Government of Tamilnadu

Department of Employment and Training

Course : TNPSC Group II Exam

Subject : Physics

Topic : **Electricity**

ELECTRICITY

Electricity

- A continuous and closed path of an electric current is called an electric circuit.
- Electric current is expressed by the amount of charge flowing through a particular area of cross section of a conductor in unit time.
- The direction of electric current is taken as opposite to the direction of the flow of electrons.

$$\boxed{I = Q/t}$$

- The S.I unit of electric charge is **coulomb.**
- This is equivalent to the charge contained in nearly 6×10^{18} electrons.

Example – 1:

A current of 0.75 A is drawn by a filament of an electric bulb for 10 minutes. Find the amount of electric charge that flows through the circuit.

Solution:

Given, I = 0.75 A,

t = 10 minutes = 600 s

We know, $Q = I \times t$

$= 0.75\ A \times 600\ s$

$\mathbf{Q = 450\ C}$

ELECTRIC POTENTIAL AND POTENTIAL DIFFERENCE:

- We define the electric potential difference between two points in an electric circuit carrying current as the work done to move a unit charge from one point to the other.

$$\boxed{V = W/Q}$$

- The S.I Unit of potential difference is volt (V)
- 1 volt = 1joule/1coulomb
- One volt is the potential difference between two points in a cur- rent carrying conductor when 1 joule of work is done to move a charge of 1 coulomb from one point to the other.

Example – 2:

How much work is done in moving a charge of 5 C across two points having a potential difference 10 V?

Solution:

Given charge, Q = 5 C

Potential difference, V = 10 V

The amount of work done in moving the charge, $W = V \times Q$

$$W = 10\ V \times 5C$$
$$W = \mathbf{50\ J}$$

- Nichrome is an alloy of Nickel, Chromium, Manganese and Iron metals
- Ohm's law states that at constant temperature the steady current (I) flowing through a conductor is directly proportional to the potential difference (V) between its ends.

$$\mathbf{V \propto I\ (or)\ V/I = constant}$$

- Resistor S.I unit is ohm, represented by the Greek letter Ω.
- If the potential difference across the two ends of a conductor is 1 volt and the current through it is 1 ampere, then the resistance of the conductor is 1 ohm.

Example – 3:

The potential difference between the terminals of an electric heater is 60 V when it draws a current of 5 A from the source. What current will the heater draw if the potential difference is increased to 120 V?

Solution:

Given the potential difference,

V = 60 V

Current, I = 5 A

According to ohm's law,

$R = V/I = 60\ V / 5\ A = 12\ \Omega$

When the potential difference is increased to 120 V,

the current is given by

$I = V/R = 120\ V / 12\ \Omega = 10\ A$

SYSTEM OF RESISTORS:

Resistors in series:

- The total potential difference across the combination of resistors in series is equal to the sum of potential difference across individual resistors. That is,

$$\mathbf{V = V_1+V_2+V_3}$$
$$\mathbf{R_s = R_1+R_2+R_3}$$

- The resistance of the combination R_s is equal to the sum of their individual resistances R_1, R_2, R_3 and is thus greater than any individual resistance.

Example – 4:

Two resistances 18 Ω and 6 Ω are connected to a 6 V battery in series. Calculate (a) the total resistance of the circuit, (b) the current through the circuit.

Solution:

(a) Given the resistance,

R1 = 18 Ω R2 = 6 Ω

The total resistance of the circuit

RS = R1 + R2 RS = 18 Ω + 6 Ω **= 24** Ω

(b) The potential difference across the two terminals of the battery

V = 6 V

Now the current through the circuit,

I = V/ RS = 6 V / 24 Ω **= 0.25 A**

Resistors in parallel:

- In parallel combination the potential difference across each resistor is the same having a value V. The total current I is equal to the sum of the separate currents through each branch of the combination.

$$I = I_1 + I_2 + I_3$$

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

- Thus the reciprocal of the equivalent resistance of a group of resistance joined in parallel is equal to the sum of the reciprocals of the individual resistance.

Example – 5:

Three resistances having the values 5 Ω, 10 Ω, 30 Ω are connected parallel with each other. Calculate the total circuit resistance.

Solution: Given, R1 = 5 Ω

R2 = 10 Ω

R3 = 30 Ω

These resistances are connected parallel therefore,

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_P} = \frac{1}{5} + \frac{1}{10} + \frac{1}{30} = \frac{10}{30}$$

$$R_P = \frac{30}{10} = 3\Omega$$

JOULES LAW OF HEATING:

- Consider a current I flowing through a resistor of resistance R. Let the potential difference across it be V.

$P = V\,(Q/t) = V\mathbf{I}$

$\mathbf{H = V\,It}$

- Applying Ohm's law we get $\mathbf{H=I^2 Rt}$. This is known as Joule's law of heating.
- The law implies that heat produced in a resistor is (1) directly proportional to the square of current for a given resistance, (2) directly proportional to the resistance for a given current, and (3) directly proportional to the time for which the current flows through the resistor.

<u>Some applications of Joule heating:</u>

(i) Electric heating device:

Electric iron, electric heater, electric toaster are some of the appliances that work on the principle of heating effect of current. In these appliances, Nichrome which is an alloy of nickel and chromium is used as the heating element for the following reasons.

(1) It has high specific resistance

(2) It has high melting point

(3) It is not easily oxidized

(ii) Fuse wire:

Fuse wire is an alloy of lead 37% and tin 63%. It is connected in series in an electric circuit. It has high resistance and low melting point.

(iii) Electric bulb:

Electric arc and electric welding also work on the principle of heating effect of current.

<u>Example – 6:</u> A potential difference 20 V is applied across a 4 Ω resistor. Find the rate of production of heat.

Solution:

Given potential difference,

$V = 20\text{ V}$

The resistance,

$R = 4\ \Omega$

The time,

$t = 1\text{ s}$

According to ohm's law,

$I = V / R \qquad I = 20\text{ V} / 4\ \Omega = 5\text{ A}$

The rate of production of heat,

$H = I^2 Rt \qquad H = 5^2 \times 4 \times 1$

$H = 100\text{J}$

Transformers are used to step up or step down AC voltage

ROLE OF FUSE:

A common application of Joule's heating is the fuse used in electric circuits.

DOMESTIC ELECTRIC CIRCUITS:

- One of the wires in the supply, usually with red insulation cover, is called live wire (or positive). Another wire, with black insulation, is called neutral wire (or negative). In our country, the potential differences between the two are 220 V.

- The earth wire which has insulation of green colour is usually connected to a metal plate deep in the earth near the house.

ELECTRIC POWER:

We know already that the rate of doing work is power. This is also the rate of consumption of energy. This is also termed as electric power.

The power P is given by $\boxed{P = VI} = PI^2 \quad R = V^2/R$

- The SI unit of electric power is watt (W). It is the power consumed by a device that carries 1 A of current when operated at a potential difference of 1V.
- Thus, 1 W = 1 volt × 1 ampere = 1 VA
- The unit of electric energy is, therefore, watt hour (Wh). One watt hour is the energy consumed when one watt of power is used for one hour. The commercial unit of electric energy is kilowatt hour (KWh), commonly known as unit.
- 1 kWh = 1000watt × 3600second

  $= 3.6\times 10^6$ watt second

  $= 3.6 \times 10^6$ joule (J)

Drift velocity and mobility:

- Drift velocity is defined as the velocity with which free electrons get drifted towards the positive terminal, when an electric field is applied. If τ is the average time between two successive collisions and the acceleration experienced by the electron be a, then the drift velocity is given by,

$$\mathbf{v_d = a\tau}$$

$\boldsymbol{\mu = \frac{e\tau}{m}}$ is the mobility and is defined as the drift velocity acquired per unit electric field.

- Its unit is $m^2V^{-1}s^{-1}$

- The drift velocity of electrons is proportional to the electric field intensity.
- It is very small and is of the order of 0.1 cm s^{-1}

Current density:

- Current density at a point is defined as the quantity of charge passing per unit time through unit area, taken perpendicular to the direction of flow of charge at that point.
- The current density **J** for a current I flowing across a conductor having an area of cross section A is

$$\boxed{\mathbf{J} = \frac{(\mathbf{q}/\mathbf{t})}{\mathbf{A}} = \frac{\mathbf{I}}{\mathbf{A}}}$$

- Current density is a vector quantity. It is expressed in A m^{-2}

Classification of materials in terms of resistivity:

- The resistivity of a material is the characteristic of that particular material. The materials can be broadly classified into conductors and insulators.
- The metals and alloys which have low resistivity of the order of $10^{-6} - 10^{-8} \Omega$ m are good conductors of electricity.
- They carry current without appreciable loss of energy.
- Example: silver, aluminium, copper, iron, tungsten, nichrome, manganin, constantan.
- The resistivity of metals increase with increase in temperature.
- Insulators are substances which have very high resistivity of the order of $10^{8} - 10^{14} \Omega$ m.
- They offer very high resistance to the flow of current and are termed non–conductors.
- Example: glass, mica, amber, quartz, wood, teflon, bakelite.
- In between these two classes of materials lie the semiconductors. They are partially conducting. The resistivity of semiconductor is $10^{-2} - 10^{4} \Omega$ m.
- Example: germanium, silicon.

Superconductivity:

- The ability of certain metals, their compounds and alloys to conduct electricity with zero resistance at very low temperatures is called superconductivity. The materials which exhibit this property are called superconductors.

- The materials which exhibit this property are called superconductors.
- The phenomenon of superconductivity was first observed by Kammerlingh Onnes in 1911. He found that mercury suddenly showed zero resistance at 4.2 K.
- The first theoretical explanation of superconductivity was given by Bardeen, Cooper and Schrieffer in 1957 and it is called the BCS theory.
- The temperature at which electrical resistivity of the material suddenly drops to zero and the material changes from normal conductor to a superconductor is called the transition temperature or critical temperature TC.

At the transition temperature the following changes are observed :

(i) The electrical resistivity drops to zero.

(ii) The conductivity becomes infinity

(iii) The magnetic flux lines are excluded from the material.

Applications of superconductors:

- Superconductors form the basis of energy saving power systems, namely the superconducting generators, which are smaller in size and weight, in comparison with conventional generators.
- Superconducting magnets have been used to levitate trains above its rails. They can be driven at high speed with minimal expenditure of energy.
- Superconducting magnetic propulsion systems may be used to launch satellites into orbits directly from the earth without the use of rockets.
- High efficiency ore–separating machines may be built using superconducting magnets which can be used to separate tumor cells from healthy cells by high gradient magnetic separation method.
- Since the current in a superconducting wire can flow without any change in magnitude, it can be used for transmission lines.
- Superconductors can be used as memory or storage elements in computers.

The heating element in an electric stove is made of Nichrome.

Carbon resistors:

- Carbon resistor consists of a ceramic core, on which a thin layer of crystalline carbon is deposited.
- These resistors are cheaper, stable and small in size.

Kirchoff's law:

1. Kirchoff's first law (current law)
2. Kirchoff's second law (voltage law)

Kirchoff's first law (current law):

- Kirchoff's current law states that the algebraic sum of the currents meeting at any junction in a circuit is zero.
- The sum of the currents entering the junction is equal to the sum of the currents leaving the junction.

Kirchoff's second law (voltage law):

- Kirchoff's voltage law states that the algebraic sum of the products of resistance and current in each part of any closed circuit is equal to the algebraic sum of the emf's in that closed circuit. This law is a consequence of conservation of energy.

Wheatstone's bridge:

- An important application of Kirchoff's law is the Wheatstone's bridge.

$$\boxed{\frac{\mathbf{P}}{\mathbf{Q}} = \frac{\mathbf{R}}{\mathbf{S}}}$$

Metre bridge:

- Metre bridge is one form of W h e a t s t o n e's bridge.

Determination of specific resistance:

- The specific resistance of the material of a wire is determined by knowing the resistance (P), radius (r) and length (L) of the wire using the expression $\rho = \frac{P\pi r^2}{L}$

Potentiometer:

- The Potentiometer is an instrument used for the measurement of potential difference.

Chemical effect of current:

- The passage of an electric current through a liquid causes chemical changes and this process is called electrolysis.
- The conduction is possible, only in liquids wherein charged ions can

be dissociated in opposite directions. Such liquids are called electrolytes.

- The plates through which current enters and leaves an electrolyte are known as electrodes.
- The electrode towards which positive ions travel is called the cathode and the other, towards which negative ions travel is called anode.

Faraday's laws of electrolysis:

- The factors affecting the quantities of matter liberated during the process of electrolysis were investigated by Faraday.

Electric cells:

- The starting point to the development of electric cells is the classic experiment by Luige Galvani and his wife Lucia on a dissected frog hung from iron railings with brass hooks.

Voltaic cell:

- The simple cell or voltaic cell consists of two electrodes, one of copper and the other of zinc dipped in a solution of dilute sulphuric acid in a glass vessel.
- Anode : Copper (Cu)
- Cathode : Zinc (Zn)
- Potential Difference : 1.08V
- Electrolyte : H_2SO_4

Primary Cell:

- The cells from which the electric energy is derived by irreversible chemical actions are called primary cells.

Daniel cell:

- Daniel cell is a primary cell which cannot supply steady current for a long time.

Leclanche cell:

- The emf of the cell is about 1.5 V, and it can supply a current of 0.25 A.
- Anode: Carbon rod
- Cathode: Zinc rod
- Electrolyte: Ammonium chloride

Secondary Cells:

- Anode : Lead
- Cathode : Lead Oxide
- Electrolyte : H_2SO_4
- The advantage of secondary cells is that they are rechargeable.

- The chemical process of obtaining current from a secondary cell is called discharge.

Seebeck effect:

- In 1821, German Physicist Thomas Johann See beck discovered that in a circuit consisting of two dissimilar metals like iron and copper, an emf is developed when the junctions are maintained at different temperatures.
- Two dissimilar metals connected to form two junctions is called thermocouple.
- The emf developed in the circuit is thermo electric emf.
- The current through the circuit is called thermoelectric current. This effect is called thermoelectric effect or Seebeck effect.

Peltier effect:

- In 1834, a French scientist Peltier discovered that when electric current is passed through a circuit consisting of two dissimilar metals, heat is evolved at one junction and absorbed at the other junction. This is called Peltier effect. Peltier effect is the converse of Seebeck effect.

Peltier Co-efficient(π):

- The amount of heat energy absorbed or evolved at one of the junctions of a thermocouple when one ampere current flows for one second (one coulomb) is called Peltier coefficient.
- It is denoted by π. Its unit is volt.

Thomson effect:

- Thomson suggested that when a current flows through unequally heated conductors, heat energy is absorbed or evolved throughout the body of the metal.
- Positive Thomson effect is observed in the case of Sb, Ag, Zn, Cd, etc.
- Negative Thomson effect is observed in the case of Pt, Bi, Co, Ni, Hg, etc.
- In the case of lead, Thomson effect is nil.

Thomson coefficient(σ):

- The amount of heat energy absorbed or evolved when one ampere current flows for one second (one coulomb) in a metal between two points which differ in temperature by 1°C is called

Thomson coefficient. It is denoted by σ.Its unit is volt per ° C

Magnetic effect of current:

- In 1820, Danish Physicist, Hans Christian Oersted observed that current through a wire caused a deflection in a nearby magnetic needle. This indicates that magnetic field is associated with a current carrying conductor.

Magnetic induction due to infinitely long straight conductor carrying current:

$$B = \frac{\mu_0 I}{2\pi a}$$

If the conductor is placed in a medium of permeability, μ

$$B = \frac{\mu I}{2\pi a}$$

Tangent galvanometer:

- Tangent galvanometer is a device used for measuring current.
- Since the tangent galvanometer is most sensitive at a deflection of 45°, the deflection has to be adjusted to be between 30° and 60°.

Cyclotron:

- Cyclotron is a device used to accelerate charged particles to high energies. It was devised by Lawrence.

Force on a current carrying conductor placed in a magnetic field:

$$\vec{F} = \vec{Il} \times \vec{B}$$

Pointer type moving coil galvanometer:

- The suspended coil galvanometers are very sensitive. They can measure current of the order of 10^{-8} ampere.

Conversion of galvanometer into an ammeter:

- A galvanometer is a device used to detect the flow of current in an electrical circuit.
- However, a galvanometer is converted into an ammeter by connecting a low resistance in parallel with it.
- As a result, when large current flows in a circuit, only a small fraction of the current passes

Gas lighters work on the basic principle of Piezo – electric effect through the galvanometer and the remaining larger portion of the current passes through the low resistance.

- The low resistance connected in parallel with the galvanometer is called shunt resistance. The scale is marked in ampere.
- R_a is very low and this explains why an ammeter should be connected in series. When connected in series, the ammeter does not appreciably change the resistance and current in the circuit. Hence an ideal ammeter is one which has zero resistance.

Conversion of galvanometer into a voltmeter:

- A galvanometer can be converted into a voltmeter by connecting a high resistance in series with it. The scale is calibrated in volt.
- R_v is very large, and hence a voltmeter is connected in parallel in a circuit as it draws the least current from the circuit.

Bohr magneton:

- The value of $\frac{eh}{4\pi m}$ is called Bohr magneton.
- By substituting the values of e, h and m, the value of Bohr magneton is found to be $9.27\times10^{-24} Am^2$

Electricity:

- AC to DC – Rectifier
- DC to AC – Inverter
- Transformer – Changes from one voltage to another