SNS COLLEGE OF ENGINEERING

Coimbatore-35
An Autonomous Institution
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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

II ECE / II SEMESTER

Unit 1 –BASIC CIRCUITS ANALYSIS

Topic 1 -Kirchoffs laws

Kirchoffs laws

KIRCHHOFF’S LAWS

Kirchhoff's laws are a set of two laws that are used to analyze electric circuits. They are Kirchhoff's current law (KCL) and Kirchhoff's voltage law.

Kirchhoff's current law (KCL)

States that the total current entering a junction in a circuit is equal to the total current leaving that junction

Also known as Kirchhoff's first law or Kirchhoff's junction rule

A consequence of the conservation of charge principle

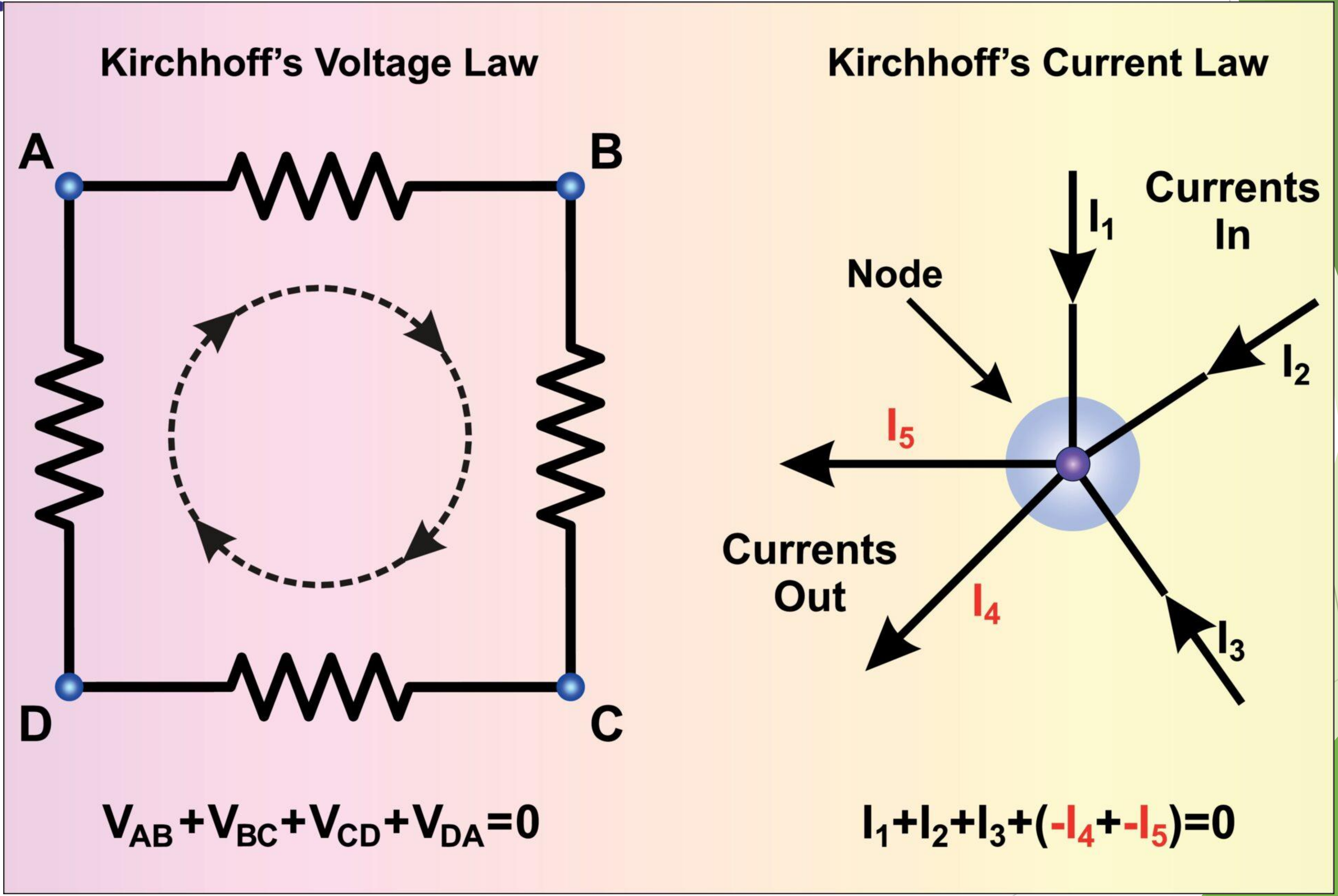
Can be used to design circuits that manage current flow efficiently

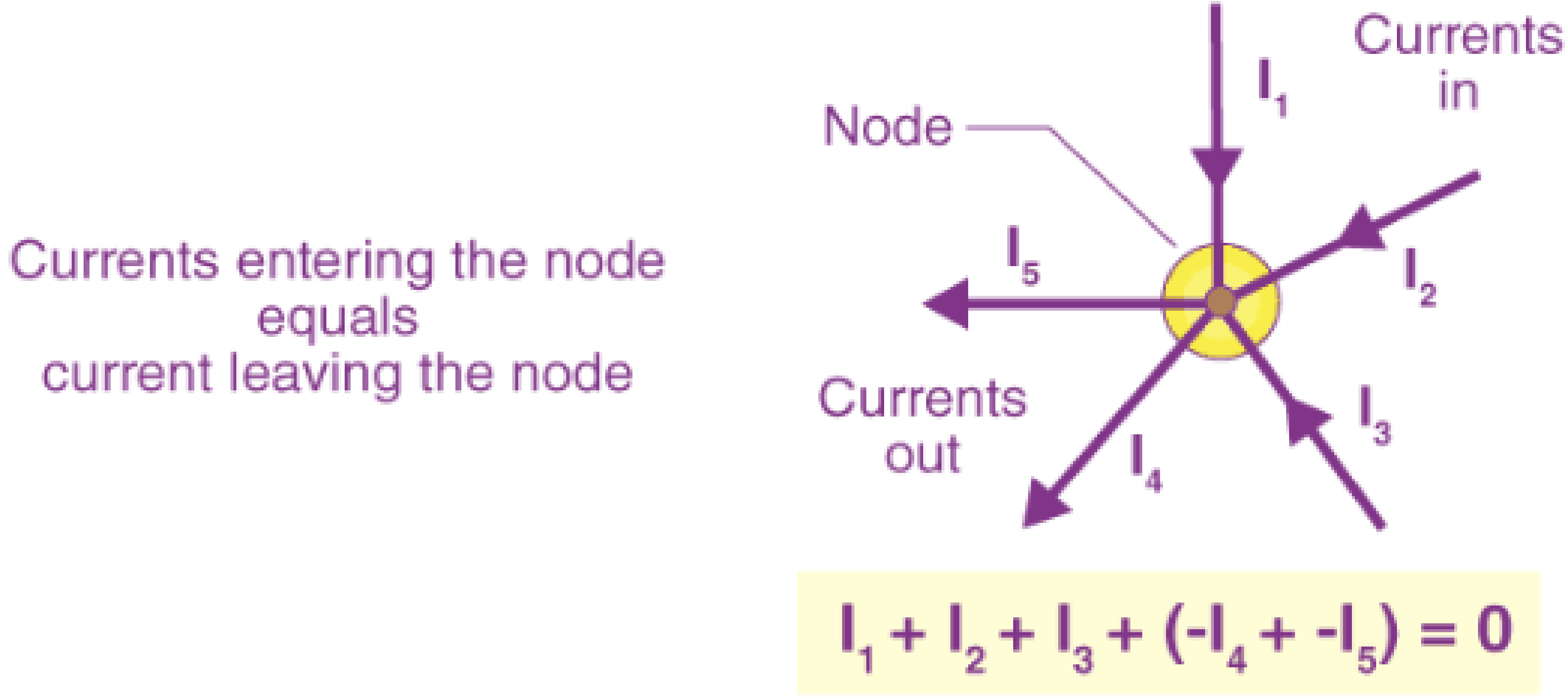
Can be used to troubleshoot and repair circuits

Kirchhoff's voltage law

States that the total voltage is equal to the sum of the voltage drops in a closed loop

Kirchhoff's laws are fundamental electrical laws that help make it easier to calculate unknown currents and voltages in a circuit.


Kirchhoff's Voltage Law
A
B
C
D
$V_{AB}+V_{BC}+V_{CD}+V_{DA}=0$
Kirchhoff's Current Law
Currents In
Node
Currents Out
I_1
I_2
I_3
I_4
I_5
$I_1+I_2+I_3+(-I_4+-I_5)=0$



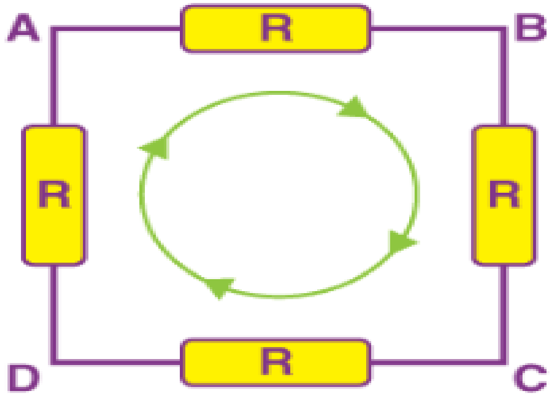
In the above figure, the currents I_1, I_2 and I_3 entering the node is considered positive, likewise, the currents I_4 and I_5 exiting the nodes is considered negative in values. This can be expressed in the form of an equation:

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

Read More: Kirchhoff's Second Law

The sum of all the voltage drops around the loop is equal to zero

$$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$$



When you begin at any point of the loop and continue in the same direction, note the voltage drops in all the negative or positive directions and returns to the same point. It is essential to maintain the direction either counterclockwise or clockwise; otherwise, the final voltage value will not be zero. The voltage law can also be applied in analyzing circuits in series.

Problem 1: Series Circuit with Two Resistors

Given:

A circuit with a 12V battery and two resistors in series: $R_1 = 4\,\Omega$, and $R_2 = 6\,\Omega$.

Objective:

Find the voltage drop across each resistor using Kirchhoff's Voltage Law (KVL).

Solution:

In a series circuit, the total resistance is the sum of individual resistances:

$$R_{\text{total}} = R_1 + R_2 = 4\,\Omega + 6\,\Omega = 10\,\Omega$$

Using Ohm's Law, the total current I is:

$$I = \frac{V_{\text{total}}}{R_{\text{total}}} = \frac{12\,V}{10\,\Omega} = 1.2\,A$$

Series and Parallel circuits

Now, use this current to calculate the voltage across each resistor:

- Voltage across R_1:

$$V_{R1} = I \times R_1 = 1.2\,A \times 4\,\Omega = 4.8\,V$$

- Voltage across R_2:

$$V_{R2} = I \times R_2 = 1.2\,A \times 6\,\Omega = 7.2\,V$$

Thus, the voltage across R_1 is 4.8V, and across R_2 is 7.2V.

KVL equation:

$$V_{\text{total}} = V_{R1} + V_{R2} \quad \Rightarrow \quad 12V = 4.8V + 7.2V$$

Problem 2: Parallel Circuit with Two Resistors

Given:

A circuit with a 24V battery and two resistors $R_1 = 6\,\Omega$ and $R_2 = 12\,\Omega$ connected in parallel.

Objective:

Find the total current using Kirchhoff's Voltage Law (KVL).

Solution:

The total resistance in a parallel circuit is given by:

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{6\,\Omega} + \frac{1}{12\,\Omega} = \frac{2}{12} + \frac{1}{12} = \frac{3}{12}$$

$$R_{\text{total}} = 4\,\Omega$$

Now, apply Ohm's Law to calculate the total current:

$$I = \frac{V_{\text{total}}}{R_{\text{total}}} = \frac{24\,V}{4\,\Omega} = 6\,A$$

Thus, the total current in the circuit is 6A.

KVL equation:

$$V_{\text{total}} = I \times R_{\text{total}} \quad \Rightarrow \quad 24V = 6A \times 4\Omega$$

Problem 3: Voltage Division in Series Circuit

Given:

A circuit with a 24V battery and two resistors in series: $R_1 = 3\,\Omega$ and $R_2 = 9\,\Omega$.

Objective:

Use Kirchhoff's Voltage Law (KVL) to find the voltage drop across each resistor.

Solution:

The total resistance in the series circuit is:

$$R_{\text{total}} = R_1 + R_2 = 3\,\Omega + 9\,\Omega = 12\,\Omega$$

Using Ohm's Law to calculate the total current:

$$I = \frac{V_{\text{total}}}{R_{\text{total}}} = \frac{24\,V}{12\,\Omega} = 2\,A$$

Now, calculate the voltage drop across each resistor:

- **Voltage across R_1:**

$$V_{R1} = I \times R_1 = 2\,A \times 3\,\Omega = 6\,V$$

- **Voltage across R_2:**

$$V_{R2} = I \times R_2 = 2\,A \times 9\,\Omega = 18\,V$$

Thus, the voltage across R_1 is 6V and across R_2 is 18V.

KVL equation:

$$V_{\text{total}} = V_{R1} + V_{R2} \quad \Rightarrow \quad 24V = 6V + 18V$$

Problem 4: Mixed Circuit (Series-Parallel)

Given:

A circuit with a 15V battery, a 10Ω resistor R_1, and a parallel combination of resistors $R_2 = 20\Omega$ and $R_3 = 30\Omega$.

Objective:

Find the current flowing through the resistors using Kirchhoff's Voltage Law.

Solution:

First, find the equivalent resistance of R_2 and R_3 in parallel:

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{20\Omega} + \frac{1}{30\Omega} = \frac{3}{60\Omega} = 20\Omega$$

Now, the total resistance in the circuit is the sum of R_1 and R_{parallel}:

$$R_{\text{total}} = R_1 + R_{\text{parallel}} = 10\Omega + 12\Omega = 22\Omega$$

Using Ohm's Law, calculate the total current:

$$I = \frac{V_{\text{total}}}{R_{\text{total}}} = \frac{15V}{22\Omega} = 0.68A$$

Applications of Kirchhoff's Circuit Law

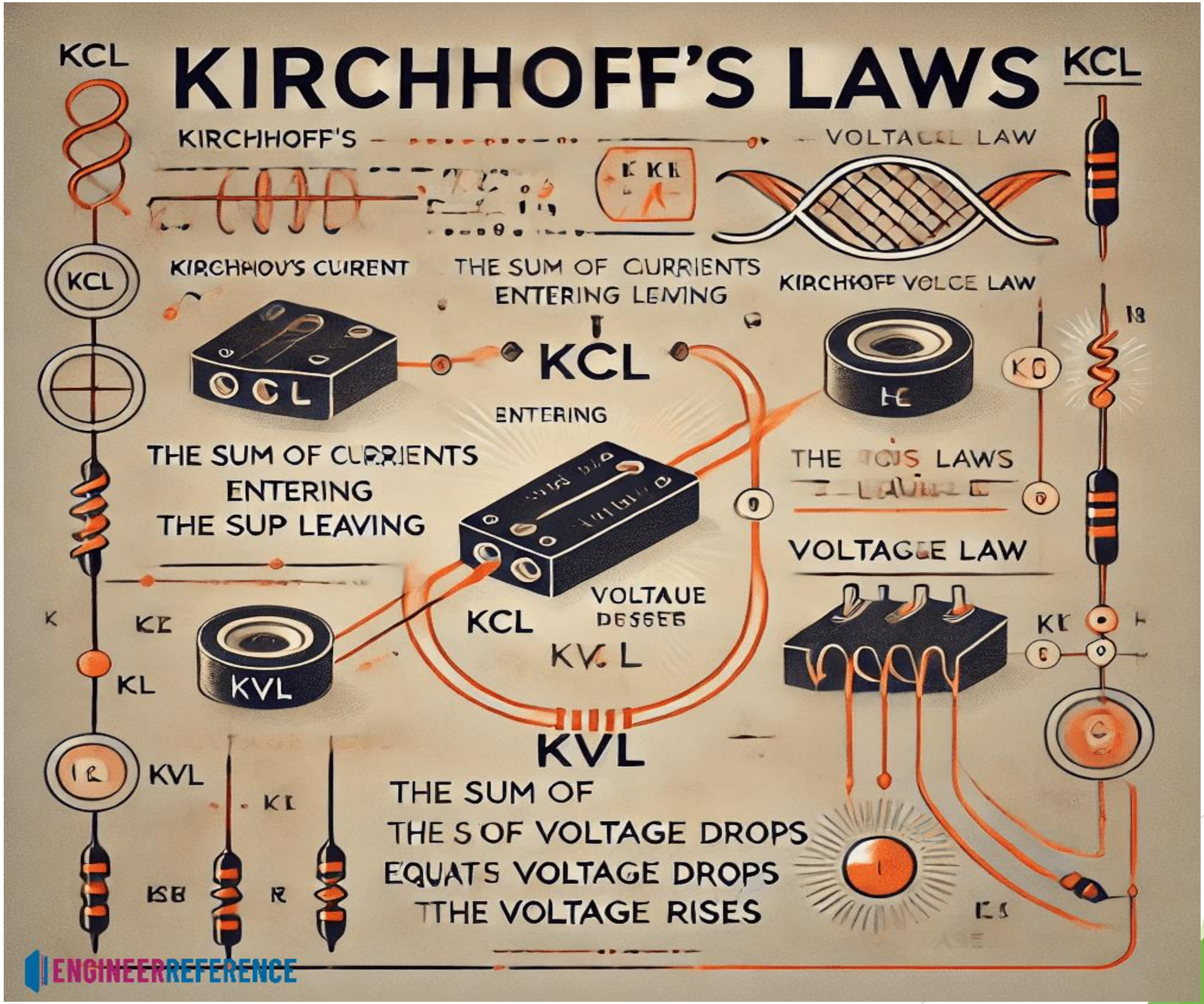
Kirchhoff's circuit laws are used to find:

1. The values of current, voltage and internal resistance in DC circuits.
2. By applying this law we can also find the unknown resistance in the circuit.
3. Wheatstone bridge is an important application of Kirchhoff's law. It is used in mesh and node analysis.

Limitations of Kirchhoff’s Circuit Laws

1.The laws of KCL and KVL are not suitable for AC circuits of high frequencies. Current law is applied only when the electric charge in a circuit is constant.

2.Where KVL is applied in an assumption that magnetic fields do not change in a closed circuit. So we cannot apply KVL when the magnetic field varies within a circuit.


KIRCHHOFF'S LAWS
KCL
KIRCHHOFF'S
VOLTAGE LAW
KIRCHHOV'S CURRENT
THE SUM OF CURRIENTS
ENTERING LEVING
KIRCHYOFF VOLCE LAW
KCL
ENTERING
THE SUM OF CURRIENTS
ENTERING
THE SUP LEAVING
VOLTAGE LAW
VOLTAUE
KCL
KVL
KVL
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THE SUM OF
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THE VOLTAGE RISES
ENGINEERREFERENCE

Advantages of Kirchhoff's laws

Calculate unknown values: Kirchhoff's laws can calculate unknown voltages and currents in a circuit.
Analyze complex circuits: Kirchhoff's laws make it easier to analyze and simplify complex circuits.
Troubleshoot circuits: Kirchhoff's laws help identify errors in circuits by analyzing current paths and voltage drops.
Design circuits: Kirchhoff's laws help engineers design more efficient circuits.
Simulate circuits: Kirchhoff's laws help engineers simulate how circuits behave under different conditions.
Understand electricity: Kirchhoff's laws help students understand the flow of electricity and circuit design.
Kirchhoff's laws are based on the assumption that there are no fluctuating magnetic fields in the circuit.

Solved Examples

1. What are the Basic Laws for Analysing Electrical Circuits?

Faraday’s Law
Newton’s Law
Einstein’s Law
Kirchhoff’s Law

Answer: Option D.

2. What is the Basic Principle on Which KCL is based?

At a node, no charge accumulation can take place.
At a node, charge accumulation is very much possible.
Charge accumulation may or may not be possible at any nodes.
A node can easily store energy.

Answer: Option A.

3. To Which of these is Kirchhoff’s Current Rule Applicable?

Electronic Devices
Circuit loops and meshes
Electrical Devices
Junction and nodes

Answer: Option D.

Examples Of Kirchhoff's Law

irchhoff's voltage law is specified with an example below:

Make a closed-loop circuit.

Draw the current flow direction in the circuit, which may or may not correspond to the actual current flow direction.

I3 becomes the sum of I1 and I2 at positions A and B. As a result, I3 = I1 + I2 can be written.

To simplify, the **algebraic** total of the voltages in a loop must be equal to zero, this property of Kirchhoff's law is called **energy conservation**.

The voltage drops at distinct branches of an electrical circuit are managed by this law.

Consider a specific point on the closed loop of an **electrical circuit**. If someone moves to another point in a comparable ring, they may discover that the potential at that second point is not quite as great as it was at the first.

The person may discover some remarkable potential in that new location if he or she continues to go off to some unusual place on the loop. If a person continues through that closed loop, he will eventually arrive at the starting point of the journey.

That is, in the aftermath of the intersection, he or she returns to a similar potential point through various voltage levels. The gain in electrical energy provided by the charge is then equivalent to the corresponding losses in energy caused by resistances.


Thank you