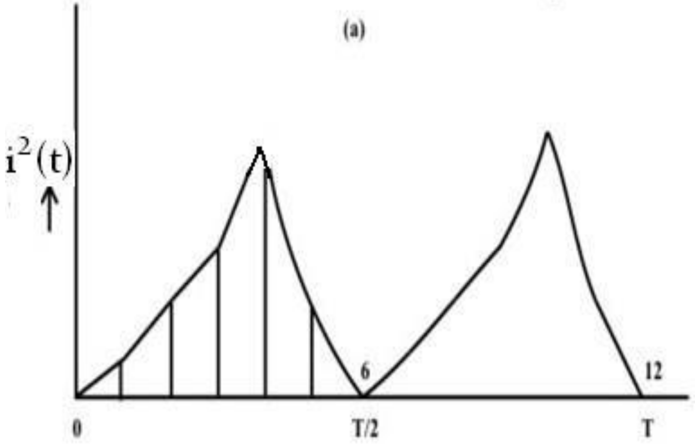
$$\propto \left[\frac{(i_1^2 + i_2^2 + i_3^2 + \cdots i_6^2)}{6}\right] R$$

$$I^2 R \,\Delta T = \left[\frac{(i_1^2 + i_2^2 + i_3^2 + \cdots i_n^2)\,\Delta T}{n\cdot}\right] R$$

$$I = \sqrt{\frac{(i_1^2 + i_2^2 + i_3^2 + \cdots i_n^2)\,\Delta T}{n\cdot\Delta T}} = \sqrt{\frac{\text{Area of } i^2 \text{ curve over half cycle}}{\text{Time period of half cycle}}}$$

$$= \sqrt{\frac{1}{T/2}\int_0^{T/2} i^2\,dt} = \sqrt{\frac{2}{T}\int_0^{T/2} i^2\,dt}$$





RMS Current (I_{rms})

Square

Mean

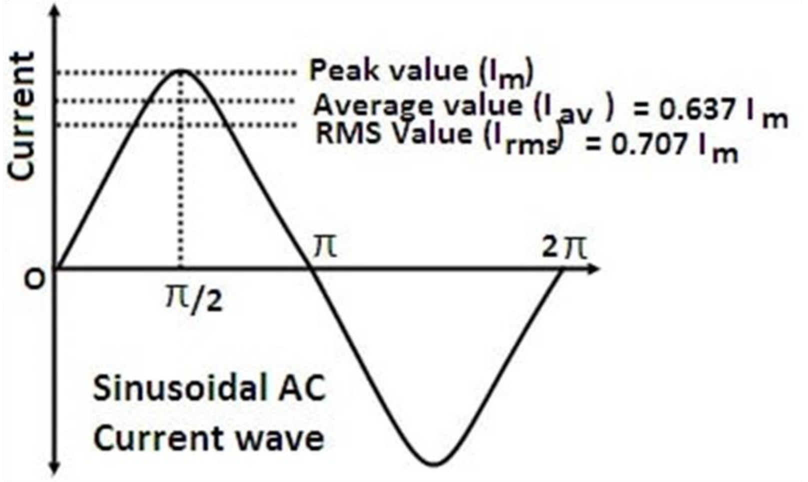
$$Iac = I_m \sin \omega t$$

$$I_{ac}^2 = I_m^2\, sin^2\, \omega t$$

$$I = \frac{\int_0^T I_m^2\, sin^2\, \omega t\, dt}{\int_0^T dt}$$

$$\boldsymbol{I\ rms = \frac{1}{\sqrt{2}} I_m}$$

$$\boldsymbol{I\ rms = 0.707\ I_m}$$



RMS Values of Sinusoidal Voltage Waveform

- The waveform of the voltage v(t), and the square of waveform, $v^2(t)$, are shown in figures 12.4a and 12.4b respectively.

Time period, $T = 1/f = (2\pi)/\omega$; in angle $(\omega T = 2\pi)$

Half time period, $T/2 = 1/(2f) = \pi/\omega$; in angle $(\omega T/2 = \pi)$

$v(\theta) = V_m \sin\theta \quad for \quad \pi \le \theta \le 0;$

$$V_{\text{rms}} = \left[\frac{1}{\pi}\int_0^{\pi} v^2 \, d\theta\right]^{\frac{1}{2}} = \left[\frac{1}{\pi}\int_0^{\pi} V_m^2 \sin^2\theta \, d\theta\right]^{\frac{1}{2}} = \left[\frac{V_m^2}{\pi}\int_0^{\pi} \frac{1}{2}(1-\cos 2\theta)\, d\theta\right]^{\frac{1}{2}}$$

$$V_{\text{rms}} = \left[\frac{V_m^2}{2\pi}\left(\theta - \frac{1}{2}\sin 2\theta\right)\Big|_0^{\pi}\right]^{\frac{1}{2}} = \left[\frac{V_m^2}{2\pi}\pi\right]^{\frac{1}{2}} = \frac{V_m}{\sqrt{2}} = 0.707\, V_m$$

or, $V_m = \sqrt{2}\, V_{\text{rms}}$

- Similarly for current RMA value

$$I_{rms} = \frac{I_{max}}{\sqrt{2}} = 0.707\, I_{max}$$

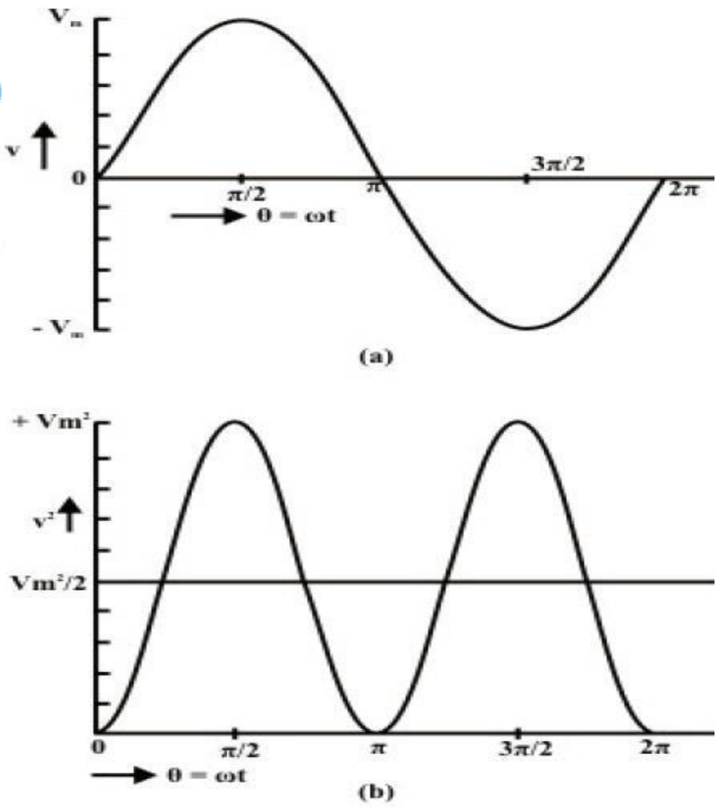


Fig. 12.4 Sinusoidal voltage waveform
(a) Voltage (v), (b) Square of voltage (v²)

Form factors

- The form factor of an alternating quantity is define as the ratio of RMS value to the average value.

$$\text{Form factor} = \frac{RMS\ value}{Average\ value} = \frac{0.707\ V_m}{0.637\ V_m} = 1.11$$

- **<u>Peak value:-</u>**
- The peck factor (crest factor or amplitude factor) of an alternating quantity is define as the ratio of maximum value to the average value

$$\text{Peak factor (P.E.)} = \frac{Maximum\ value}{RMS\ value}$$

$$= \frac{Peak\ Value}{Peak\ Value/\sqrt{2}} = \sqrt{2}$$

$$P.F. = 1.414$$

- **<u>NOTE:-</u>**
  - The rms value is always greater than the average value.
  - Except for a rectangular waveform, in which case the heating effect remains constant, so that the average and the rms values are same

Question

Q1) determine the average value and RMS value of sinusoidal current of peak value 40A.

Solution:-

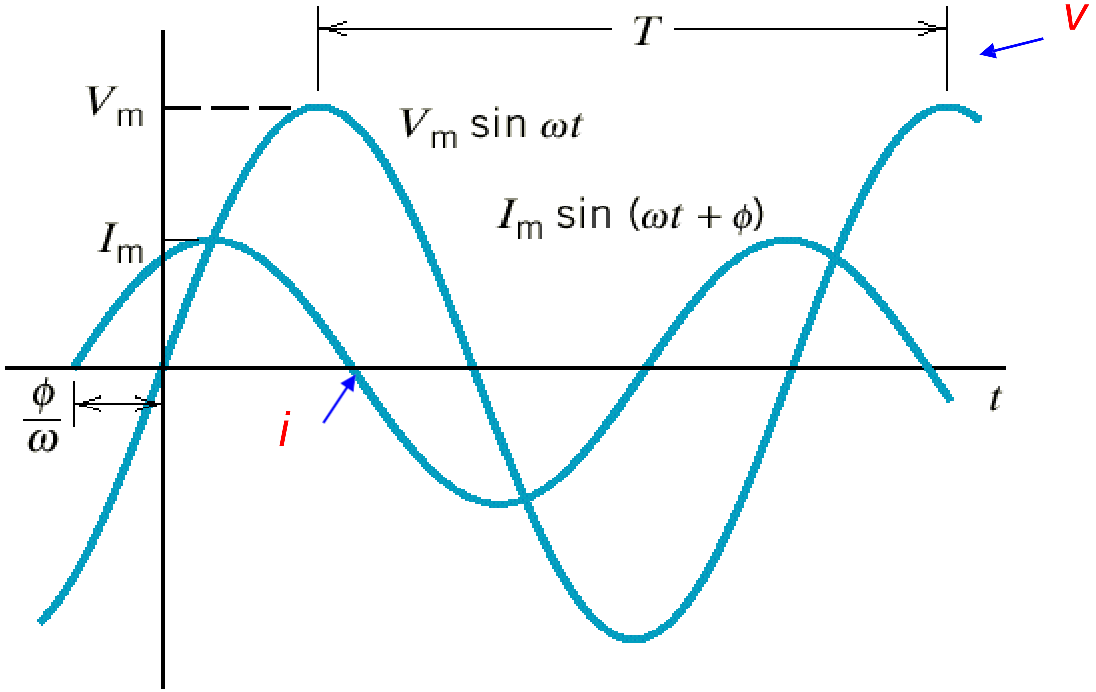
Q2) write the instantaneous value for a 50Hz sinusoidal voltage supply for domestic purposes at 230V.

Solution:-

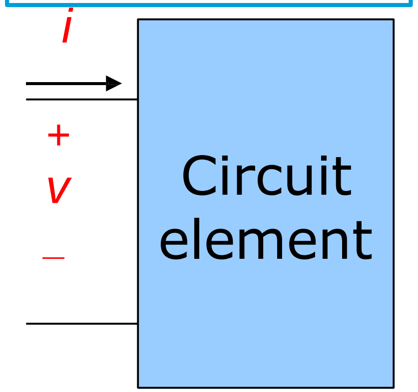
Example

$$\cos\theta = \sin\left(\theta + \frac{\pi}{2}\right)$$

$$\sin\theta = \cos\left(\theta - \frac{\pi}{2}\right)$$



Voltage and current of a circuit element.



The current *leads* the voltage by ϕ radians.

OR

The voltage *lags* the current by ϕ radians.