# ELECTRICAL CIRCUITS


Presented

By

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# ELECTRICAL CIRCUITS

## Unit I: Electrical Circuits (25 Questions)

**Circuit elements – Kirchoff’s Laws – Mesh and Nodal Analysis – Network Theorems and Applications for DC and AC circuits: Thevenin’s Theorem, Norton’s Theorem, Superposition Theorem, Maximum Power Transfer Theorem – Sinusoidal Steady State Analysis of RL–RC-RLC Circuits - Resonant Circuits –Natural and Forced Response – Transient Response of RL-RC-RLC Circuits – Two – port networks – Three Phase Circuits – Star - delta transformation – real and reactive power – power factor**

# ELECTRICAL CIRCUITS

- An Electric circuit is an interconnection of various elements in which there is at least one closed path in which current can flow. An Electric circuit is used as a component for any engineering system.
- All control systems are studied by representing them in the form of electric circuits.

## Elements of an Electric circuit:

An Electric circuit consists of following types of elements.

## Active elements:

- Active elements are the elements of a circuit which possess energy of their own and can impart it to other element of the circuit.
- Active elements are of two types

  **a) Voltage source    b) Current source**

- A Voltage source has a specified voltage across its terminals, independent of current flowing through it.
- A current source has a specified current through it independent of the voltage appearing across it.

# ELECTRICAL CIRCUITS

## Passive Elements:

- The passive elements of an electric circuit do not possess energy of their own. They receive energy from the sources.
- The passive elements are the resistance, the inductance and the capacitance. When electrical energy is supplied to a circuit element, it will respond in one and more of the following ways.
- If the energy is consumed, then the circuit element is a pure resistor.
- If the energy is stored in a magnetic field, the element is a pure inductor.
- And if the energy is stored in an electric field, the element is a pure capacitor.

## Linear and Non-Linear Elements.

- Linear elements show the linear characteristics of voltage & current. That is its voltage-current characteristics are at all-times a straight-line through the origin.
- For example, the current passing through a resistor is proportional to the voltage applied through its and the relation is expressed as $V \propto I$ or $V=IR$.
- A linear element or network is one which satisfies the principle of superposition, i.e., the principle of homogeneity and additivity.
- Resistors, inductors and capacitors are the examples of the linear elements and their properties do not change with a change in the applied voltage and the circuit current.

## Linear and Non-Linear Elements.

- Non linear element's V-I characteristics do not follow the linear pattern i.e. the current passing through it does not change linearly with the linear change in the voltage across it. Examples are the semiconductor devices such as diode, transistor.

## Bilateral and Unilateral Elements:

- An element is said to be bilateral, when the same relation exists between voltage and current for the current flowing in both directions.

Ex: Voltage source, Current source, resistance, inductance & capacitance. The circuits containing them are called bilateral circuits.

- An element is said to be unilateral, when the same relation does not exist between voltage and current when current flowing in both directions. The circuits containing them are called unilateral circuits.

Ex: Vacuum diodes, Silicon Diodes, Selenium Rectifiers etc.

## Lumped and Distributed Elements

Lumped elements are those elements which are very small in size & in which simultaneous actions takes place. Typical lumped elements are capacitors, resistors, inductors.

Distributed elements are those which are not electrically separable for analytical purposes.

For example a transmission line has distributed parameters along its length and may extend for hundreds of miles.

The circuits containing them are called unilateral circuits.

# Types of Sources:

## Independent & Dependent sources:

If the voltage of the voltage source is completely independent source of current and the current of the current source is completely independent of the voltage, then the sources are called as independent sources.

The special kind of sources in which the source voltage or current depends on some other quantity in the circuit which may be either a voltage or a current anywhere in the circuit are called Dependent sources or Controlled sources.

# ELECTRICAL CIRCUITS

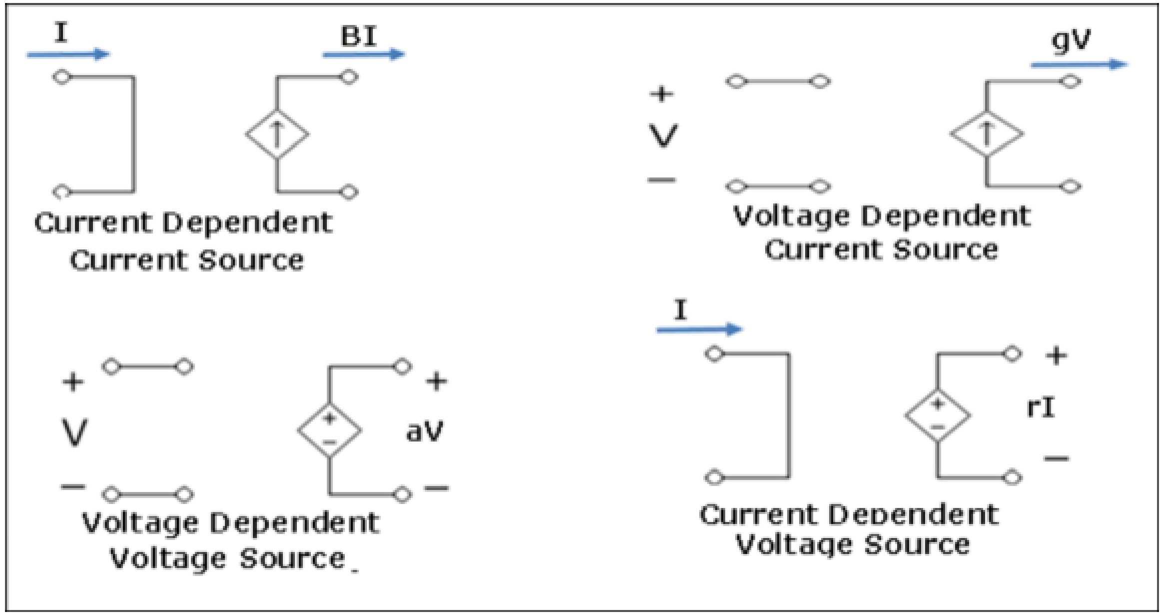
**Four possible dependent sources:**

a) Voltage dependent Voltage source

b) Current dependent Current source

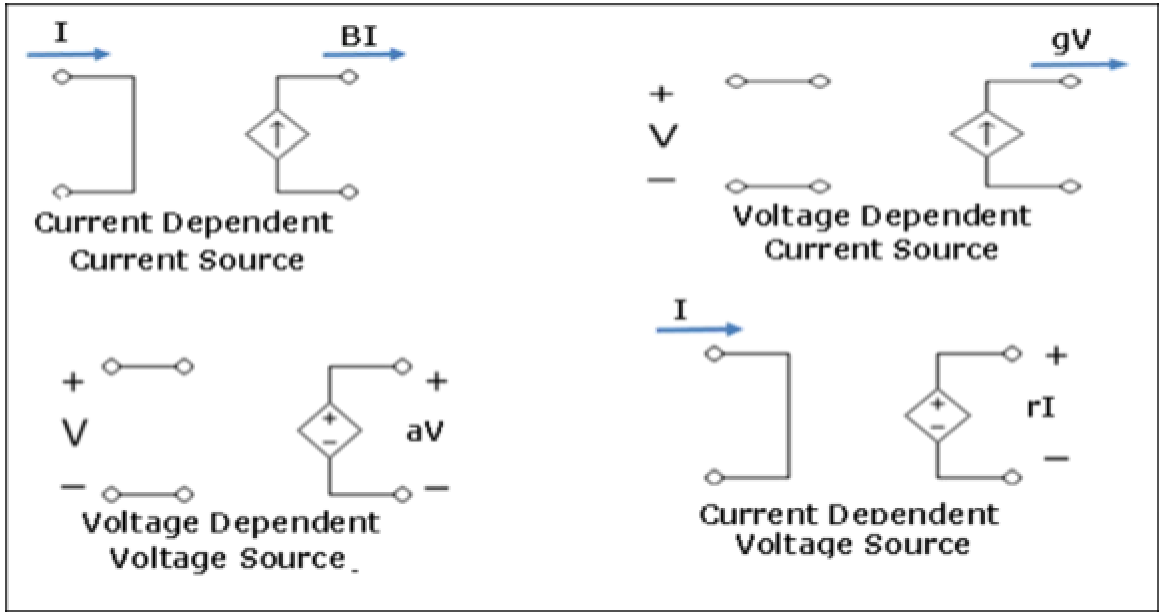
c) Voltage dependent Current source

d) Current dependent Current source



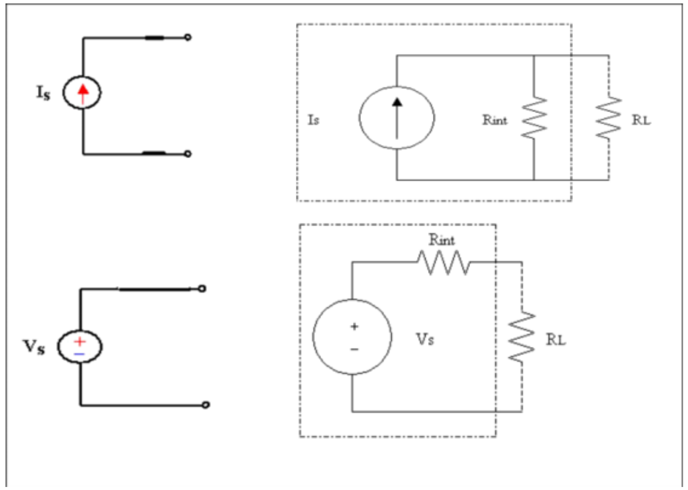
# ELECTRICAL CIRCUITS

- The constants of proportionalities are written as B, g, a, r in which B & a has no units, r has units of ohm & g units of mhos.
- Independent sources actually exist as physical entities such as battery, a dc generator & an alternator. But dependent sources are used to represent electrical properties of electronic devices such as OPAMPS & Transistors.



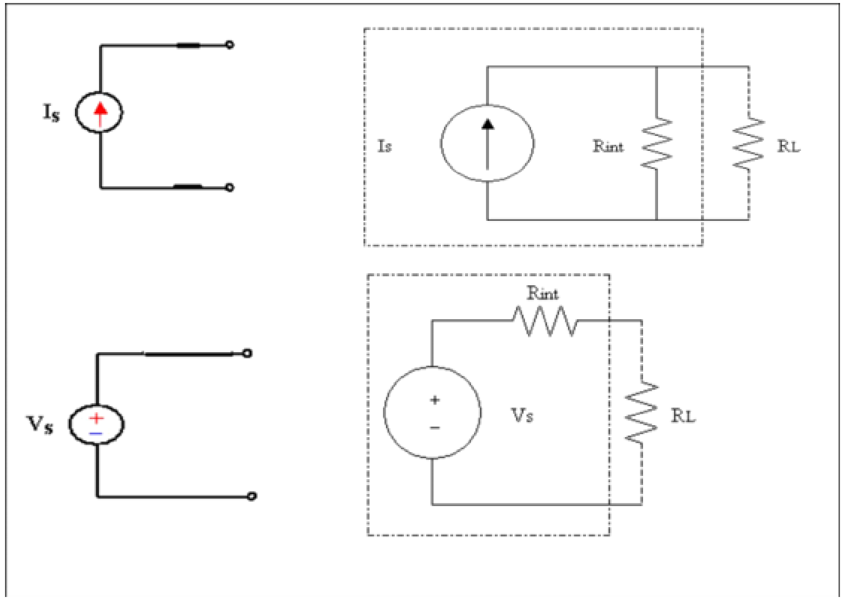
## Ideal & Practical sources:

- An ideal voltage source is one which delivers energy to the load at a constant terminal voltage, irrespective of the current drawn by the load.
- An ideal current source is one, which delivers energy with a constant current to the load, irrespective of the terminal voltage across the load.
- A Practical voltage source always possesses a very small value of internal resistance r. The internal resistance of a voltage source is always connected in series with it & for a current source; it is always connected in parallel with it.



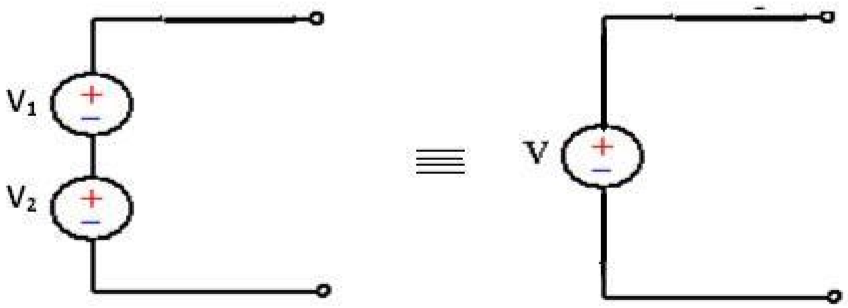
## Ideal & Practical sources:

- As the value of the internal resistance of a practical voltage source is very small, its terminal voltage is assumed to be almost constant within a certain limit of current flowing through the load.
- A practical current source is also assumed to deliver a constant current, irrespective of the terminal voltage across the load connected to it.

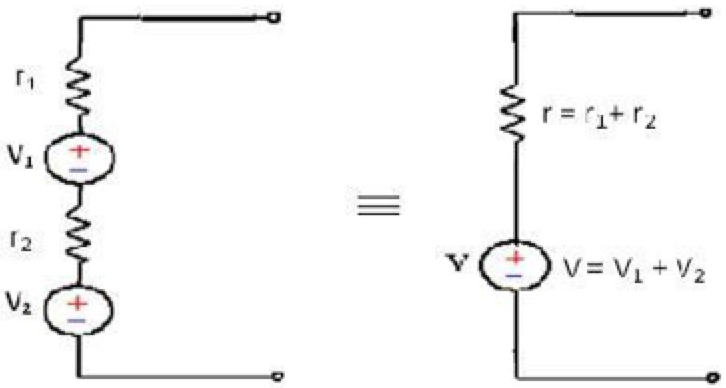


## Ideal voltage source connected in series:

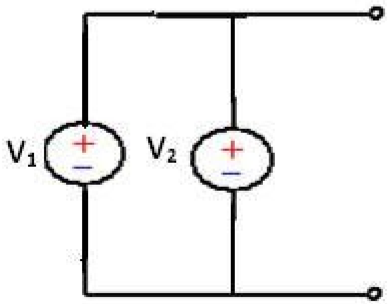
- The equivalent single ideal voltage some is given by V= V1 + V2
- Any number of ideal voltage sources connected in series can be represented by a single ideal voltage some taking in to account the polarities connected together in to consideration.




**Practical voltage source connected in series:**

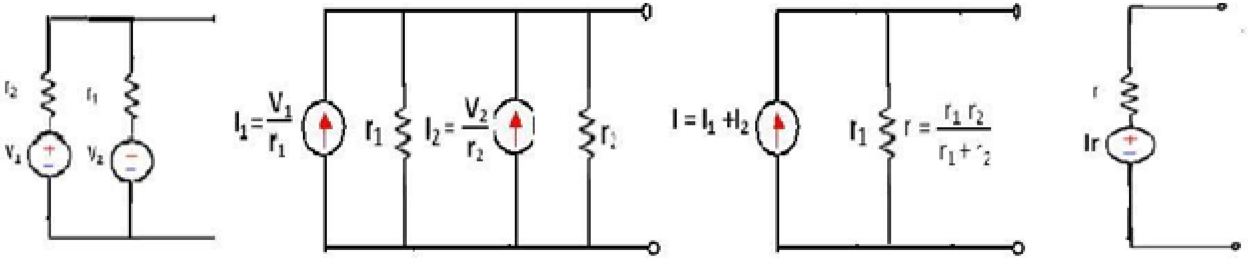


## Ideal voltage source connected in parallel:




- When two ideal voltage sources of emf's V1 & V2 are connected in parallel, what voltage appears across its terminals is ambiguous.
- Hence such connections should not be made.
- However if V1 = V2= V, then the equivalent voltage some is represented by V.
- In that case also, such a connection is unnecessary as only one voltage source serves the purpose.

## Practical voltage sources connected in parallel:

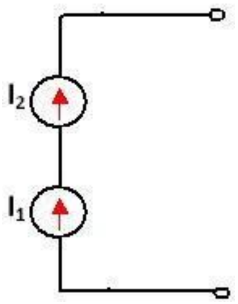



Equivalent Circuit

Single Equivalent Voltage Source

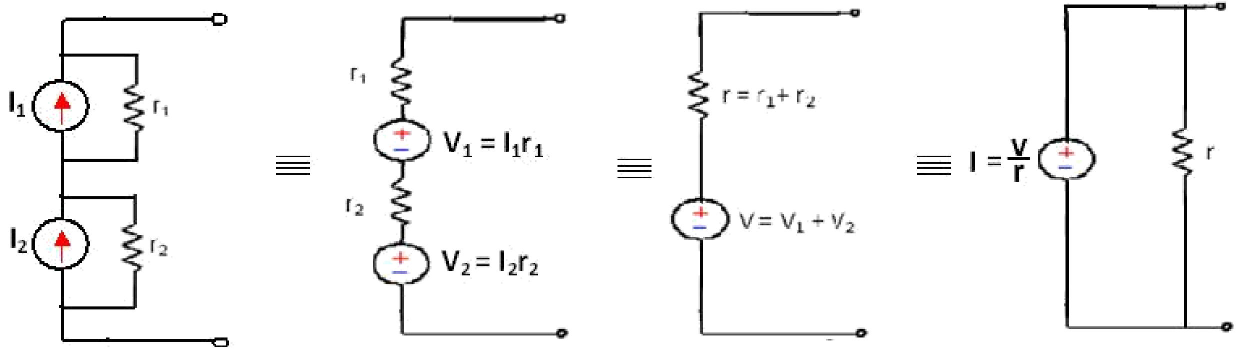
# ELECTRICAL CIRCUITS

## Ideal current sources connected in series:



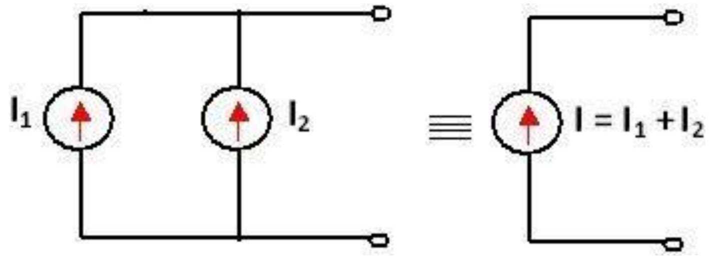

- When ideal current sources are connected in series, what current flows through the line is ambiguous. Hence such a connection is not permissible.
- However, it I1 = I2 = I, then the current in the line is I.
- But, such a connection is not necessary as only one current source serves the purpose.

## Practical current sources connected in series:

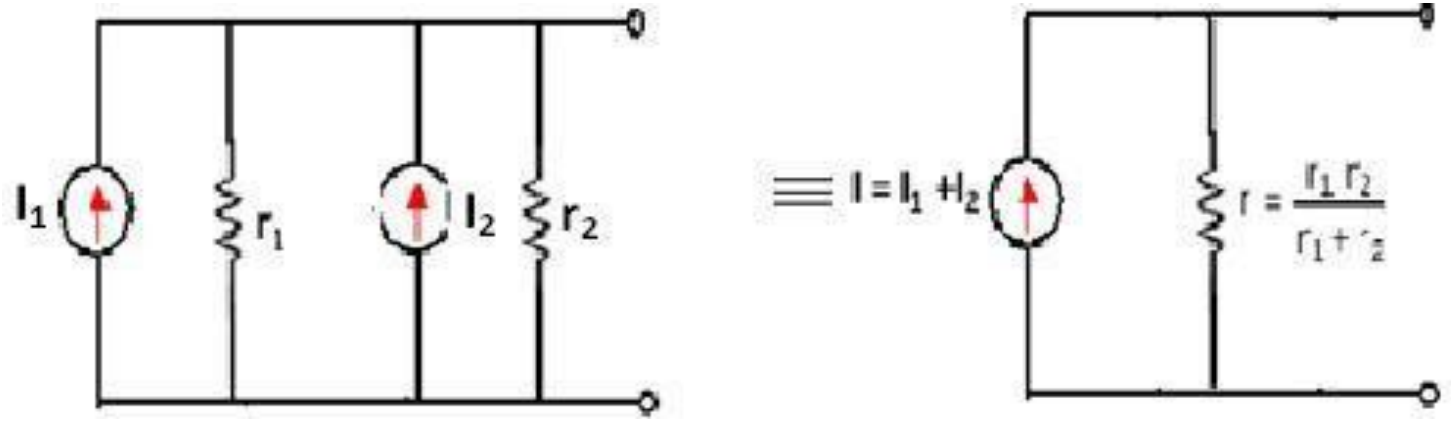


## Ideal current sources connected in parallel

- Two ideal current sources in parallel can be replaced by a single equivalent ideal current source.




## Practical current sources connected in parallel



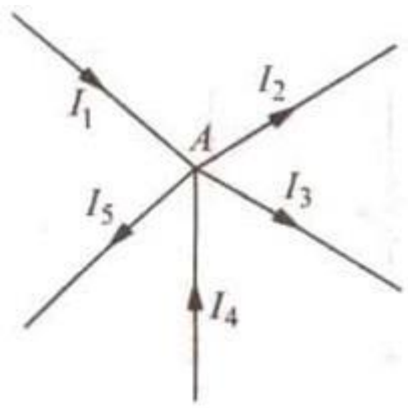
## Kirchhoff`s Laws:

- Kirchhoff’s laws are more comprehensive than Ohm's law and are used for solving electrical networks which may not be readily solved by the latter.
- Kirchhoff`s laws, two in number, are particularly useful in determining the equivalent resistance of a complicated network of conductors and for calculating the currents flowing in the various conductors.

## Kirchhoff`s Current Law (KCL)

- In any electrical network, the algebraic sum of the currents meeting at a point (or junction) is Zero.
- That is the total current entering a junction is equal to the total current leaving that junction. Consider the case of a network shown in Fig (a).

$I_1+(-I_2)+(I_3)+(+I_4)+(-I_5) = 0$




$I_1+I_4-I_2-I_3-I_5 = 0$ Or

$I_1+I_4 = I_2+I_3+I_5$ Or

- Incoming currents =Outgoing currents

## Kirchhoff's Mesh Law or Voltage Law (KVL)

- In any electrical network, the algebraic sum of the products of currents and resistances in each of the conductors in any closed path (or mesh) in a network plus the algebraic sum of the e.m.f.'s. in that path is zero.
- That is, $\sum IR + \sum e.m.f = 0$ round a mesh
- It should be noted that algebraic sum is the sum which takes into account the polarities of the voltage drops.

## Kirchhoff's Mesh Law or Voltage Law (KVL)

- That is, if we start from a particular junction and go round the mesh till we come back to the starting point, then we must be at the same potential with which we started.
- Hence, it means that all the sources of emf met on the way must necessarily be equal to the voltage drops in the resistances, every voltage being given its proper sign, plus or minus.

## Determination of Voltage Sign

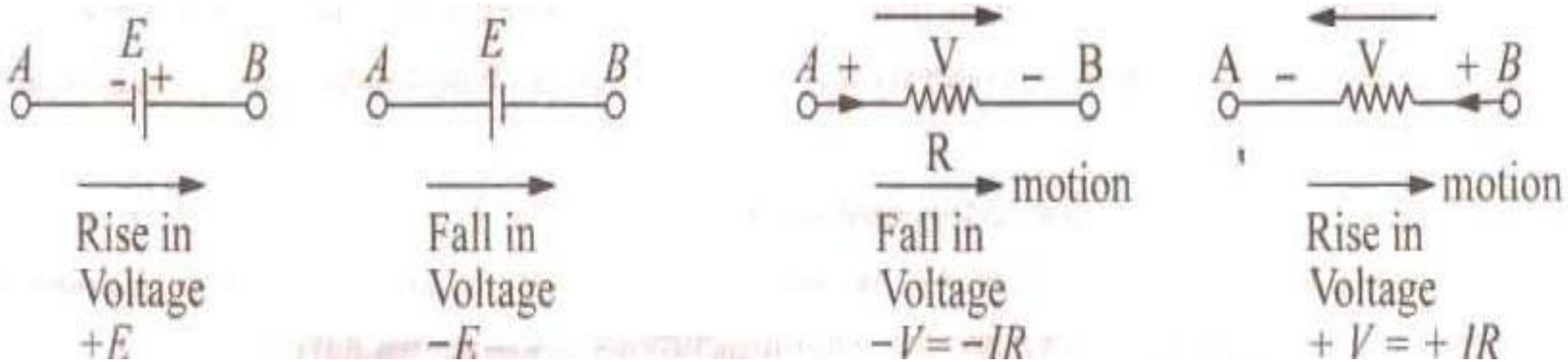
- In applying Kirchhoff's laws to specific problems, particular attention should be paid to the algebraic signs of voltage drops and e.m.fs.

## Sign of Battery E.M.F.

- A rise in voltage should be given a + ve sign and a fall in voltage a -ve sign. That is, if we go from the -ve terminal of a battery to its +ve terminal there is a rise in potential, hence this voltage should be given a + ve sign.

- And on the other hand, we go from +ve terminal to -ve terminal, then there is a fall in potential, hence this voltage should be preceded by a -ve sign.

- The sign of the battery e.m.f is independent of the direction of the current through that branch

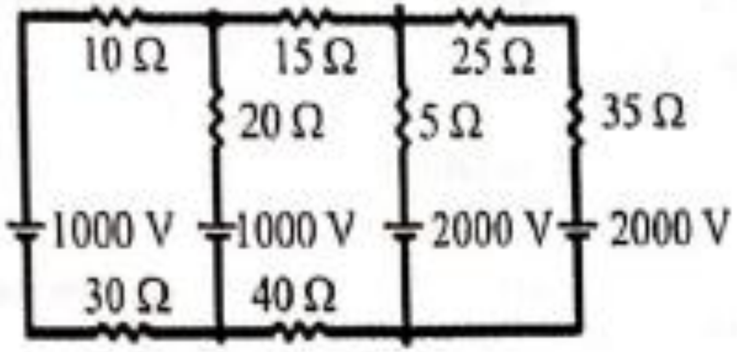



**Sign of IR Drop**

- Now, take the case of a resistor (Fig. 2.4). If we go through a resistor in the same direction as the current, then there is a fall in potential because current flows from a higher to a lower potential..
- Hence, this voltage fall should be taken -ve. However, if we go in a direction opposite to that of the current, then there is a rise in voltage. Hence, this voltage rise should be given a positive sign.

## Assumed Direction of Current:

- In applying Kirchhoff's laws to electrical networks, the direction of current flow may be assumed either clockwise or anticlockwise. If the assumed direction of current is not the actual direction, then on solving the question, the current will be found to have a minus sign.
- If the answer is positive, then assumed direction is the same as actual direction.
- However, the important point is that once a particular direction has been assumed, the same should be used throughout the solution of the question.
- Kirchhoff's laws are applicable both to d.c. and a.c. voltages and currents. However, in the case of alternating currents and voltages, any e.m.f. of self-inductance or that existing across a capacitor should be also taken into account.




In the network shown in the given figure, the value of $\frac{\text{number of junctions}}{\text{number of branches}}$ is :

(a) $\frac{1}{2}$ (b) $\frac{4}{3}$

(c) $\frac{2}{3}$ (d) $\frac{3}{4}$

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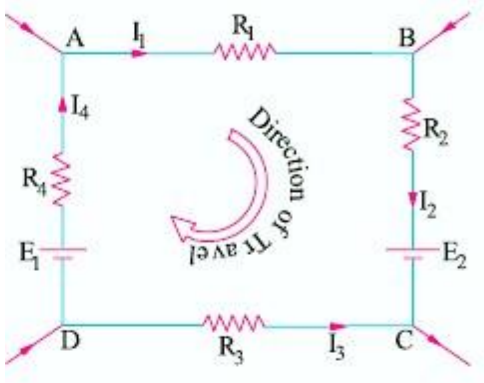
Consider the closed path ABCDA in Fig .

As we travel around the mesh in the clockwise direction, different voltage drops will have the following signs :




- ❖ $I_1R_1$ is - ve (fall in potential)
- ❖ $I_2R_2$ is - ve (fall in potential)
- ❖ $I_3R_3$ is + ve (rise in potential)
- ❖ $I_4R_4$ is - ve (fall in potential
- ❖ $E_2$ is - ve (fall in potential)
- ❖ $E_1$ is + ve (rise in potential)

Using Kirchhoff's voltage law, we get $- I_1R_1 – I_2R_2 – I_3R_3 – I_4R_4 – E_2 + E_1 = 0$ Or

$I1R1 + I2R2 – I3R3 + I4R4 = E1 –E2$

# ELECTRICAL CIRCUITS

**1. The circuit in which current has a complete path to flow is called ______ circuit.**

a) Short

b) open

c) closed

d) open loop

**1. The circuit in which current has a complete path to flow is called ______ circuit.**

a) Short

b) open

c) closed

d) open loop

**Answer: c**

**Explanation:** The circuit in which current has a complete path to flow is called a closed circuit. When the current path is broken so that current cannot flow, the circuit is called an open circuit.

# ELECTRICAL CIRCUITS

**2. The basic laws for analyzing an electric circuit are**

a) Einstein's theory

b) Newton's laws

c) Kirchhoff's laws

d) Faradays laws

2. **The basic laws for analyzing an electric circuit are**

a) Einstein's theory

b) Newton's laws

c) Kirchhoff's laws

d) Faradays laws

**Answer: c**

**Explanation:** Kirchhoff's laws are used for analyzing an electric circuit.

3. A junction where two (or) more than two network elements meet is known as a ______________

a) Node

b) Branch

c) Loop

d) Mesh

3. A junction where two (or) more than two network elements meet is known as a ____________

a) Node

b) Branch

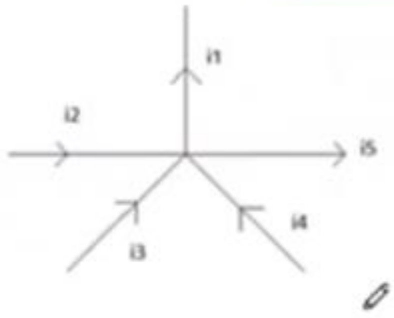
c) Loop

d) Mesh

**Answer: a**

**Explanation:** Node is a junction where two or more than two network elements meet.

6. Relation between currents according to KCL is




a) i1=i2=i3=i4=i5

b) i1+i4+i3=i5+i2

c) i1-i5=i2-i3-i4

d) i1+i5=i2+i3+i4

**4.KCL is based on the fact that**

a) There is a possibility for a node to store energy.

b) There cannot be an accumulation of charge at a node.

c) Charge accumulation is possible at node

d) Charge accumulation may or may not be possible.

**4.KCL is based on the fact that**

a) There is a possibility for a node to store energy.

b) There cannot be an accumulation of charge at a node.

c) Charge accumulation is possible at node

d) Charge accumulation may or may not be possible.

**Answer: b**

**Explanation:**Since the node is not a circuit element, any charge which enters node must leave immediately.

**5. Which statement/statements is/are correct regarding KCL?**

a) Sum of incoming currents is equal to sum of outgoing current

b) Algebraic sum of all currents for any node is zero.

c) Algebraic sum of voltages around any closed path in a network is equal to zero

d) Both a & b

**5. Which statement/statements is/are correct regarding KCL?**

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Answer: d

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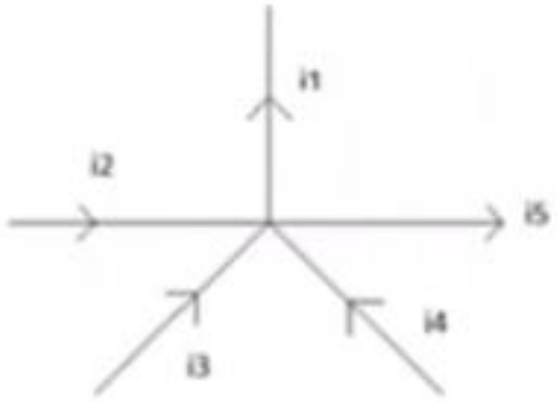


a) i1=i2=i3=i4=i5

b) i1+i4+i3=i5+i2

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d) i1+i5=i2+i3+i4

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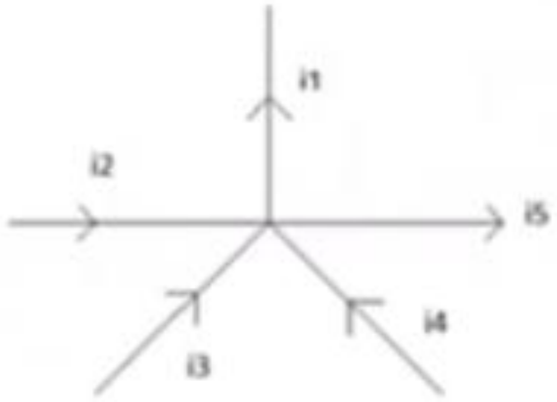



a) i1=i2=i3=i4=i5

b) i1+i4+i3=i5+i2

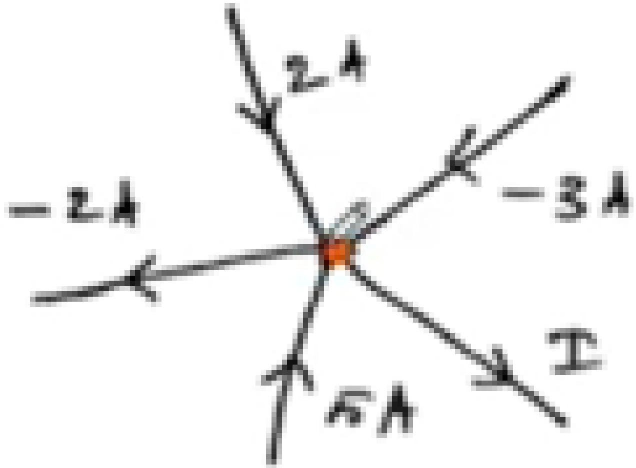
c) i1-i5=i2-i3-i4

d) i1+i5=i2+i3+i4

Answer: d

Explanation: According to KCL,sum of entering currents = sum of leaving currents.

7.Find the value of I.



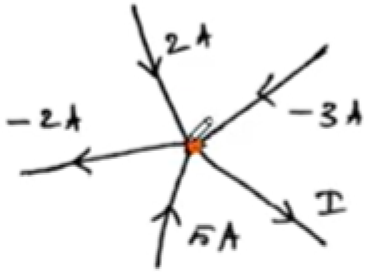

a) 6 A

b) -6A

c) 2A

d) 12A

7.Find the value of I.




a) 6 A

b) -6A

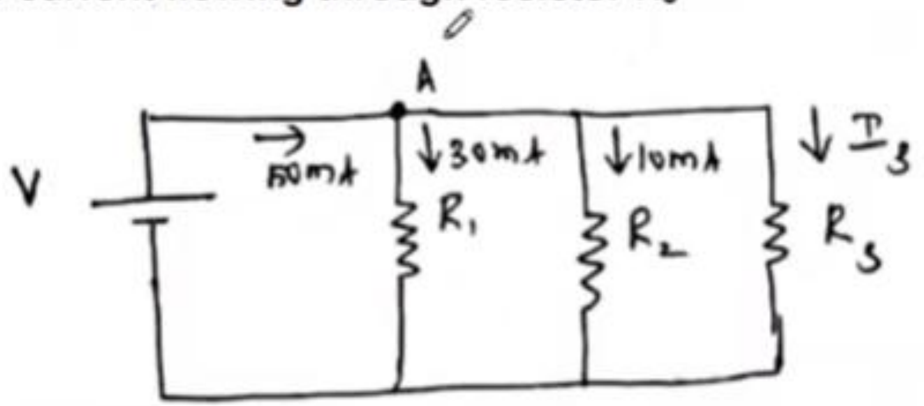
c) 2A

d) 12A

**Answer: A**

**Explanation:**According to KCL,sum of entering currents = sum of leaving currents

8. Determine the current flowing through resistor $R_3$



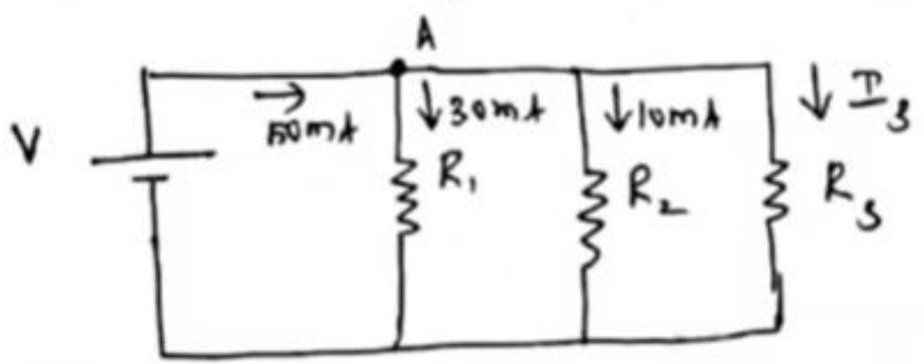

a) 90mA

b) 10mA

c) 9mA

d) 10A

8. Determine the current flowing through resistor $R_3$




a) 90mA

b) 10mA

c) 9mA

d) 10A

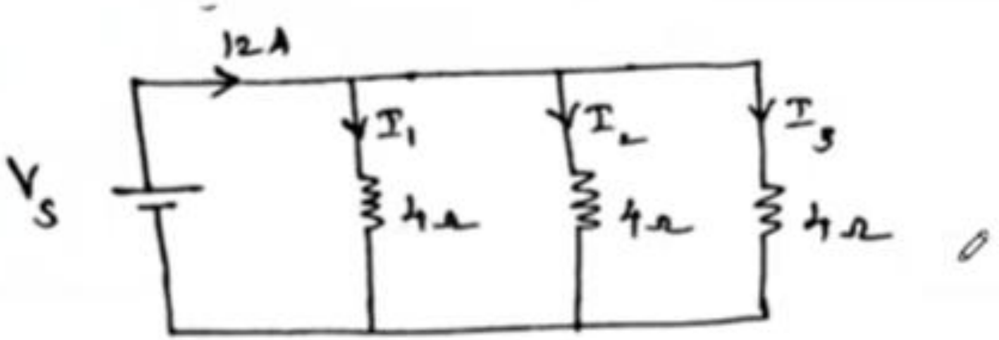
**Answer: B**

**Explanation:** According to KCL,sum of entering currents = sum of leaving currents

$$50 = 30 + 10 + I3$$

$$I3 = 10mA$$

9. Determine the current flowing through all resistors?



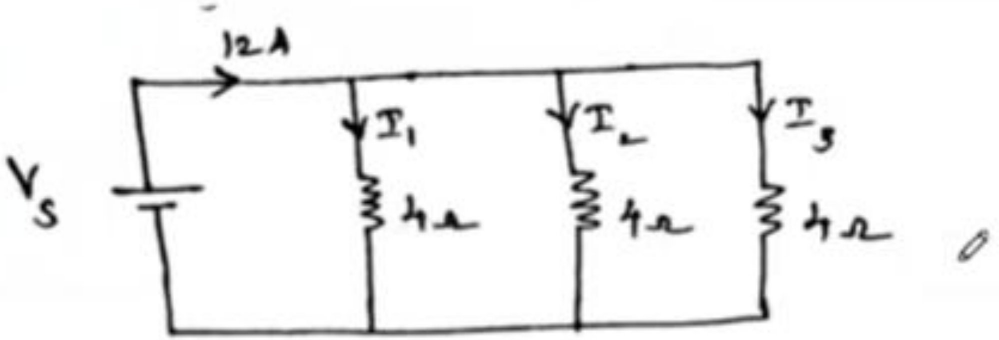

a) 4,4,4 A

b) 12,12,12 A

c) 3,3,6 A

d) 1,4,7 A

9. Determine the current flowing through all resistors?




a) 4,4,4 A

b) 12,12,12 A

c) 3,3,6 A

d) 1,4,7 A

Answer: A

10.The algebraic sum of voltages around any closed path in a network is equal to ________

a) Infinity

b) 1

c) 0

d) Negative polarity

10.The algebraic sum of voltages around any closed path in a network is equal to ____________

a) Infinity

b) 1

c) 0

d) Negative polarity

Answer: c

**11. Which statement/ statements is/are correct regarding KVL?**

a) sum of incoming currents is equal to sum of outgoing current

b) Algebraic sum of all currents for any node is zero.

c) algebraic sum of voltages around any closed path in a network is equal to zero

d) Both a & b

**11. Which statement/ statements is/are correct regarding KVL?**

a) sum of incoming currents is equal to sum of outgoing current

b) Algebraic sum of all currents for any node is zero.

c) algebraic sum of voltages around any closed path in a network is equal to zero

d) Both a & b

**Answer: C**

12. All _____________ are loops but _______________ are not meshes

a) Loops, Meshes

b) Meshes, loops

c) Branches, loops

d) Nodes, Branches

12. All ______________ are loops but ________________ are not meshes

a) Loops, Meshes

b) Meshes, loops

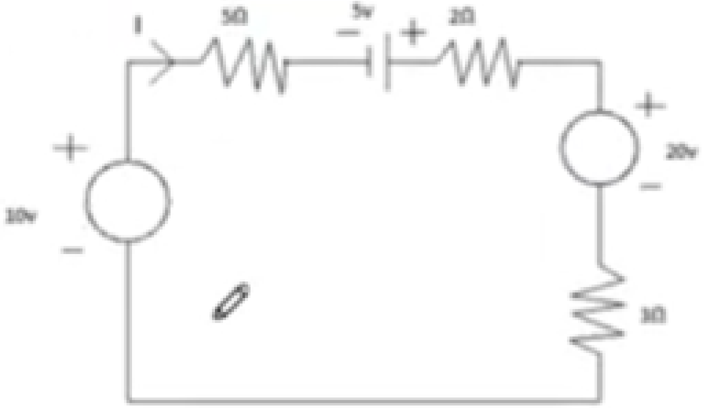
c) Branches, loops

d) Nodes, Branches

**Answer: b**

**Explanation:** A mesh cannot be divided further in loops.

13. Find the current I.




a) -0.5A

b) 0.5A

c) -0.2A

d) 0.2A

Assertion : At any junction of a network, algebraic sum of various currents is zero
Reason : At steady state there is
no accumulation of charge at the junction.

1) Both (A) and (R) are true and (R) is the correct explanation of A.

2) Both (A) and (R) are true but (R) is not the correct explanation of A.

3) (A) is true but (R) is false

4) (A) is false but (R) is true

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Reason : At steady state there is
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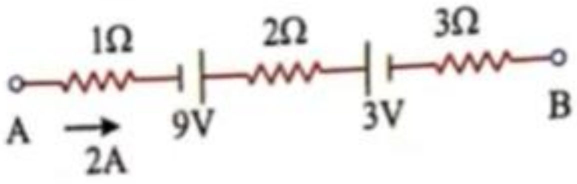
3) (A) is true but (R) is false 4) (A) is false but (R) is true

# ELECTRICAL CIRCUITS

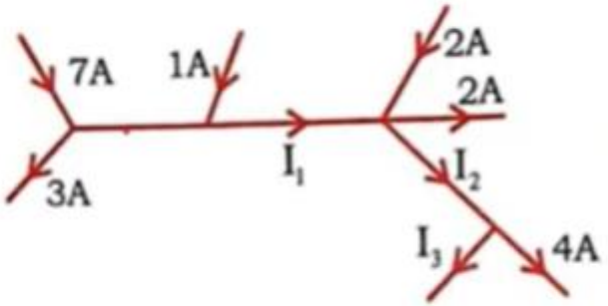
**Single Correct Choice Type:**

1. The potential difference between A & B in the given branch of a circuit is




1) 6V 2) 12V 3) 9V 4) 0V

2. Find $I_1, I_2, I_3$ from the given figure.




1) $I_1 = 5\,A, I_2 = 5\,A; I_3 = 4A$
2) $I_1 = 4\,A, I_2 = 5\,A; I_3 = 4A$
3) $I_1 = 5\,A, I_2 = 5\,A; I_3 = 1A$
4) None of the above

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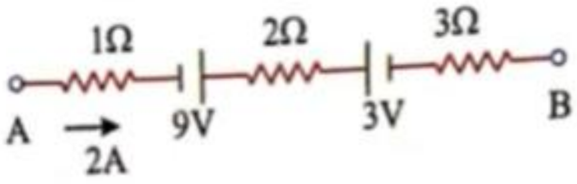
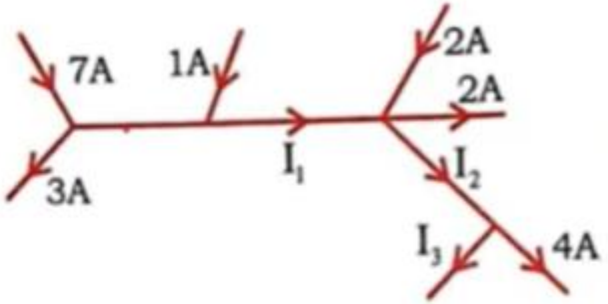
**Single Correct Choice Type:**

1. The potential difference between A & B in the given branch of a circuit is




1) 6V 2) 12V 3) 9V 4) 0V

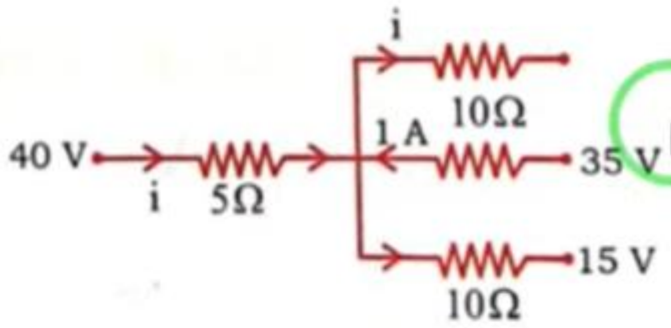
2. Find $I_1, I_2, I_3$ from the given figure.




1) $I_1 = 5\text{ A}, I_2 = 5\text{ A}; I_3 = 4\text{A}$
2) $I_1 = 4\text{ A}, I_2 = 5\text{ A}; I_3 = 4\text{A}$
3) $I_1 = 5\text{ A}, I_2 = 5\text{ A}; I_3 = 1\text{A}$
4) None of the above

# ELECTRICAL CIRCUITS

3. In the given circuit the current i is




1) 1 A　　2) 2 A　　3) 3 A　　4) 4 A

3. In the given circuit the current i is

$V_A \xrightarrow[I]{R} V_B$

$I = \frac{V_A - V_B}{R}$

$I = \frac{40-x}{5}$

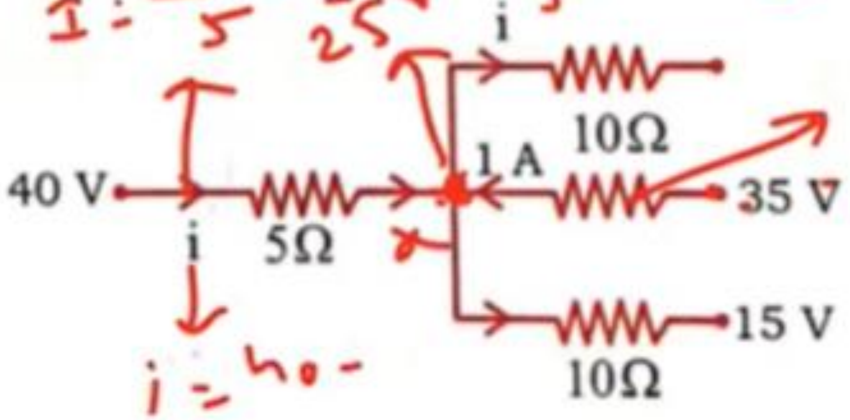
$25V$

$\frac{40-25}{5} = \frac{15}{5} = 3A$

$\frac{35-x}{10} = 1$

$35 - x = 10$

$x = 25V$



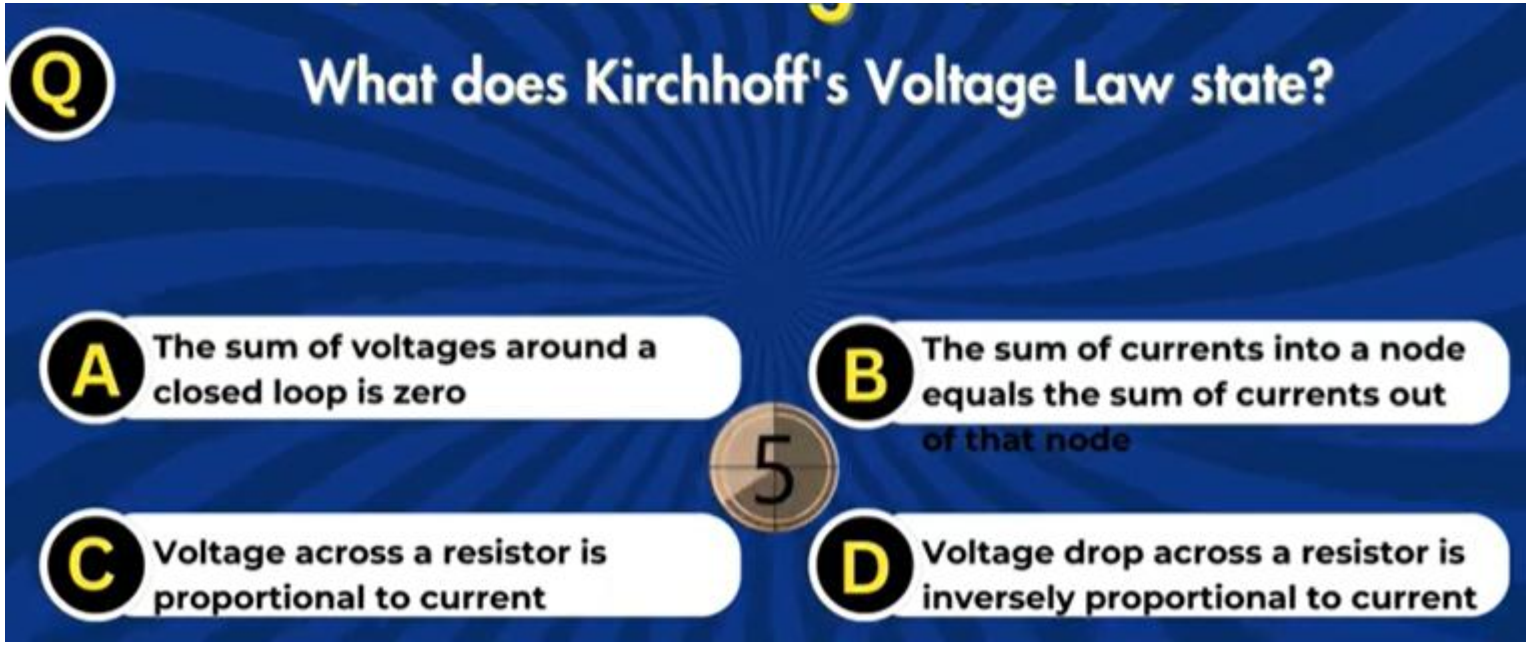

1) 1 A

2) 2 A

3) 3 A

4) 4 A

# ELECTRICAL CIRCUITS



# ELECTRICAL CIRCUITS

**Q** In KVL, what is the significance of positive and negative signs for voltages?

**A** Indicates direction of voltage drop

**B** Indicates magnitude of voltage

**C** Indicates resistance value

**D** Indicates current flow

# ELECTRICAL CIRCUITS

Q How many voltages are typically involved in KVL around a loop?

A Multiple

B Two

C Three

D None

**Q** What is the mathematical representation of Kirchhoff's Voltage Law around a closed loop?

**A** ΣV = 0

**B** ΣI_in = ΣI_out

**C** V = IR

**D** P = VI

# ELECTRICAL CIRCUITS

**Q** Which principle does KVL follow?

**A** Law of Conservation of Energy

**B** Law of Conservation of Charge

**C** Ohm's Law

**D** Newton's Law of Motion

# ELECTRICAL CIRCUITS

**Q** What is the practical application of Kirchhoff's Voltage Law?

**A** Circuit analysis

**B** Mechanical engineering

**C** Chemical reactions

**D** Magnetic fields

# ELECTRICAL CIRCUITS

**Q** How many equations are typically formed by applying KVL to all loops in a circuit?

**A** Equal to number of loops

**B** Equal to number of nodes

**C** Equal to number of branches

**D** Equal to number of components

# ELECTRICAL CIRCUITS

Q What is the sum of voltages across components in KVL if the loop is a source?

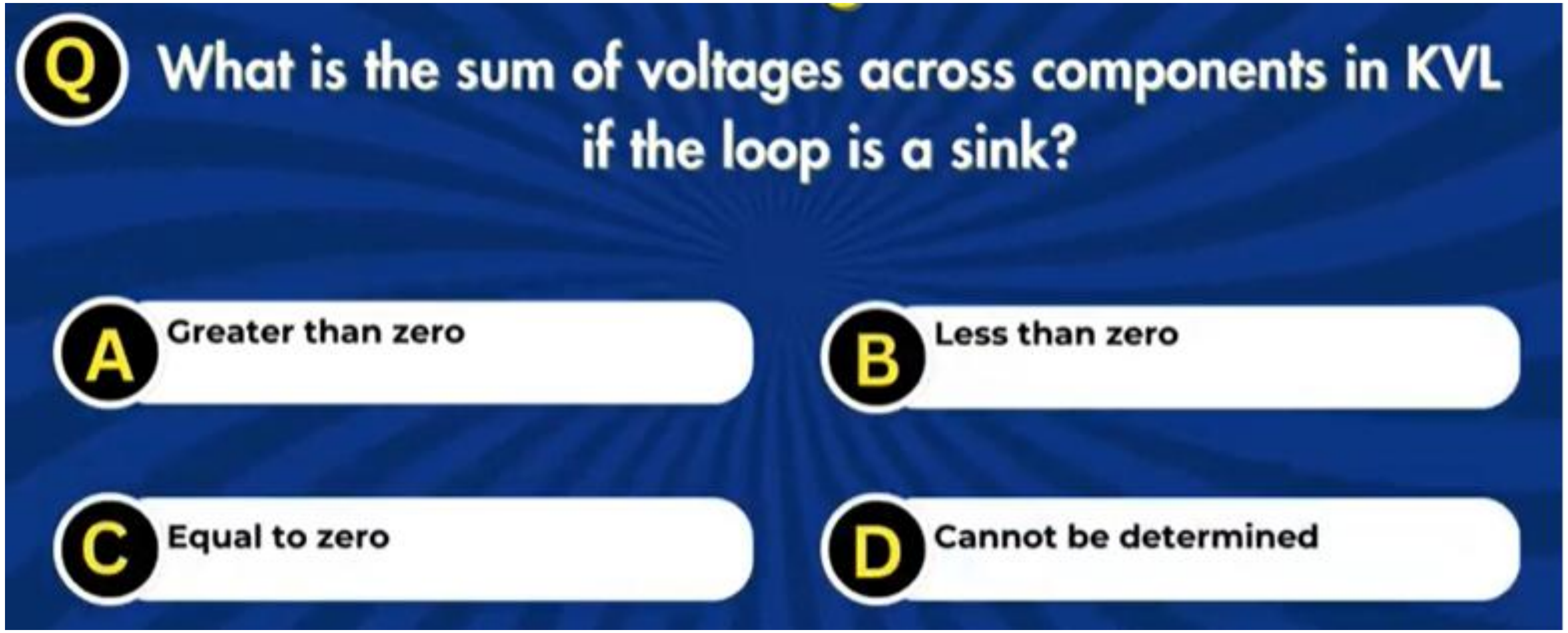
A Greater than zero

B Less than zero

C Equal to zero

D Cannot be determined

# ELECTRICAL CIRCUITS



# ELECTRICAL CIRCUITS