ELECTRICAL CIRCUITS

Electric Current &
Ohm's Law

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Modern Theory of Electricity

- The modern theory of electricity is termed the "Electronic Theory."
- Matter: The three forms of matter known to us are under the following category:
- Solids - such as steel, iron, wood, wax, porcelain, paper, etc.
- Liquids - such as water, mercury, oils, etc.
- Gases - such as hydrogen, oxygen, air, coal gas, etc.
- ❑ **The Molecule :** A molecule is the smallest portion of any substance which cannot be subdivided further without its properties being destroyed. It is the smallest complete and normal unit of any substance.
- ❑ **The Atom :** The molecules are made up of smaller particles called atoms. An atom is the smallest unit particle into which matter can be divided by chemical separation.
- A molecule may consist of one, two, or more atoms of the same kind, or it may consist of two or more atoms of different kinds.
- Thus two atoms of hydrogen (H) will combine to form a molecule of hydrogen (H_2). Two atoms of hydrogen and one atom of oxygen will combine to form one molecule of water (H_2O). The number of atoms in a molecule varies with the substance. In a molecule of salt there are two atoms, in a molecule of alum there are about one hundred atoms, etc.

Modern Theory of Electricity

- **The Proton:** The nucleus may he thought of as a charge of positive electricity or "proton" concentrated at a point. at the center of the atom, around which the electrons-restrained in their orbits by it - revolve.
- **The Electron:**It is believed that atoms are made up of minute particles of negative electricity - termed "electrons" - and of a central nucleus in which practically the whole mass of the atom resides. The number of electrons in the universe is constant and unvarying. Electricity can neither be created or destroyed.Electrons can be set in motion and caused to be moved from one location to another. thus producing what are known as electrical phenomena.
- **The "E. M. F.":**But electricity or electrons - can be neither made nor eradicated. It is therefore evident that electricity can be neither "produced" nor "generated" in spite of the fact that the term "generation of electricity" is frequently used. When a statement is made that "electricity is generated by a battery or dynamo" what is really meant is that the battery or dynamo is forcing some of this electricity, which is already in existence, to move. It exerts an "electro-motive" force (abbreviated e.m.f) measured in volts. A battery or dynamo does not generate electricity in the wires connected to it any more than a pump, which is impelling a stream of water in a pipe, generates the water.

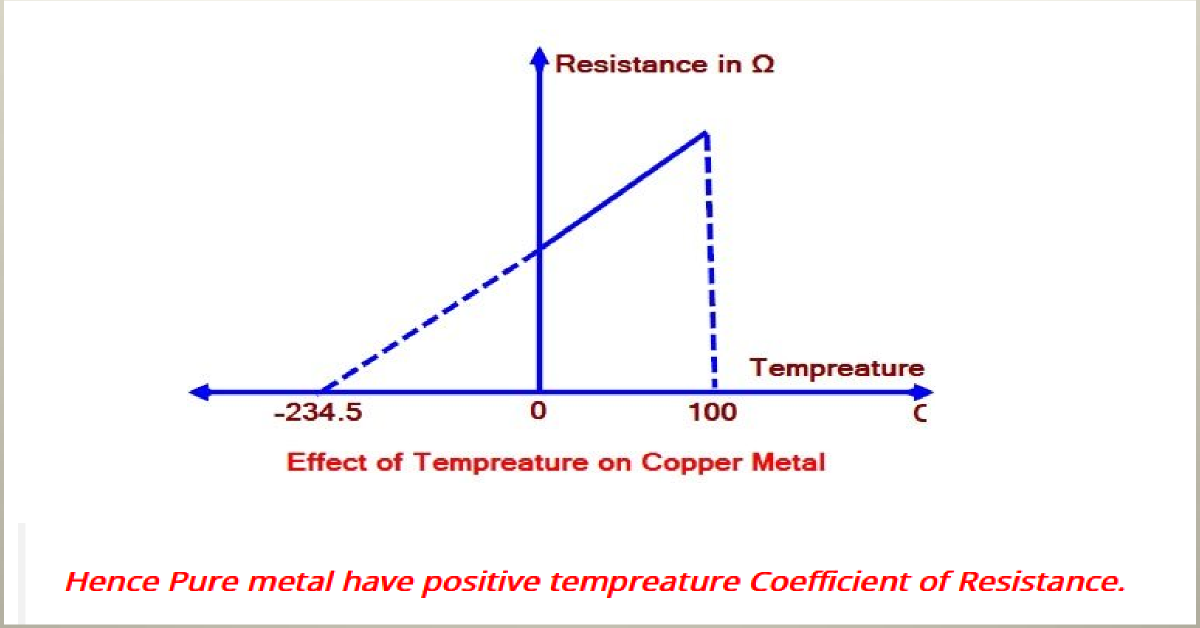
Effect of Temparature of Resistance

- The electrical resistance changes with the change of temperature. The resistance does not only increase with the rise in temperature but it also decreases in some cases. In fact, for the different type of materials, the amount of change in resistance due to change in temperature is different which are discussed as follow:

- **Metal**: The resistance of all pure metals increases linearly with increase in temperature over a limited temperature range. At low temperature, the ions are almost stationary. As the temperature increases, the ions inside the metal acquire energy and start oscillating about their mean positions. These vibrating ions collide with the electrons Hence resistance increases with increase in temperatures.

- For e.g. the resistance of copper is 100Ω at 0°c then it increases linearly upto 100°c. At a temperature of -234.5°c the resistance of copper is almost zero as shown in the figure.

Effect of Temparature of Resistance

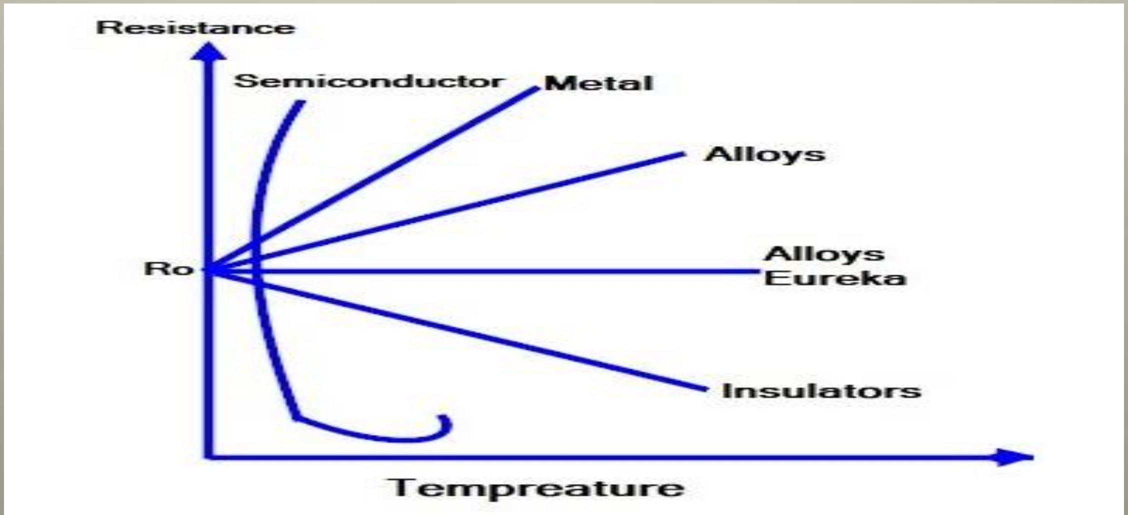


- **Alloy:** The resistance of almost all alloys increases with increase in temperature but the rate of change of resistance is less than that of metals. In fact, the resistance of certain alloys such as Manganin, Eureka, and Constantan show practically no change in resistance fo a considerable range of temperature. Due to this property, the alloy is used to manufacture the resistance box.

Effect of Temparature of Resistance

- **Semiconductor,Insulator, and Electrolyte:** The resistance of semiconductor, Insulator, and Electrolyte(silicon, Glass, Varnish etc) decrease with increase in temperature.At zero temperature, the semiconductor behaves as a perfect insulator. As the temperature increases, some of the electrons acquire energy and become free for conduction. Hence, conductivity increase and resistance decrease with increase in temperature.

- Semiconductor has negative tempreature cofficent of resistivity therefore since with the increase in the tempreature the resistance decreases.



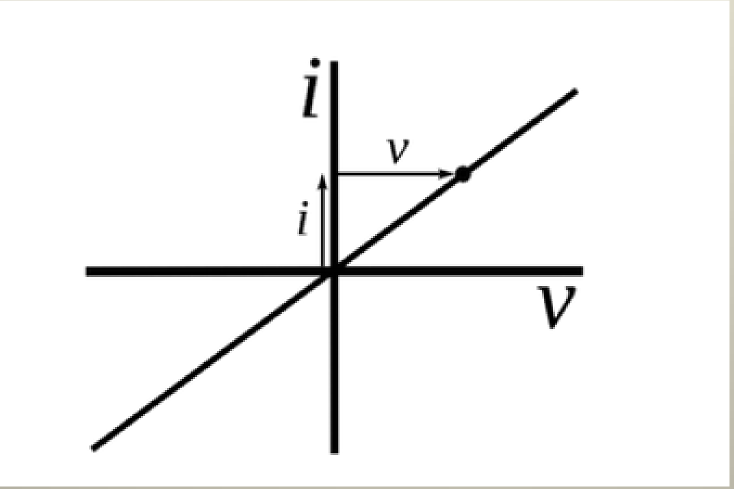
Effect of Tempreature on Resistance

EMF And Potential Difference

Basis For Comparison	Electromotive Force	Potential Difference
Definition	It is the amount of energy supply to one coulomb of charge.	The amount of energy used by one coulomb of charge in moving from one point to another.
Unit	Volt	Volt
Symbol	ε	V
Source	Dynamo or Battery	Battery
Resistance	Independent from the resistance of the circuit	Proportional to the resistance of the circuit.
Current	It transmits current throughout the circuit.	It transmits current between any two points.
Magnitude	Greater than the potential difference between any two points	Always less than the maximum value of emf when the battery is fully charged.
Variation	It remains constant	Does not remain constant.
Relation	Cause	Effect
No current	Not Zero	Zero
Voltage	It is the maximum voltage that the battery can transfer	It is less than the maximum voltage that cell can deliver.

Ohm's Law

❖ **Ohm's law:** Ohm's law states that the current through a conductor between two points is directly proportional to the voltage across the two points.



Ohm's Law Formula

Voltage= Current× Resistance

V= I×R

V= voltage, I= current and R= resistance

The SI unit of resistance is **ohms** and is denoted by **Ω**

Electrical Energy and Power

- Electrical energy is defined as the overall work done in an electrical circuit. We all know that energy specifies the amount of work done to move an object. And we know in an electrical circuit, electric charges show movement. Thus the work done on the electric charges in order to cause movement is known as electrical energy.
- Electrical Power is defined as the rate at which work is done on an electrical system.

Comparison Chart

Basis for Comparison	Electrical Energy	Electrical Power
Basic	It represents the overall work done on an electrical circuit.	Power defines the work done per unit time in an electrical circuit.
Denoted as	E	P
Given as	E = VI*t (or P*t)	P = V*I
SI unit	Joule	Watt

Heating Effects of the Electric Current

Heating effects of the electric current:

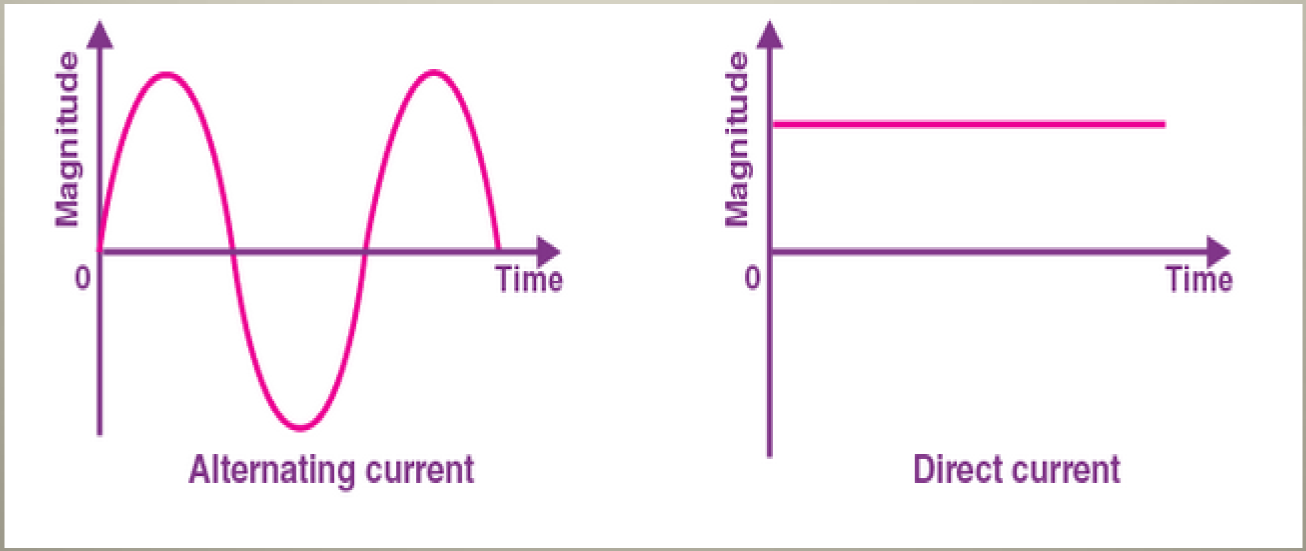
When a current flows through a conductor, heat energy generates in the conductor. The heating effects of electric current depend on three factors:

- The resistance of the conductor. A higher resistance produces more heat.
- The time for which the current flows. The longer the time the amount of heat production is high.
- Higher the current the amount of heat generation is also large.

Hence the heating effect produced by an electric current, I through a conductor of resistance, R for a time, t is given by $\mathbf{H = I^2Rt}$. This equation is the **Joule's equation** of electrical heating.

Concepts of Alternating Current

An alternating current can be defined as a current that changes its magnitude and polarity at regular intervals of time. It can also be defined as an electrical current that repeatedly changes or reverses its direction opposite to that of Direct Current or DC which always flows in a single direction as shown below.



Concepts of Alternating Current

From the graph, we can see that the charged particles in AC tend to start moving from zero. It increases to a maximum and then decreases back to zero completing one positive cycle. The particles then reverse their direction and reach the maximum in the opposite direction after which AC again returns to the original value completing a negative cycle. The same cycle is repeated again and again.

Alternating currents are also accompanied usually by alternating voltages. Besides, alternating current is also easily transformed from a higher voltage level to a lower voltage level.

AC waveform

Important terms in AC waveform:

- **Amplitude:**

In the waveform, the maximum value attained by an alternating quantity(voltage or current) either during the positive half cycle or negative half cycle is known as amplitude. It is generally represented as E_m or V_m for voltage and I_m for current.

- **Cycle:**

A complete set of positive and negative half-cycles constitutes a complete cycle. One cycle corresponds to 360^0 or 2π radians.

- **Time period:**

The time taken by an alternating quantity to complete one complete cycle is known as the time period. It is denoted by T seconds. Hence, each cycle repeats for every T seconds.

- **Frequency**

The number of cycles per second of an alternating quantity is called frequency*(f)* and its unit is expressed in *cycles/second or Hertz(Hz)*. Frequency is equal to the reciprocal of time period and is given by,

$$f = \frac{1}{T}$$

AC waveform

❖ **Angular Velocity:**

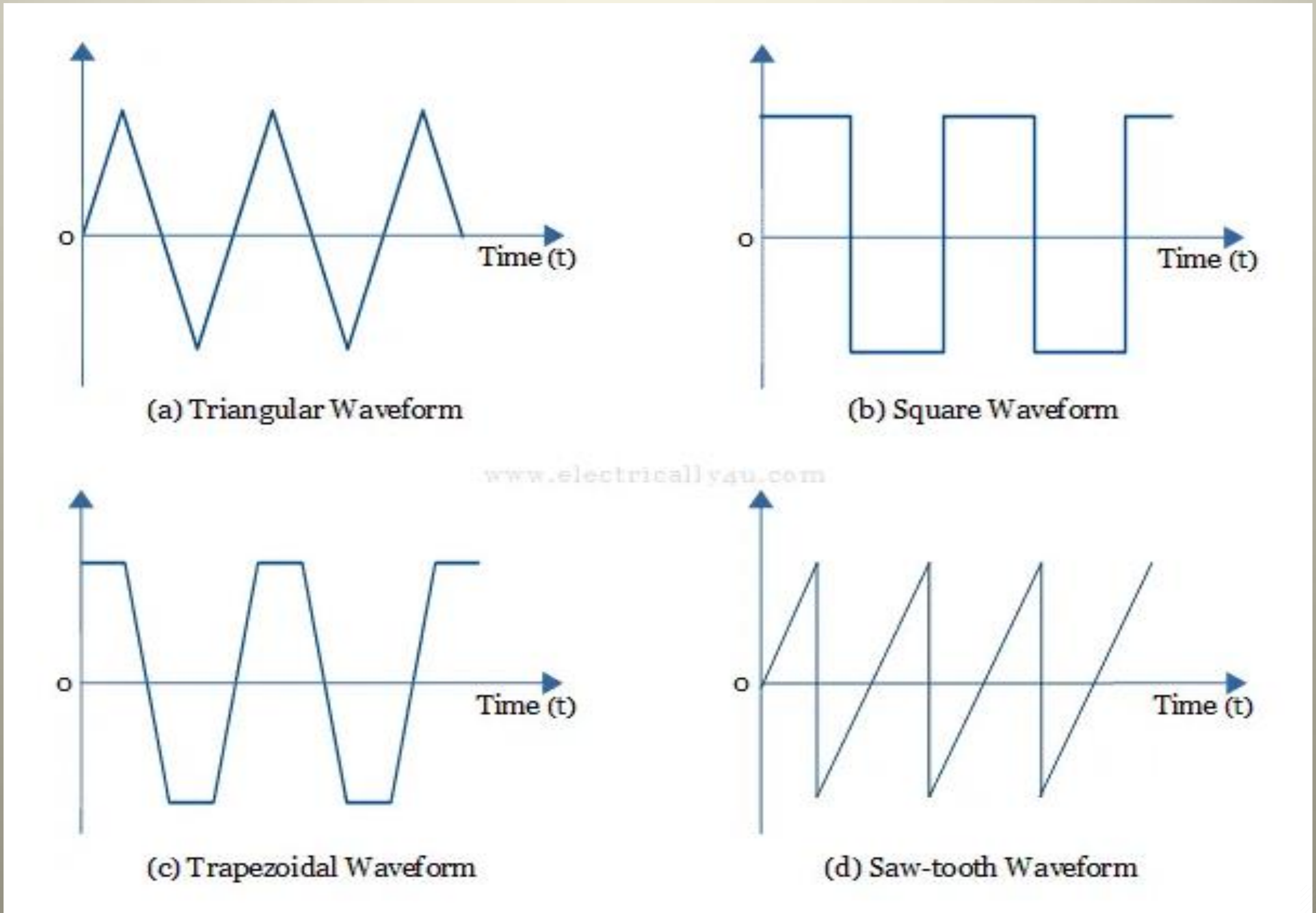
Each cycle spans 2π radians. If this quantity is divided by the time period, we get the angular velocity of the sine wave. It is denoted by ω and is expressed in radians per second.

$$\text{Angular Velocity}, \omega = \frac{\text{Angle turned}}{\text{Time taken}} = \frac{2\pi}{T} = \frac{2\pi}{1/f} = 2\pi f \quad \text{radians/second}$$

➢ Types of AC waveform

A quantity that varies with time in its magnitude and direction is termed as an alternating quantity. Such quantity is drawn by means of waveforms, called AC waveforms.
There are different types of AC waveforms in practice such as sine waveform, square form, triangular waveform and trapezoidal waveform. These waveforms are shown below.

AC waveform


o
Time (t)
(a) Triangular Waveform
o
Time (t)
(b) Square Waveform
www.electrically4u.com
o
Time (t)
(c) Trapezoidal Waveform
o
Time (t)
(d) Saw-tooth Waveform

AC waveform

Of all the AC waveforms, the sinusoidal waveform is preferred over the other types of waveform. It is because of its added advantages.

- Sinusoidal waves have less amount of distortion when transmitting over the linear circuit.
- The sinusoidal waveforms retain their shape even after differentiation and integration.
- The mathematical calculation of sinusoidal function is easy comparing it to other waveforms.