Unit I – Electricity and Ohms law

Definitions: Current – Potential – Potential Difference – Power –Energy
Electric Circuit – Types of Circuit – Direct Current (DC) and Alternating Current (AC) – Comparison of AC and DC – Fundamental Concepts of AC – Network Terminology – Ohm's law and its limitations – Kirchhoff's laws

Definitions

1. Current

Current is the rate of flow of electric charges is known as current

$$I = Q/t$$

Where, **I** ⟶ Current
Q ⟶ charge
t ⟶ time

Unit: Coulomb/Sec (or) Ampere

2 Potential

The electrical potential is defined as the capability of the charged body to do work.

$$electric\ potential = \frac{Work\ Done}{Charge}$$

$$V = \frac{W}{Q}$$

Unit: Joules/ Coulomb or Volt.

3. Potential difference

Potential difference is defined as the difference in the electric potential of the two charged bodies. Potential difference is also known as voltage.

The force required for the flow of electron is called voltage.

Unit: Volt.

4. Power

The rate at which work done is known as Power.

Power is also defined as the "rate of energy transfer per unit time".

Unit: Watt.

$$Power\ (P) = V \times I \quad Watt$$

Power (P) = (Work/Time)

Power (P) = (Energy/Time)

5. Energy

The energy is defined as the ability to do work.

Unit: Watt Sec or Joules.

Energy, (W)= (Work*Time)

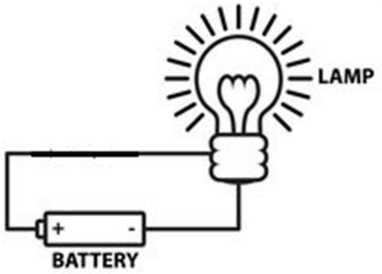
Electric Circuit

An Electric circuit is a closed loop conducting path in which current flows. The electric circuit consists of three parts. Battery, Load, Connecting wire

Example:

Consider the simple circuit shown in fig

Circuit diagram:



Description:

A Battery is connected to a lamp with wires. There is a closed path exists from positive terminal to negative terminal of the battery through the lamp. The purpose of the circuit is to transfer energy from the source to load.

Types of Circuit

i)Open circuit ii) Closed circuit iii) Short circuit

1. Open circuit

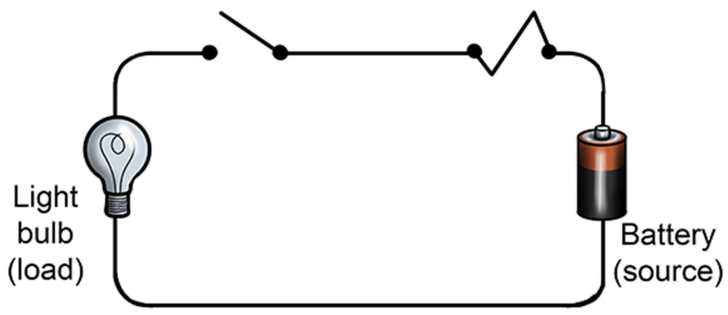
Introduction:

When the electric circuit path breaks or opens, current through the path interrupts. Thus, an incomplete electric circuit path causes an open circuit.

Example:

A Bulb is connected to the DC supply source. The circuit has a series of connections of Bulb, on/off switch, and current limiting resistor(R).

Circuit Diagram:



Description:

The electric current does not flow from the supply to Bulb when the switch is open. Hence, Bulb remains off in this condition.

2. Closed Circuit

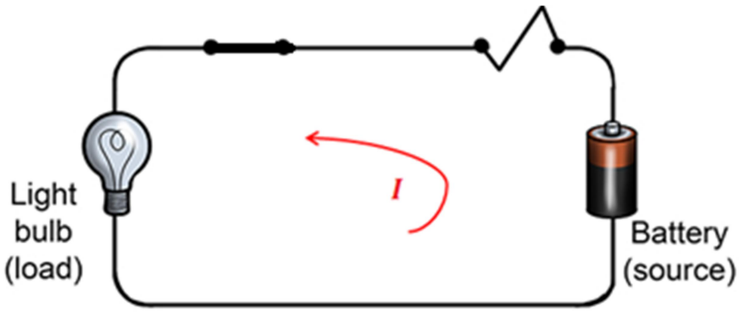
Introduction:

The closed path makes the circuit complete and forms closed loop which leads to the current flow in the closed circuit.

Example:

A Bulb is connected to the DC supply source. The circuit has a series of connections of Bulb, on/off switch, and current limiting resistor(R).

Circuit Diagram:



Description:

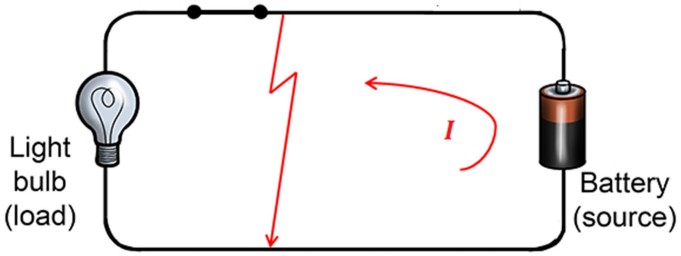
The electric current flows from the supply to Bulb when the switch is closed. Hence, Bulb goes to ON

3. Short Circuit

Introduction:

Short circuit occurs when the two terminals i.e., positive and negative get connected to each other and maximum current starts to flow in such a situation. A Short circuit can damage the circuit or cause a fire

Circuit Diagram:



Description:

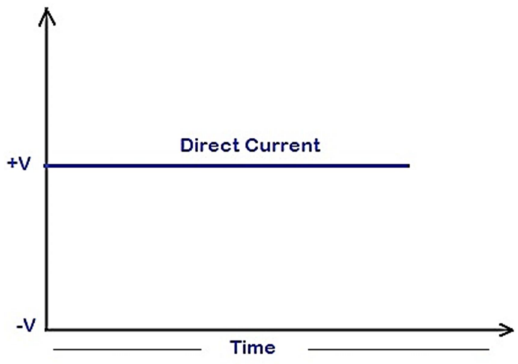
The electric current does not flow from the supply to Bulb because its path is shortened and its value is increased than rated is called as Short circuit.

DC and AC

DC

DC refers to Direct Current. It is a unidirectional flow of current. It does not change the magnitude and polarity with time. The frequency of the DC current is zero. DC is used in electronic gadgets and small devices like clocks, laptops, cell phones, and Sensors.

Waveform:



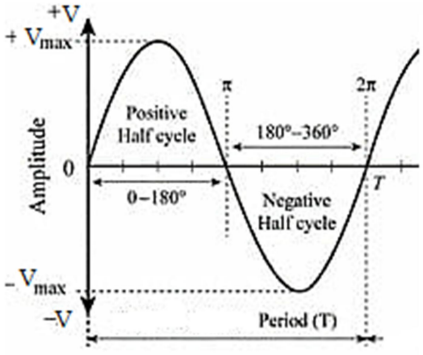
Description:

The graph is drawn between the magnitude of DC and time. The DC current graph has a constant line showing magnitude and direction is constant

AC

AC refers to Alternating Current. AC current changes its polarity and magnitude periodically and continuously with respect to time. AC is widely used in industrial equipment and consumer electronics like AC, Freezer, Cooler, washing machines, lights, and fans

Waveform:



Description:

The alternating current (AC) current changes its direction during flow. AC current can be a sinusoidal wave, square wave, or triangular wave.

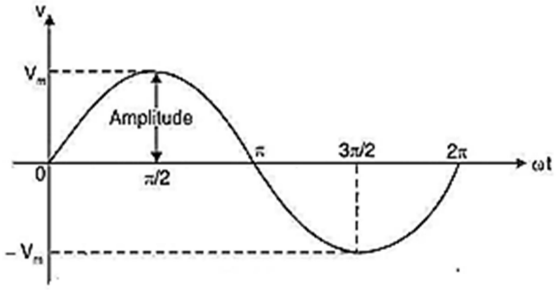
Comparison of AC and DC

S.No	Alternating Current	Direct Current
1	AC flows in a **bidirectional** way.	DC flows in a **unidirectional** way.
2	It works on the AC voltage **110V, 240V, 11kV, 33kV, etc.**	It works on DC source voltage **5V, 12V, 24V**, etc.
03	AC can be converted into DC using Rectifiers	DC can be converted into AC using Inverters.
04	AC has a **variable** frequency.	DC has **zero** frequency.
05	The magnitude of AC is always **varying with time.**	The magnitude of DC is always **constant.**
06	AC load can be Capacitive, Inductive or Resistive	DC load is always Resistive
07	The efficiency of AC voltage is **high**	It provides **less** efficiency.
08	Power factor of AC varies between **0 to 1**	Power factor of DC always remains **1**.
09	AC is produced by the **generators or alternators**	DC is produced by the **cell, battery, and solar cells.**
10	The AC circuit does not obey ohm's law.	DC circuit obeys ohm's law.
11	AC **can be easily transferred** to the long-distance by using transformer.	DC **can't be easily transferred** to the long-distance.
12	It **can be easily** regulated and maintained.	It **can't be easily** regulated and maintained.

Fundamental Concepts of AC

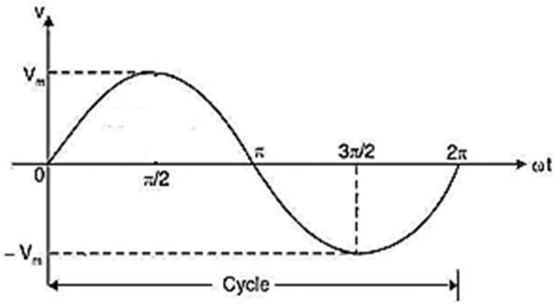
1. Amplitude

Amplitude is the maximum value of current or voltage. The magnitude of the signal is called amplitude.



2. Cycle

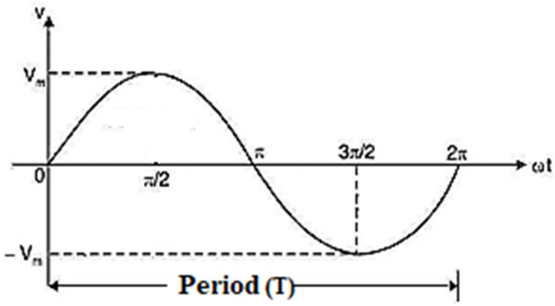
One complete set of positive and negative values of an alternating quantity is known as a cycle.



3. Time Period (T)

The time taken by an alternating quantity to complete one cycle is known as the time period.

Unit: Second.



4. Frequency (F)

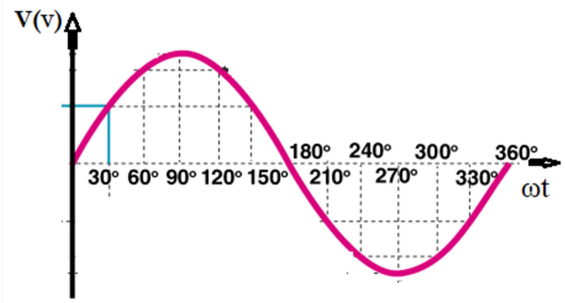
The number of cycles per second is known as the frequency.

Frequency F = 1/T

Unit: Hertz.

5. Phase

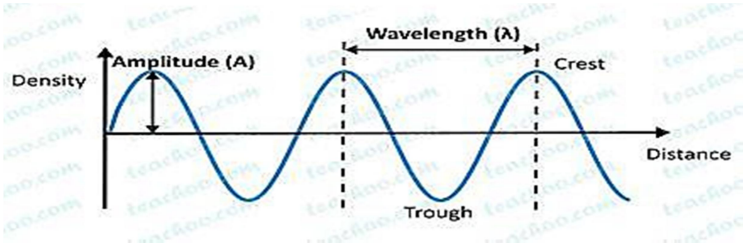
The phase is defined as the position of the waveform at a fraction of time period. Phase is expressed in angle or radian.



6. Wavelength

Wavelength means the length of one wave.

The distance between two consecutive positive peaks is called the wavelength.

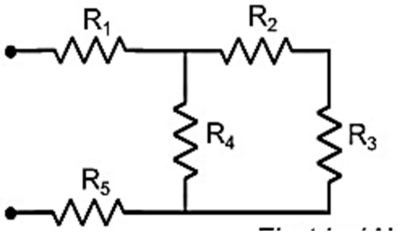


Unit: Meter.

Network Terminology

1. Network

A network is an interconnection of devices or elements. It contains closed path as well as open path.

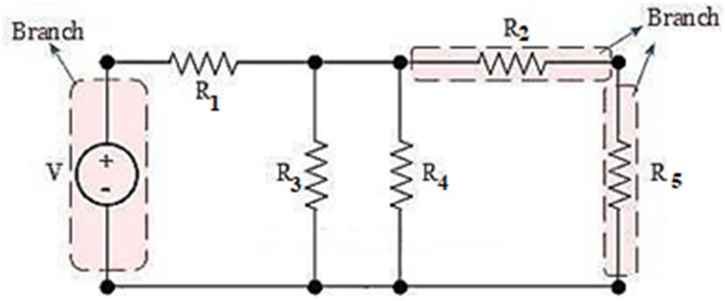


2. Path

Path is a single line of connecting elements or sources

3. Branch

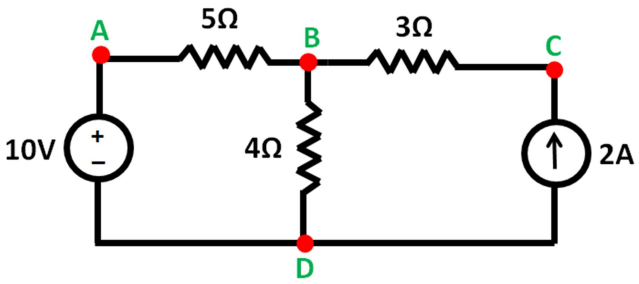
A branch is a circuit element like resistor, capacitor, inductor, voltage, or current source. A branch is a path between two nodes.



Circuit contains the 6 branches. The branches are Voltage source, R_1, R_2, R_3, R_5 and R_6.

4. Node

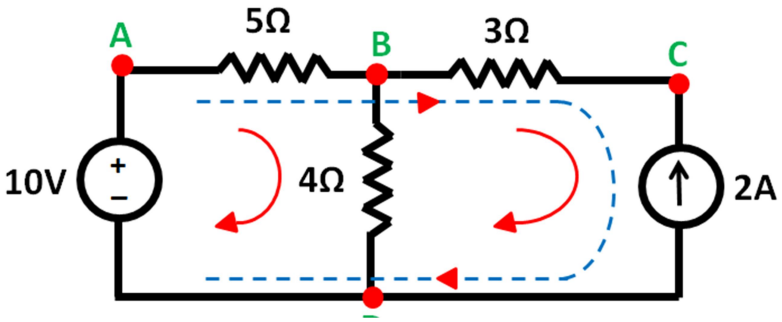
A node is the point where two or more branches are connected together. A node is indicated by a dot.



Circuit contains the four nodes. The nodes are A, B, C, and D.

5. Loop

A loop is any closed path in a circuit.



First loop → A-B-D-A, Second loop → B-C-D-B and Third loop → A-B-C-D-A.

Ohm's law and its limitations

German Scientist Georg Ohm developed Ohm's law to define the relationship between Current, Voltage and Resistance in an electrical circuit.

Statement

Ohm's law states that the "At a constant temperature, current 'I' flows through a conductor is directly proportional to the voltage 'V' applied across it.

Formula:

Mathematically:

$$V \propto I$$

(or)

$$V = I \times R$$

Where,

R is the Constant proportionality known as Resistance (Ω)

V is the Voltage applied (V)

I is the current flowing through the circuit (A)

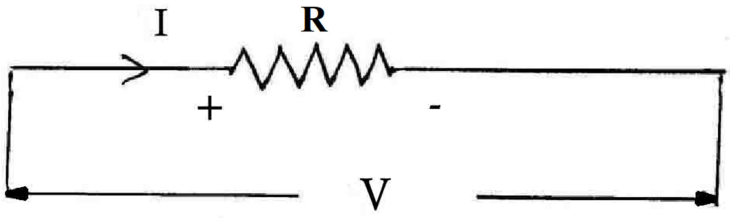
According to Ohm's Law, the current flowing through the conductor is,

$$I = V / R$$

Similarly, resistance can be defined as,

$$R = V / I$$

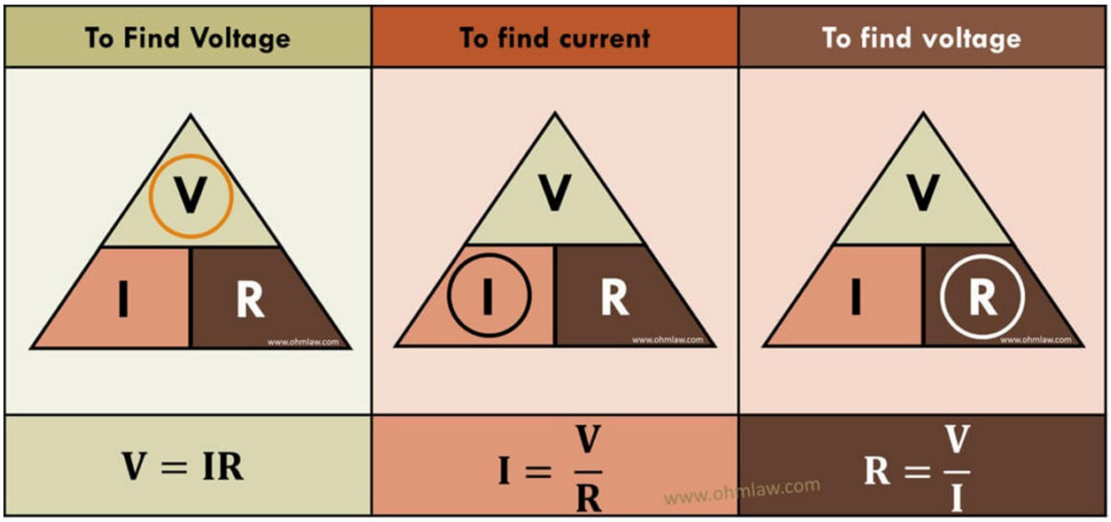
Circuit Diagram:



Description

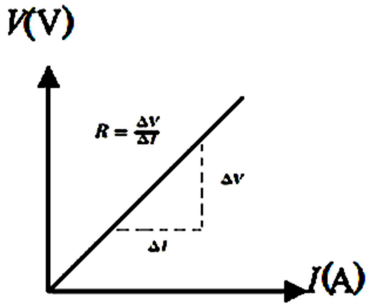
The voltage across a resistor is directly proportional to the current flowing through it.

Ohm's Law Triangle



Model Graph

The graph is drawn between the voltage and current.



Description

The graph is also known as Volt amp characteristics.

Current (I) increases with increase in Voltage (V).

The Slope determines the resistance value

$R = \Delta V/\Delta I$ (Ω)

Limitations:

- It is not applicable for the non-metallic conductors.
- If the temperature changes, the law is not valid
- It does not apply to the nonlinear devices like thyristor
- It does not apply to the unilateral elements like diode, transistor

Kirchhoff's laws

A German scientist Gustav Kirchhoff developed two laws enabling easy analysis of interconnection of any number of circuit elements. The laws describe the conservation of voltage and current in an electrical circuit.

- Kirchhoff's Current Law (KCL)
- Kirchhoff's Voltage Law (KVL)

Kirchhoff's Current Law (KCL)

Kirchhoff's Current Law (KCL) is also known as Kirchhoff's junction law.

Statement

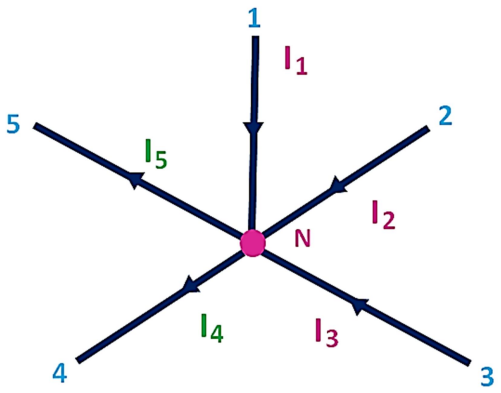
Kirchhoff's current law (KCL) states that, "In a node, the sum of incoming current must be equal to the sum of the outgoing current".

$$(i.e)\ \sum I_{IN} = \sum I_{OUT}$$

In other words, It states that "the algebraic sum of the currents at a junction is zero".

$$(i.e)\ \Sigma I = 0$$

Circuit Diagram:



Analysis:

The network has node N and 5 branches. The current in five branches is $I_1, I_2, I_3, I_4,$ and I_5. I_1, I_2, and I_3 are incoming current at the node N, while current I_4 and I_5 are outgoing current.

According the KCL, the sum of incoming current is equal to the sum of outgoing current.

$$\therefore I_1 + I_2 + I_3 = I_4 + I_5 \text{ — —-(1)}$$

According the Kirchhoff's Current Law, $\Sigma I = 0$

$$\therefore I_1 + I_2 + I_3 - I_4 - I_5 = 0 \text{ — —-(2)}$$

Kirchhoff's Voltage Law (KVL)

Kirchhoff's Voltage Law (KVL) is also known as Kirchhoff's Loop law.

Statement

Kirchhoff's Voltage law (KVL) states that, "the algebraic sum of voltages around a closed path is zero".

(i.e) Around a closed path **Σ V = 0**

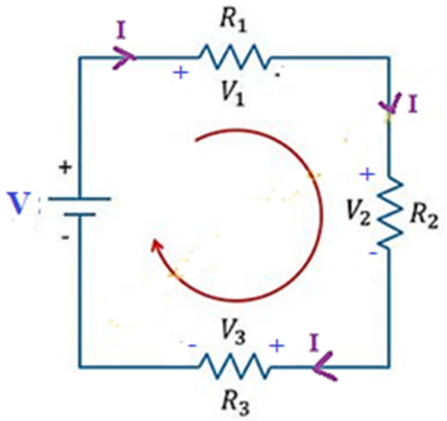
In other words, it states that "In a closed loop, the sum of voltage rise is equal to the sum of voltage drop".

Mathematically:

Σ Voltage rise = Σ Voltage drop

Circuit Diagram:

Consider a series circuit with three resistors:



Analysis:

Let V - Supply voltage.

R_1, R_2 & R_3 - Resistors in the circuit.

I - Current flow through the circuit

The voltage drop across R_1, R_2 & R_3 as V_1, V_2 & V_3.

$V_1 = IR_1$; $V_2 = IR_2$; $V_3 = IR_3$

According the Kirchhoff's Voltage Law, around a closed path **Σ V = 0**

$$V - V_1 - V_2 - V_3 = 0$$

$$V = V_1 + V_2 + V_3 \text{---------- (1)}$$

Substitute, V_1, V_2 & V_3 in equation (1)

$$V = I R_1 + I R_2 + I R_3$$

It shows that, the sum of voltage rise is equal to the sum of voltage drop