ELECTRICITY

Gist of the Lesson:

1. **Positive and Negative Charges:** The charge acquired by a glass rod when rubbed with silk is called positive charge and the charge acquired by an ebonite rod when rubbed with wool is called Negative Charge.
2. **Coulomb:** It is the S.I. unit of charge. One coulomb is defined as that amount of charge which repels an equal and similar charge with a force of 9×10^9 N when placed in vacuum at a distance of 1 meter from it.

   Charge on an electron = -1.6×10^{-19}coulomb.
3. **Static and Current Electricity:** Static electricity deals with the electric charges at rest while the current electricity deals with the electric charges in motion.
4. **Conductor:** A substance which allows passage of electric charges through it easily is called a conductor'. A conductor offers very low resistance to the flow of current. For example copper, silver, aluminum etc.
5. **Insulator:** A substance that has infinitely high resistance does not allow electric current to flow through it. It is called an insulator'.

   For example rubber, glass, plastic, ebonite etc.
6. **Electric Current:** The flow of electric charges across a cross-section of a conductor constitutes an electric current. It is defined as the rate of flow of the electric charge through any section of a conductor.

   Electric current = Charge/Time or

   $I = Q/t$

   Electric current is a scalar quantity.
7. **Ampere:** It is the S.I. unit of current. If one coulomb of charge flows through any section of a conductor in one second, then current through it is said to be one ampere.

   1 ampere = 1 coulomb/1 second or 1 A = 1C/1s = $1Cs^{-1}$ $1Cs^{-1}$

   1 mill ampere = 1 mA = 10^{-3} A

   1 microampere = 1μA = 10^{-6} A
8. **Electric Circuit:** The closed path along which electric current flows is called an Electric Circuit'.
9. **Conventional Current:** Conventionally, the direction of motion of positive charges is taken as the direction of current. The direction of conventional current is opposite to that of the negatively charged electrons.

10. **Electric Field:** It is the region around a charged body within which its influence can be experienced.

11. **Electrostatic Potential:** Electrostatic potential at any point in an electric field is defined as the amount of work done in bringing a unit positive charge from infinity to that point. Its unit is volt. Positive charges move from higher to lower potential regions. Electrons, being negatively charged, move from lower to higher potential regions.

12. **Potential difference between two points:** The Potential difference between two points in ar. electric field is the amount of work done in bringing a unit positive charge from one to another. Potential difference = Work done/Charge or $V = W/Q$

13. **One volt Potential Difference:** The Potential difference between two points in an electric field is said to one volt if one joule of work has to be done in bringing a positive charge of one coulomb from one point to another. 1 volt = 1 joule/1 coulomb or 1 V= 1J/1C

14. **Galvanometer:** It is device to detect current in an electric circuit.

15. **Ammeter:** It is device to measure current in a circuit. It is always connected in series in a circuit.

16. **Voltmeter:** It is a device to measure potential difference. It is always connected in parallel to the component across which the potential difference is to be measured.

17. **Ohm's Law:** This law states that the current passing through a conductor is directly proportional to the potential difference cross its ends, provided the physical conditions like temperature, density etc. remains unchanged.

$$V \propto I \text{ or } V = RI$$

The proportionality constant R is called resistance of conductor.

18. **Resistance:** It is a property of a conductor by virtue of which it opposes the flow of current through it. It is equal to the ratio of the potential difference applied across its ends and the current flowing through it. Resistance = Potential difference/Current or $R = V/I$

19. **Ohm:** It is the S.I. unit of resistance. A conductor has a resistance of one ohm if a current of one ampere flows through it on applying a potential difference of one volt across its ends.

1 ohm = 1 volt/1 ampere or $1\Omega = 1V/1A$

20. Factors on which resistance of a conductor depends: The resistance R of a conductor depends

i) Directly on its length Li.e. R α L.

ii) Inversely on its area of cross-section A i.e. R a 1/A

iii) On the nature of material of the conductor on.

On combining the above factors, we get

R α L/A

R =ρ*L/A the proportionality constant ρ is called resistivity of conductor.

21. Resistivity: It is defined as the resistance offered by a cube of a material of side 1 m when current flows perpendicular to its opposite faces. Its S.I. unit is ohm-meter (Ωm) Resistivity, ρ = RA/L

22. Equivalent Resistance: If a single resistance can replace the combination of resistances in such a manner that the current in the circuit remains unchanged, then that single resistance is called the equivalent resistance.

23. Laws of Resistances in Series:

i) Current through each resistance is same.

ii) Total voltage across the combination = Sum of the voltage drops.

$V= V_I + V_2 + V_3$

iii) Voltage drops across any resistor is proportional to its resistance.

$V_1= IR_1, V_2 = 1R_2, V_3 - IR_3$

iv) Equivalent resistance = Sum of the individual resistances.

$R_s = R_1 + R_2 + R_3$

v) Equivalent resistance is larger than the largest individual resistance.

24. Laws of Resistances in Parallel:

i) Voltage across each resistance is same and is equal to the applied voltage.

ii) Total current = Sum of the currents through the individual resistances.

$I = + I_1 + I_2 + I_3$

iii) Currents through various resistances are inversely proportional to the individual resistances.

$I_1= V/R_1, I_2 = V/R_2, I_3 = V/R_3$

iv) Reciprocal of equivalent resistance = Sum of reciprocals of individual resistances.

$I/R_p = 1/R_1 + 1/R_2 + 1/R_3$

v) Equivalent resistance is less than the smallest individual resistance.

25. Joule's Law of Heating: It states that the heat produced in a conductor is directly proportional to

(i) The square of the current I through it

(ii) Proportional to its resistances R and

(iii) The time t for which current is passed. Mathematically, it can be expressed as

$H = I^2Rt$ joule $= I^2Rt /4.18$ cal

Or

$H = VIt$ joule $= VIt /4.18$ cal

26. Electric Energy: It is the total works done in maintaining an electric current in an electric circuit for given time.

Electric energy, $W = VIt = I^2Rt$ joule

27. Electrical Power: Electrical power is the rate at which electric energy is consumed by an appliance.

$P = W/t = VI = I^2R = V^2/R$

28. Watt: It is the S.I. unit of power. The power of an appliance is 1 watt if one ampere of current flows through it on applying a potential differences of 1 volt across its ends.

1 watt = 1 joule/1 second =1 volt x 1 ampere

Or $1\ W = 1\ Js^{-1} = 1\ VA$

1 kilowatt =1000 W

29. Kilowatt Hour: It is the commercial unit of electrical energy. One kilowatt hour is the electric energy consumed by an appliance of 1000 watts when used for one hour.

1 kilowatt hour (kWh) = 3.6 x 106 J

One Mark Questions (One word or one sentence)

1. Is electric charge a scalar or vector quantity?

A. Scalar quantity

2. Name SI unit of electric potential?

A. Volt.

3. Define potential difference?

A. The potential difference between two points in an electric field is the amount of work done is bringing a unit positive charge from one point to another.

4. What is the SI unit of current?

A. Ampere

5. What is the SI unit of charge?

A. Coulomb.

6. How are ammeter and voltmeter connected in a circuit?

A. An ammeter is connected in series in a circuit while a voltmeter is connected in parallel with the component across which the potential difference is to be measured.

7. State Ohm's law?

A. Ohm's law states that the current passing through a conductor is directly proportional to the potential difference across its ends, provided the physical conditions like temperature, density, etc. remain unchanged.

8. What is the conventional direction of current?

A. The direction of flow of positive charges.

9. What is the cause of resistance of a conductor?

A. When free electrons drift inside a conductor, they' frequently collide with its positive ions or atoms i.e.., the motion of the electrons is opposed during the collisions. This is the basic cause of resistance.

10. Why do we use copper wires as connecting wires?

A. This is because copper has very low resistivity or very high electrical conductivity.

11. What is the SI unit of resistivity?

A. Ohm-meter (Ωm)

12. How many joules are there in 1 kilowatt hour?

A. 3.6 x 10^6 J.

13. The temperature of the filament of an electric bulb is 2700° C when it glows. Why it is not burnt up at such a high temperature?

A. This is because the lamp's filament has high melting point and is held in an atmosphere of inert gas which prevents its oxidation.

Two Marks Questions (30 words)

1. Mention some important uses of electricity in our daily life?

A. Electricity has played an important role in modern society. Some of its important uses are as follows:

(i) In our houses, hospitals, hotels, office buildings, food storage plants for heating, lighting, cooking, operating fans, geysers, etc.

(ii) In industries to run various types of machines.

(iii) In transportation to pull electric trains, trams, etc.

(iv) In agriculture for irrigation purposes.

2. Define ampere (as rate of flow of charge)?

A. **Ampere:** If one coulomb of charge flows through any section of a conductor in one second, then current through it is said to be one ampere.

$$1\text{ampere}=\frac{1\text{coulomb}}{1\text{second}} \text{ or } 1A=\frac{1C}{1s}=1Cs^{-1}$$

The smaller units of current are mill ampere and microampere.

1 mill ampere = 1 mA = 10^{-3} A

1 microampere = $1\ \mu A=10^{-6} A$

3. What is an electric circuit?

A. **Electric Circuit:** A closed and continuous path, along which an electric current flows is called an Electric Circuit.

In a torch, a switch provides a conducting link between a battery (a number of cells placed in proper order) and a bulb. When the switch is turned ON, electric current flows through the bulb and it gives light. Such a continuous and closed path of an electric current is called an electric circuit. When the circuit is broken anywhere (or the switch is turned OFF), the current stops flowing and the bulb does not glow.

4. What is the need of using combination of resistances in electrical circuits? Define equivalent resistance?

A. **Combination of Resistances:** In order to obtain a desired value of current in an electrical circuit, a number of resistances have to be used. Resistances can be combined together in the following three ways:

(i) Series combination.

(ii) Parallel combination.

(iii) Mixed combination.

Equivalent Resistance: if a single resistance can replace the combination of resistances in such a manner that the current in the circuit remains unchanged, then that single resistance is called the equivalent resistance.

5. Give four reasons why Nichrome element is commonly used in household appliances?

A. In most of the household heating appliances, Nichrome element is used because of the following reasons:

(i) Its melting point is high.

(ii) Its resistivity is large.

(iii) It can be easily drawn into thin wires.

(iv) It is not easily oxidised by the oxygen of the air when heated.

6. Define the term electric power. Write an expression for it.

A. **Electric Power:** The electric power of an appliance is the rate at which it consumes electric energy. Or it is defined as the watt at which work is done in maintaining an electric current in an electric circuit.

When a current I flows through a circuit for a time *t* at a constant potential difference V, then the work done is,

$$W = VIt \ joule$$

$$\therefore Electric \ power, P = \frac{W}{t} = \frac{VIt}{t}$$

$$\text{Or } \boxed{P = VI = I^2R = \frac{V^2}{R}}$$

Electric power = Voltage x Current

Three Marks Questions (50 words)

1. What are the factors on which the resistance of a conductor depends? Give the corresponding relation?

A. Factors affecting the resistance: At a constant temperature, the resistance of a conductor depends on the following factors:

(i) Length: Resistance R of a conductor is directly proportional to its length L, i.e.

$$R \propto L$$

(ii) Area of cross-section: Resistance R of conductor is inversely proportional to its area of cross-section A, i.e., -

$$R \propto \frac{1}{A}$$

(iii) Nature of the Material: Resistance also depends on the nature of the material of which the conductor is made. The resistance of a copper wire is much less than that of a Nichrome wire of same length and area of cross-section.

Combining the above factors, we get,

$$R \propto \frac{L}{A} \text{ or } R = \rho\frac{L}{A}$$

The proportionality constant is called resistivity or specific resistance which depends on the nature of the material.

2. How can we classify solids on the basis of their resistivity values?

A. On the basis of their resistivity values, solids can be classified into three categories:

(i) Conductors: Metals and their alloys have low resistivity in the range 10^{-8} ohm m to 10^{-6} ohm m. These are known as good conductors of electricity. They offer very low resistance to the flow of current. Copper and aluminum have lowest resistivities.

(ii) Insulators: These are the substances which have large resistivities, more than 10^{4} ohm m. Insulators like glass and rubber have high resistivities in the range of 10^{12} to 10^{17} ohm m.

(iii) Semiconductors: These are the substances whose resistivities lie in between those of conductors and insulators i.e., between 10^{-6} to 10^{4} ohm m. Germanium and silicon are typical semiconductors which are of great importance in chips fabrication.

Class	Substances	Resistivity(in ohm m)
Metals	Silver	1.60 x 10^{-8}
(Conductors)	Copper	1.62 x 10^{-8}
	Aluminium	2.63 x 10^{-8}
	Tungsten	5.20 x 10^{-8}
	Nickel	6.84 x 10^{-8}
	Iron	10.0 x 10^{-8}
	Chromium	12.9 x 10^{-8}
	Mercury	94.0 x 10^{-8}
	Manganese	1.84 x 10^{-8}
Alloys	Constantan	49 x 10^{-6}
(Conductors)	(Cu 60%, Ni 40%)	
	Manganin	44 x 10^{-6}
	(Cu84%,Mn12%, Ni 4%)	
	Nichrome	100 x 10^{-6}
	(Ni60%,Cr12%,Mn2%,Fe 26%)	
Semiconductors	Germanium	0.46
Insulators	Silicon	2.300
	Glass	10^{10} — 10^{14}
	Hard rubber	10^{13} — 10^{16}
	Ebonite	10^{15} — 10^{17}
	Diamond	10^{12} — 10^{13}
	Paper (dry)	10^{12}

Five Marks Questions (70 words)

1. Derive an expression for the combination of three resistances connected in parallel?

A. **Parallel Combination of Resistances:** If a number of resistances are connected in between two common points so that each of them provides a separate path for current, then they are said to be connected in parallel.

As shown in Fig. 12.21, consider three resistances R_1, R_2 and R_3 connected in parallel. Suppose a current I flows through the circuit when a cell of voltage V is connected across the combination. The current I at point A is divided into three parts I_1, I_2 and I_3 through the resistances R_1, R_2 and R_3 respectively. These three parts recombine at point B to give the same current I.

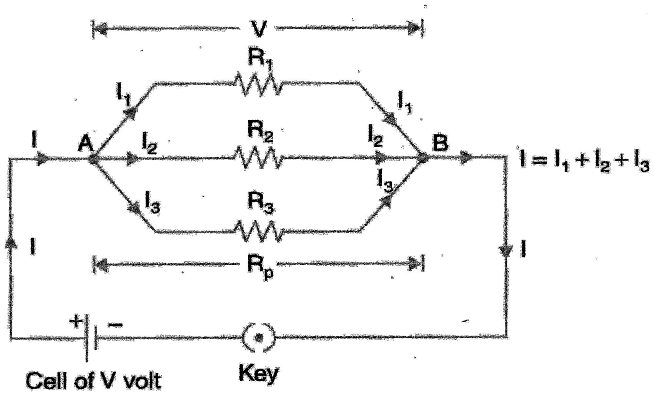

Fig. 12.21. *Resistances connected in parallel*

$\therefore I = I_1 + I_2 + I_3$

As all the three resistances have been connected between the same two points A and B, so voltage V across each of them is same. By Ohm's law,

$$I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}, I_3 = \frac{V}{R_3}$$

If R_p be the equivalent resistance of the parallel combination, then

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

But $I = I_1 + I_2 + I_3$

$$\therefore \frac{V}{R_p} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

Or $\boxed{\frac{V}{R_p} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}}$

Laws of Resistances in Parallel:

(i) Voltage across each resistance is same and is equal to the applied voltage.

(ii) Total current = Sum of the currents through the individual resistances.

(iii) Currents through various resistances are inversely proportional to the individual resistances.

(iv) Reciprocal of equivalent resistance = Sum of reciprocals of individual resistances.

(v) Equivalent resistance is less than the smallest individual resistance.

2. Derive an expression for the equivalent resistance of three resistances connected in series.

A. **Series Combination of Resistances:** If a number of resistances are joined end to end so that the same current flows through each of them in succession, then the resistances are said to be connected in series.

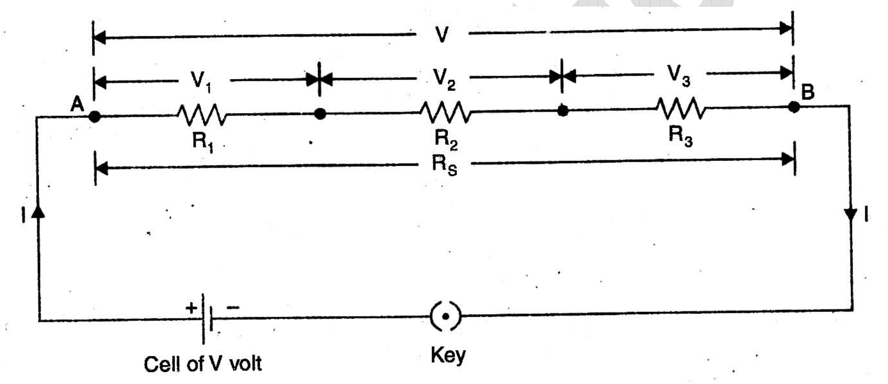

Fig. 12.16. *Resistances connected in series*

As shown in Fig. 12.16, consider three resistances R_1, R_2 and R_3 connected in series. Suppose a current I flows through the circuit when a cell of voltage V is connected across the combination.

By Ohm's law, the potential differences across the three resistances will be,

$$V_1 = IR_1\ ,\ V_2 = IR_2\ ,\ V_3 = IR_3$$

If R_8 be the equivalent resistance of the series combination, then on applying a potential difference V across it, the same current I must flow through it. Therefore,

$$V = IR_8$$

But $\quad V = V_1 + V_2 + V_3$

$$IR_S = IR_1 + IR_2 + IR_3$$

Or $\quad \boxed{R_s = R_1 + R_2 + R_3}$

Laws of Resistances in Series:

(i) Current through each resistance is same.

(ii) Total voltage across the combination = Sum of the voltage drops.

(iii) Voltage drop across any resistor is proportional to its resistance.

(iv) Equivalent resistance = Sum of the individual resistances.

(v) Equivalent resistance is larger than the largest individual resistance.

//o0o