# -:(Physics):-

## Semester 01:-

## Chapter 06:-

### QNO1:-

What is electric current and current density and write its unit?

**Answer:-**

"The rate of flow of charges through a conductor is called electric current."

$$I = \frac{dq}{dt}$$

The SI unit of electric current is called Ampere.

"The current established in conductor is equal to one ampere when one coulomb charges flows through a conductor in one second.

## Current Density:-

The current per unit cross sectional area of a conductor is called current density.

It is denoted by $\vec{J}$. It is a vector quantity. SI unit is $Am^{-2}$

$$J = \frac{dI}{da} \Rightarrow dI = \vec{J}.\vec{da}$$

$$I = \int \vec{J}.\vec{da}$$

$$I = JA$$

$$\boxed{J = \frac{I}{A}}$$

## QNO2:-

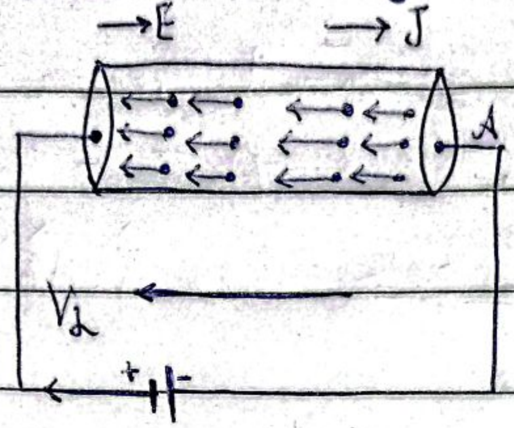
**What is drift velocity? Establish a relation between drift velocity and current density?**

Ans:-

"The constant average velocity acquired during this process by free electron against electric field is called Drift velocity." $(V_L)$

The drift velocity is of the order $10^{-3} ms^{-1}$.

**Relational between drift velocity and current density:-**




One carrier charge = e

nAL carrier charge = ALne

The total charge q on conductor is:

$$q = nALe \quad \text{(i)}$$

$$I = \frac{q}{t}$$

$$q = It \quad \text{(ii)}$$

$$I \times t = nALe$$

$$\{\because L = V_d t\}$$

$$I \times \cancel{t} = nAV_d\cancel{t}\,e$$

$$I = nAV_d e$$

$$\frac{I}{A} = nV_d e$$

$$J = neV_d$$

$$\boxed{V_d = \frac{J}{ne}}$$

## QNO3:-

Define electrical resistance, conductance, resistivity, conductivity and write their units?

**Answer:-**

### Electrical Resistance:-

"The measurement of opposition to flow of charges through a conductor due to collision with ionic cores of conductor is called Electrical resistance."

"The conductor used in a circuit to provide specified resistance is called Resistor."

$$R = \frac{V}{I}$$

Unit: ohm ($\Omega$)

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## Conductance:-

The reciprocal of resistance is called conductance. It is denoted by G.

$$G = \frac{1}{R} = \frac{I}{V}$$

**Unit:** mho ($\Omega^{-1}$) or siemen

## Resistivity:-

"The ratio of electric field E applied to a conductor and current density J is called resistivity."

"The resistance of one $(\text{meter})^3$ of a material is called resistivity."

It is denoted by $\rho$.

$$\rho = \frac{E}{J}$$

**Unit:** Ohm-meter ($\Omega m$)

## Conductivity:-

The reciprocal of resistivity is called conductivity. It is denoted by $\sigma$.

$$\sigma = \frac{1}{\rho} = \frac{J}{E}$$

**Unit:** mho-meter $(\Omega m)^{-1}$

:(Applied Physics):-

## Chapter 06:-

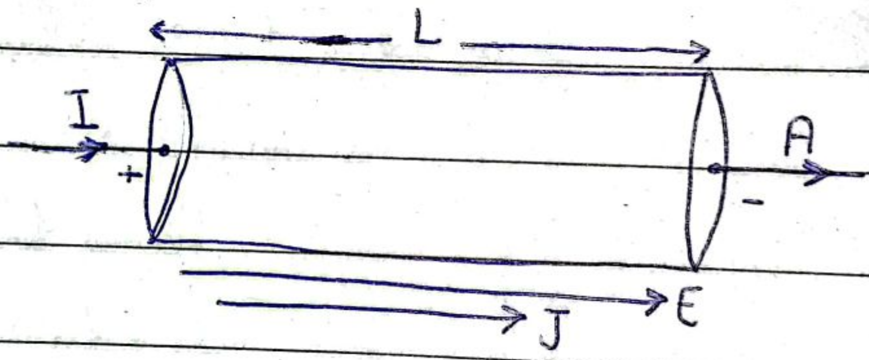
### Q.No4:-

A potential V is applied across length L of a conductor. Relate:

(i) J with $\rho$ and E with V and L.

(ii) Prove that $\rho = RA/L$ ?

Answer:-




Consider a cylinderical conductor having length L and cross sectional Area A. The current I flows through conductor when V is applied at the end of a conductor.

The electric field E and Pd V are related as:

$$E = \frac{V}{L}$$

$$E = \frac{IR}{L} \quad \text{———} \quad (i)$$

Resistivity is given as:

$$\rho = \frac{E}{J}$$

$$E = \rho J \quad \text{———} \quad (ii)$$

Compairing eq (i) and (ii)

$$\rho J = \frac{IR}{L}$$

$$J = \frac{IR}{\rho L} \quad \text{———} \quad (iii)$$

The current density is:

$$J = \frac{I}{A} \quad \text{———} \quad (iv)$$

Compairing eq (iii) and (iv)

$$\frac{\cancel{I}}{A} = \frac{\cancel{I}R}{\rho L} \Rightarrow A = \frac{\rho L}{R}$$

$$R = \frac{\rho L}{A} \Rightarrow \boxed{\rho = \frac{RA}{L}}$$

This is the relation between resistivity and resistance.

**QNO5:-**

What is temprature coefficient of resistivity. Derive its formula and explain effect of temprature variation ~~of~~ on resistivity?

**Answer:-**

"The fractional change in resistivity per unit charge in tempreture is called temperature coefficient of resistivity."

It is denoted by $\alpha$. Its SI unit is $(Kelvin)^{-1}$

**Explanation:-**

Consider a conductor having resistivity $\rho_0$ at temperature $T_1$. The resistivity of conductor increased by amount $d\rho = \rho_t - \rho_0$

It is experimently found that

increase in resistivity $d\rho$ is directly proportional to the changes in temperature $dT$ and original resistivity $\rho_0$.

$$\cancel{d\rho \propto \rho}$$

$$d\rho \propto \rho_0 dT$$

$$d\rho = \alpha \rho_0 dT$$

$$\alpha = \frac{d\rho}{\rho_0 dT}$$

The final resistivity of material is given by:

~~F. Resistance = Original~~

Final $\rho$ = original $\rho$ + Increase in $\rho$

$$\rho_t = \rho_0 + d\rho$$

$$\rho_t = \rho_0 \ \alpha \rho_0 dT$$

$$\rho_t = \rho_0 (1 + \alpha dT)$$

Using the relation of resistivity and resistance, we get

$$R_t = R_0 (1 + \alpha dT)$$

-:(Applied Physics):-

## Chapter 06:-

### QNo06:-

Define current density. State and explain Ohm's law and write its macroscopic and microscopic form in terms of current density and electric field intensity?

**Answer:-**

"The current flowing through a conductor per unit area is called current density."

It is a vector quantity.

$$\boxed{J = \frac{I}{A}} \qquad Am^{-2} = \text{Unit}$$

## OHM's Law:-

The Ohm's law can be stated in two ways called macroscopic form and microscopic form.

(i) **Macroscopic Form:-**

The macroscopic form of ohm's law states that current flows through a conductor when P.d is applied at the ends of this conductor. The amount of this current is directly proportional to the applied P.d provided that physical state of conductor such as temperature remains constant.

$$V \propto I$$

$$V = IR$$

where R is proportionality constant called resistance of conductor.

**Ohmic and Non-Ohmic Circuits:-**

The material or circuit elements which obeys ohm's law is called ohmic. The graph b/w current and voltage is a straight line.

The material or circuits elements such as diode, bulb which does not obey ohm's law is called non-ohmic. The graph b/w current and voltage is non linear.

(ii) **Microscopic form:-**

The microscopic form of Ohm's law states that current density established in conductor is directly proportional to the electric field which is applied at the end of a conductor.

**Explanation:-**

Consider a conductor having length L and cylindrical cross sectional area A. The current I flows through conductor whe Pd 'V' is applied at its end.

$$V = IR$$

As $R = \frac{\rho L}{A}$

So,

$$V = I \frac{\rho L}{A}$$

$$\left\{ J = \frac{I}{A} \right\}$$

$$V = \rho J L$$

$$\frac{V}{L} = \rho J \quad \text{--- (i)}$$

Potential difference per unit length is equal to electric field.

$$\frac{V}{L} = E \quad \text{--- (ii)}$$

$$\boxed{E = \rho J}$$

This is called microscopic form of Ohm's law.

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## Chapter 06:-

### QNo7:-

Describe the relation b/w macroscopic and microscopic Parameter of Ohm's law?

**Answer:-**

(i) The macroscopic parameter current I and microscopic parameter current density of ohm's law are related as:

$$I = \int \vec{J} \cdot \vec{da}$$

(ii) The macroscopic parameter potential difference 'V' and microscopic parameter electric field E is related as:

$$V = \int \vec{E} \cdot \vec{dr}$$

(iii) The macroscopic parameter resistance R and microscopic parameter resistivity $\rho$ off ohm's law is related as:

$$R = \frac{\rho L}{A}$$

QNo8:-

Show that metals obey Ohm's law taken into account microscopic form of Ohm's law, Prove $\rho = m/ne^2\tau$ :-

Answer:-

Metals Obey Ohm's law:-

The ohm's law is not a fundamental law of electromagnetism. It depends upon the properties of conducting material. Almost all the metals are conductors and having conduction electrons and ionic cores. The assembly of conduction electrons is called electron gas.

The electric force $F_e$ experienced by electron having charge e due to applied electric field E is:

$$F_e = eE$$

This electric force $F_e$ produces acceleration 'a' in electron having mass 'm'.

$$F_e = ma$$

Compairing both eq.

$$ma = eE$$

$$a = \frac{eE}{m} \quad \text{——— (i)}$$

The acceleration in term of drift velocity $V_d$ and mean free time $\tau$ b/w collision is:

$$a = \frac{V_d}{\tau} \quad \text{(Put in (i))}$$

$$\frac{V_d}{\tau} = \frac{eE}{m}$$

$$V_d = \frac{eE\tau}{m} \quad \text{——— (ii)}$$

The drift velocity in term of current density is:

$$V_d = \frac{J}{ne} \quad \text{(Put in eq (ii))}$$

$$\frac{J}{ne} = \frac{eE\tau}{m}$$

$$J = \frac{ne^2E\tau}{m} \quad \text{—— (iii)}$$

The microscopic form of Ohm's law is:

$$E = \rho J$$

$$J = \frac{E}{\rho} \quad \text{(Put in (iii))}$$

$$\frac{\cancel{E}}{\rho} = \frac{ne^2\cancel{E}\tau}{m}$$

$$\frac{1}{\rho} = \frac{ne^2\tau}{m}$$

$$\boxed{\rho = \frac{m}{ne^2\tau}}$$ Hence proved

where $m, n, e^2$ and $\tau$ is constant of proportionality. So,

$\rho =$ constant

Therefore, It is concluded that parameter $\rho$ is constant for metals. The microscopic form of Ohm's law is:

$$E = \rho J$$

$$\rho \longrightarrow \text{constant}$$

$$E \propto J$$

Hence, it is concluded that all metals obey ohm's law.

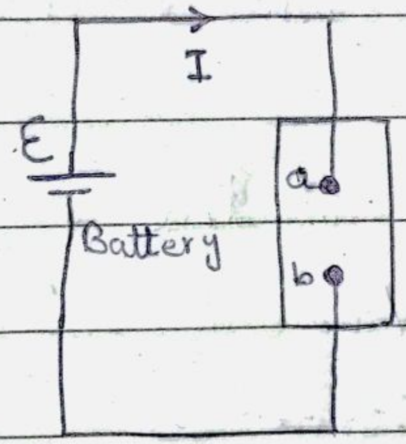
## Chapter 06:-

### QNo 7:-

Describe how electrical energy is transferred to any other form of energy in electrical circuit. Also define electrical power and write its unit?

### Answer:-

#### Energy transfer in Electric Circuits:-




Consider an electric circuit in which a battery is connected with a black box. The steady current 'I' is established in wires that causes steady potential difference $V_{ab}$ b/w terminal "a" and "b".

The terminal "a" has high potential and terminal "b" has low potential. The conservation of energy tells that this energy is transferred in the box from electrical energy to some other form of energy.

$$dU_e = dq\, V_{ab}$$

$$dU_e = I\,dt\, V_{ab}$$

$$\frac{dU_e}{dt} = I V_{ab}$$

The term $\frac{dU_e}{dt}$ is rate of energy transfer is called electric power.

$$P_e = I V_{ab} \quad \text{——— (i)}$$

## Power Dissipation:-

Now consider a special case that device inside box is a resistor. Then by Ohm's law.

$$V_{ab} = IR \quad \text{Put in (i)}$$

$$P_e = I(IR)$$

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$$\boxed{P_e = I^2 R} \quad \text{——— (a)}$$

$$\left\{ I = \frac{V}{R} \right\}$$

$$P_e = \frac{V^2}{R^2} R \Rightarrow \boxed{P_e = \frac{V^2}{R}} \quad \text{——— (b)}$$

The equation (a) or (b) is called Joules law

**Unit:-**

The unit of electric power is watt.

The unit watt is equal to $\frac{J}{s}$

## Chapter 06:-

### Q.No9:-

Describe analogy between current and heat flow?

**Answer:-**

The flow of charges through a conductor due to potential difference and flow of heat through a conductor due to temperature difference has close analogy between them.

### (i) Current flow in Conductor:-

Consider a conducting slab having thickness 'dx' and cross-sectional area 'A'. The current I flows through a conductor when 'dV' is maintained at the ends of conductor.

$$I = \frac{V_a - V_b}{R}$$

$$I = -\frac{(V_b - V_a)}{R}$$

$$I = -\frac{dV}{R}$$

$$\left\{ \because R = \frac{\rho L}{A} ; \quad L = dx \right\}$$

$$I = \frac{\rho dx}{A} dV \qquad I = -\frac{dV}{\frac{\rho dx}{A}}$$

$$I = -\frac{A dV}{\rho dx} \qquad \left\{ \sigma = \frac{1}{\rho} \right\}$$

$$I = -A \sigma \frac{dV}{dx}$$

$$\boxed{\frac{dq}{dt} = -A \sigma \frac{dV}{dx}}$$

The negative sign means positive charge flows in the direction of decreasing V.

It means $dq/dt$ is positive when $dV/dx$ is negative.

(ii) Heat flow in Conductor:-

Now consider same slab of homogeneous metallic material having length L. The cross sectional area of each of opposite face of slab is A.

The heat Q flows from hotter face towards colder face. The rate of conduction of thermal energy 'H' is :

$$H = \frac{Q}{t}$$

The SI unit is watt.

(i) Cross sectional area of the material $\Rightarrow$ $H \propto A$ ——— (i)

(ii) Length of the material

$$H \propto \frac{1}{dx} \quad \text{——— (ii)}$$

(iii) Temprature difference between ends of material.

$$H \propto dT \quad \text{——— (iii)}$$

These three experimental facts can be as:

$$H \propto A \frac{dT}{dx}$$

$$\boxed{H = -KA\frac{dT}{dx}}$$

The negative sign means heat flows in the direction of decreasing $\frac{dT}{dx}$.

$\frac{dT}{dx}$ is called Temprature gradiant.