CHAPTER # 14 **CURRENT ELECTRICITY**

Electric Current:-

The rate of flow of electric charges through any cross sectional area is called electric current.

Formula:-

$$\text{Electric current} = \frac{Charge}{Time}$$

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

Unit:-

The unit of electric current Ampere

Ampere:-

We know that

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

$$1A = \frac{1C}{1sec}$$

If a charge of one coulombs passes through any cross sectional area in one second then electric current will be one ampere.

Conventional Current:-

The current that flows from positive terminal of the battery towards negative terminal of the battery due to flow of positive charges is called conventional current.

Ohm's Law:-

The amount of current passing through a conductor is directly proportional to the potential difference applied across its ends provided the temperature and physical state of the conductor does not change.

Mathematically:-

$$V \propto I$$

$$V = (\text{constant})$$

Here, constant = R

$$V = IR$$

$$V = IR$$

Where "R" is a constant known as resistance of the conductor.

Resistance:-

The property of a substance which offers opposition to the flow of current through it is called resistance. The opposition to the flow of the current comes from the collision of moving electrons with atoms of the current.

Unit of Resistance:-

The unit of resistance is ohm, and it is represented by the symbol "Ω" (omega).

Ohm:-

We know that

$$V = I\,R$$

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

$$1\ \Omega = \frac{1\ Volt}{1\ Ampere}$$

When a potential difference of "1" volt is applied across the ends of the conductor and a current of 1 ampere passing through it then its resistance will be one ohm.

Ohmic Conductors:-

Those conductors that obey ohm's law are called ohmic conductors. These conductors have a constant resistance over a wide range of voltage.

Non Ohmic Conductors:-

Those conductors that do not obey ohm's law are called non ohmic conductors. These conductors do not have a constant resistance over a wide range of voltage.

Factor Affecting Resistance:-

At a certain temperature the resistance of conductor depends upon three factors.

i) Length of the conductor

ii) Area of cross sectional

iii) Nature of material of the conductor.

From different experiment. It has been found that the resistance of the conductor is directly proportional to the length of the conductor and inversely proportional to area of its cross sectional, $R \propto L$.

It means that if the length of the conductor increases then its resistance also increases

$$R \propto \frac{L}{A}$$

Its mean that if area of cross section of the conductor increases then its resistance decreases.

From i) and ii)

$$R \propto \frac{L}{A}$$

R = (constant)

Constant = p

So,

$$R = p\,\frac{L}{A}$$

Here 'p' is a constant known as specific resistance and its value depends upon nature of material of the conductor.

Q. Why the resistance of the conductor increases due to increase in temperature?

Ans: - We know that the resistance offered by a conductor is due to the collusion of free electron with atom of the conductor when the temperature of the conductor increases then due to this increase in temperature the rate of collusion of free electrons also increases. As a result of this increase in rate of collusion the resistance of the conductor also increases.

Series Combination of Resistor:-

Such a combination of resistor in which all the resistor are connected end to end in such a way that there is only one path for the flow of current is called series combination of resistor.

Characteristic:-

i. In series combination of resistor the value of current through each of the resistor is same

$$I_1 + I_2 + I_3 = I$$

ii. In series combination of resistor the value of voltage across each of the resistor is different

$$V_1 \neq v_2 \neq v_3$$

iii. In series combination of resistors the total value of the voltage of the battery is divided across all the resistors and the voltage across each resistor.

Voltage of battery = $V_1 + V_2 + V_3$

$$V = V_1 + V_2 + V_3$$

Using ohm's law

$$V = I_1R_1 + I_2R_2 + I_3R_3$$

Here 'I' is same i.e.

$$I_1 + I_2 + I_3 = I$$

So,

$$V = I_1R_1 + I_2R_2 + I_3R_3$$

Taking 'I' common

$$V = I\,[R_1 + R_2 + R_3]$$

The series combination of resistor can be replaced by a single resistor. This single resistor is called equivalent resistor and its resistance is represented by 'Re'. Its value is

$$Re = R_1 + R_2 + R_3$$

If there are 'n' number of resistors connected in series then.

$$Re = R_1 + R_2 + \dots\dots\dots\ R_n$$

Parallel Combination of Resistors:-

Such a combination of resistors in which one end of each resistor is connected with positive terminal of the battery and the other end of each resistor is connected with negative terminal of the battery in such a way that there are multiple paths for the flow of current is called parallel combination of resistors.

Characteristics:-

i. In parallel combination of resistors the value of voltage across each of the resistor is same.

$$V_1 = V_2 = V_3 = V$$

ii. In parallel combination of resistors the value of current through each of the resistor is different.

$$I_1 = I_2 = I_3$$

iii. In parallel combination of resistors the total value of current is equal to sum of the current in various resistors.

Total resistor $= I_1 = I_2 = I_3$

$$I = I_1 = I_2 = I_3$$

$$I = \frac{V_1 + V_2 + V_3}{R_1\ R_2\ R_3}$$

Here, $V_1 = V_2 = V_3 = V$

So, $$I = \frac{V + V + V}{R_1\ R_2\ R_3}$$

Taking 'V' common

$$I = V\ \frac{1 + 1 + 1}{R_1\ R_2\ R_3}$$

iv. The parallel combination of resistors can be replaced by a single resistor. This single resistor is called equivalent resistor and its resistance is represented by 'Re' and its value is.

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

If there are 'n' number of resistors converted in parallel then.

$$\frac{1}{R_e} = \frac{1+1+1}{R_1\ R_2\ R_3} \dots \dots \dots . + \frac{1}{R_n}$$

Q: - What are the advantages of parallel circuits over series circuit?

Ans: - there are two big advantages of parallel circuits over series circuit.

i. In parallel circuit each device in the circuit receives the full battery voltage.

ii. In parallel circuits any device in the circuit can be turned off without affecting any other device. This principle is used in household wiring.

Joule's Law: -

Statement: -

The amount of heat energy generated in a resistance due to flow of charges is equal to the product of square of current 'I' resistance 'R' and the time duration 'T'.

Explanation: -

Consider two points with a potential difference of 'V' volts, if a charge of one coulomb passes between these points then an amount of energy delivered by the charge can be found by using formula.

$$\text{Electric potential} = \frac{Work}{Charge}$$

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

$$W = V \times Q$$

Here, Work – energy

So, Energy = V x Q ⟶ (i)

By ohm's law

$$V = IR$$

$$V = IR$$

By definition of current:

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

Q = I x t

Q = I x t

Putting values of 'P' and 'Q' in eq (i)

Energy = V x Q

= (I R) x (I x T)

= I^2 R t

Energy = I^2 R t

Electric Power: -

The amount of energy supplied by current in unit time is called electric power.

Formula: -

Electric power = $\frac{Electric\ \ energy}{Time}$

P = $\frac{I^2 R\ t}{t}$

= $\frac{I^2\ R\ t}{t}$

P = I^2 R

Unit: -

The unit of electric current is watt.

Kilowatt- Hour:-

Kilowatt hour is the large unit of electric energy. It is defined as "The amount of energy delivered by a power of one kilowatt in one hour is called kilowatt- hour".

Electric energy in kilowatt are can be obtained by using the formula.

The amount of energy in KWH = $\frac{Watt\ \times time\ \ of\ \ use\ \ in\ \ hour}{1000}$

If the cost of one kilowatt hour (one unit) is known then we can calculate the amount of electricity bill by the following formula.

Cost of electricity = $\frac{\boldsymbol{Watt \times time\ of\ use\ in\ hour}}{\boldsymbol{1000}}$ **x cost of one unit**

Page # 107 **Example: 14.8**

Power = p = 50 volt.

Number of hours used in one day = 8 hours.

Number of hours used in 30 days = 8 x 30 = 240 hour

Cost of one unit = 12 Rs.

Cost of electricity =?

We know.

Cost of electricity $= \frac{Watt \times time\ of\ use\ in\ hour}{1000}$ **x cost of one hour**

$= \frac{50 \times 240}{1000} \times 12$

= 12 x 12

= 144 Rs.

Q: - Define kilowatt hour and prove that 1KWH = 3.6 MJ?

Ans: - Kilowatt – hour:

The amount of energy delivered by a power of one kilowatt in one hour is called kilowatt hour

1 KWH = (100) WH

= (1000) (H) (W)

= (1000) (3600 sec) W

= 3.6 x 10^5 W sec

= 3.6 x 10^{5+1} W sec

= 3.6 x 10^6 W sec (i)

We know

Power = $\frac{Work}{time}$

Watt = $\frac{Joule}{second}$

(1 watt) (Sec) = joule

W sec = J put in (i)

1 KWH = 3.6 x 10^6 W sec

= 3.6 x 10^6 joules

Here, 10^6 = mega = M

So, 1 KWH = 3.6 M joule

Direct Current:- Such a current that flows only in one direction is called direct current. It is constant in magnitude therefore its values do not change. It is also called unidirectional current. In direct the positive and negative terminals of the battery remains constant with time.

Example: -

The current derived from a cell or a battery is direct current.

Alternating current:-

Such a current that changes after equal intervals of time is called alternating current (AC). In alternating current the positive and negative terminals of a battery changes again and again. The magnitude of this current also changes regularly.

The current supplied to our homes is alternating current. In Pakistan the frequency of A.C is 50 Hz.

Fuse:-

Fuse is a safety device that is connected in series with the live wire. In the circuit to protect the electrical appliances. When excess amount current flows.

Procedure:-

Fuse is a basically a short and thin piece of metal wire that melts when a large amount of current passes through it. It is always connected in series with live wire. Whenever the current exceeds the safety limit. Then the fuse wire melts and breaks the circuit. As a result the supply current stop. Therefore the other electrical appliances are protected from heavy current. We replaced the damaged fuse with a new fuse so that the supply of current again starts in normal way.

Circuit Breaker:-

Circuit breaker is a safety device which disconnects the supply of current if it exceeds the safety limit. Whenever the current exceeds the safety limit then the switch of circuit breaker goes off and as a result the supply of current stops. After removing the fault the switch of circuit breaker is pressed on and supply of current again start in the normal way.

Hazards of Electricity:-

Electricity has become a very important part of our lives therefore care should be taken to save our self from hazards of electricity voltage of 50volts and a current of 50mA can be fatal. Major dangers of electricity are electric shock and electric fire. Some of the faults in electrical circuit that may cause electricity hazards are given below.

i. Insulation damage.
ii. Damp conditions.

i. Insulation Damage:-

All electrical cables are insulated with some plastic cover for safety purpose but when the electrical current exceeds a safety limit then it can damage the insulation due to overheating of cables. As a result a short circuit occurs. In order to avoid short circuit the electricity wires should never be naked rather they should wire contain two layers of insulation.

EXERCISE QUESTIONS

Q.1: Why energy saver light bulbs are better than in candescent bulbs?

Ans: - Energy saver light bulbs transform most of the electrical energy into light.

Their wast very small amount of electrical energy into bulbs transform small amount of electrical energy into light and they wast more amount of electrical energy into heat energy.

Example: -

An energy saver light bulb that uses 11 J of electrical energy each second gives all most the same amount of light. But an ordinary [incandescent] bulb uses 60J of electrical energy to give same amount of light. Therefore we can say that energy light bulbs are much better then incandescent bulbs.

Q.2: What is called grounding?

Ans: - The earth is a good electrical conductor. Therefore if a charge object is connected with earth by a piece of metal then the charge is conducted away from the object to the earth. This method of removing the charge from an object is called grounding of the object.

Q.3: If the values of all the resistors in a parallel circuit are same the how can defined the value of equivalent resistor?

Ans: - if the values of all the resistor in a parallel circuit are same then equivalent resistor can be found by using formula.

$$\frac{1}{R_e} = \frac{N}{R}$$

Taking reciprocal

$$Re = \frac{N}{R}$$

Where "N" is the number of resistors.

Q.4: A bird can sit harmlessly on high tension wire but it must not reach and grab neighboring wire do you know why?

Ans: - As long as the bird is sitting on a same wire then there will be no potential difference but when this bird reach and drab a neighboring wire then a potential difference is created. Due to this potential difference a current flow through the body of the body.

CONCEPUTAUL QUESTIONS

Q.1: Why in conductors charge is transferred by free electrons rather than positive charge?

Ans: - We know that positively charge protons in conductor are bound in the nucleus of the atom. Therefore these positive charges are not free to move inside the conductor. But large distance from the nucleus. Therefore these electrons are called free electron. These free electrons can moves freely inside the conductor and they can transfer charge in conductors.

Q.2: What is difference between cell and battery?

Ans: - A cell is a single unit which converts chemical energy into electrical energy. Where as a battery consist of number of cells joined in series to give high values of voltage.

Q.2: Can current flow in a circuit without potential difference?

Ans: - No, A current cannot flow in a circuit without potential difference because we know that according to ohm's law current passing through a conductor is directly proportional to the potential difference across the ends of the conductor. Therefore if the potential difference in a circuit is zero than no current will flow through it.

Q.3: Two points on an object are at different electric potentials. Does charge necessarily flow between them?

Ans: - We know that if two points on an object are at difference electric potential then charge will flow through the object. This is because if the electric potential at one point is higher than the electric potential at other point than the charge will flow through an object due to difference of electric potential.

Q.4: In order to measure current in a circuit why ammeter is always connected in series?

Ans: - An ammeter is an electrical device which is used to measure the value of current. It is always connected in series with the circuit so that maximum current flows through it. In this way it can measure the accurate value of current.

Q.5: In order to measure voltage in a circuit volt meter is always connected in parallel discuss.

Ans: - Volt meter is a device which is used to measure the value of potential difference in a circuit. It is always connected in parallel with the circuit. In this way volt meter does not disturb the current passing through the circuit. As a result it can measure the accurate value of potential difference.

Q.6: How many watt-hours are there in 1000 joules?

Ans: - We know

1 KWH = 3.6 M J

1 KWH = 3.6×10^6 J

1 K (W) (H) = 3600000 J

(1000) WH = 3600000 J

WH = $\frac{3600000}{1000}$ J

WH = 3600 J

$\frac{WH}{3600}$ = 1 J

1 J = $\frac{WH}{3600}$

Also, 1000 J = $\frac{WH}{3600}$ x 1000

1000 J = $\frac{1000}{3600}$ WH

1000 J = 0.2777 WH

CHAPTER-NO-14 **NUMERICAL PROBLEMS**

14.1. A current of 3mA is flowing through a wire for 1 minute. What is the charge flowing through the wire?

Given: - Current = I = 300 mA

= 300 x 10^{-3} A

Time = t= 1min

Charge = q =?

Solution: -

We know that

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

And q= I x t

By putting values:-

q= (300x 10^{-3}) (60)

q = (300 x 60) x 10^{-3}

q = 18000 x 10^{-3}C

14.2. At 100,000Ω, how much current flows through your body if you touch the terminals of a 12V battery? If your skin is wet, so that your resistance is only 1000Ω, how much current would you receive from the same battery?

Given: - 1st resistance = R_1 = 100,000 Ω

1st voltage = V_1 = 12 volt

1st current = I_1 =?

2nd resistance = R_2 = 100 Ω

2nd voltage = V_2 = 12 volt

2nd current = I_2 =?

Solution: -

By OHM's law we know that

V = IR

Also,

$V_1 = I_1 R_1$

12 = I_1 (100,000)

$\frac{12}{100,000} = I_1$

$\frac{12}{10^5}$ I_1

I_1 = 10 x 10^{-5} A

$V_2 = I_2 R_2$

12 = I_2 (100)

$\frac{12}{100} = I_2$

$\frac{12}{10^2}$ I_2

I_2 = 1 x 10^{-2}

14.3. The resistance of a conductor wire is 10MΩ. If a potential difference of 100 volts is applied across its ends, then find the value of current passing through it in mA.

Given: - Resistance = R 10 MΩ

R= 10 x 10^6 Ω

Potential difference = V = 100 volt

Current in mA =?

Solution: -

By OHM's law.

V= IR

$100 = I\,(10 \times 10^{6})$

$\frac{100}{10 \times 10^{+6}} = I$

$\frac{100 \times 10^{-6}}{10}$

$10 \times 10^{-6}\ A = I$

For mA $I = \frac{10 \times 10^{-6}}{10^{-3}}\ mA$

$I = 10 \times 10^{-6+3}$

$I = 10 \times 10^{-3}\ mA$

$I = 0.01mA$

14.4. By applying a potential difference of 10 V across a conductor, a current of 1.5 a passes through it. How much energy would be obtained from the current in 2 minute?

Given: - potential difference =V = 100 volt
Electric current = I = 1.5 A
Time = t= 2 min
t= 2 x 60
t= 120 sec
Energy = E =?

Solution:-

We know that: -
Electric energy = V x I R
E= 10 x 1.5 x 120
E= 1800 J.

14.5. Two resistances of 2 KΩ and 8KΩ are joined in series, if a 10V battery is connected across the ends of this combination, find the following quantities:

a) The equivalent resistance of the series combination.

b) Current passing through each of the resistances.

c) The potential difference across each resistance.

Given: - Voltage = V= 10volt
1st resistance = $R_1 = 2\ K\Omega$
$= R_1 = 2 \times 10^{3}\ \Omega$
2nd resistance = $R_2 = 8\ K\Omega$
$= R_2 = 8 \times 10^{3}\ \Omega$
Equivalent resistance = Re =?
Current through each resistor = I=?
Voltage through each resistor = V_1 =?
= V_2 =?

Solution: -

We know that in series combination of resistors the equivalent resistance is: -
$Re = R_1 + R_2$
$Re = 2K\Omega + 8K\Omega$

$Re = 10\ K\Omega$

14.7: - An electric bulb is marked with 220 V, 100 W. find the resistance of the filament of the bulb. If the bulb is used 5 hours daily, find the energy in kilowatt-hours consumed by the bulb in one month (30 days).

Given: - Voltage = V = 220volts

Power = P = 100 watt

Resistance = R =?

Time = 5 hours

Total time = 5 x 30 = 150 hrs

Energy in KWH?

Solution: -

$$P = \frac{V^2}{R}$$

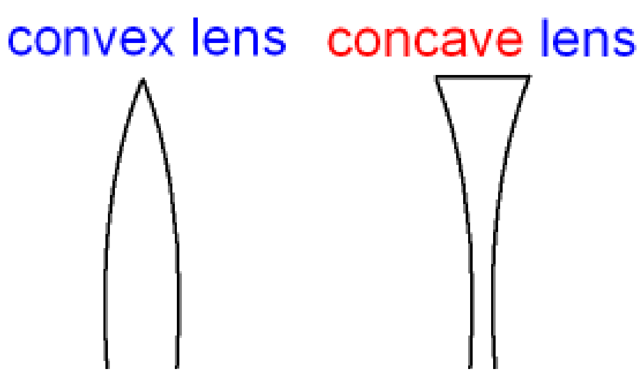
$$100 = \frac{(220)^2}{R}$$

$$R = \frac{48400}{100} = 484\ \Omega$$

Now, Energy in KWH = $\frac{Watt\ \times time\ \ in\ hours}{1000}$

$$= \frac{100 \times 150}{1000}$$

= 15 KWH



Refraction of light