ELECTRICITY

Electricity has an important role in modern society. In a span of more than 100 years, electricity has indeed, developed from a mere experimental activity in the laboratory into one of the most convenient and widely used forms a energy in the world. One of the practical advantage of electricity as a from of energy, is that it can readily transmitted over considerable distance with relatively small loss in energy. This makes it possible to supply electricity from a central generating plant to any location.

1.1 ELECTRIC CHARGE :

When we run our shoed across a carpet and reach for a metal doorknob, we can be zapped by an agoing spark of electricity. The answers to this lie in the branch of Physics called Electrostatics. The word electricity comes from the Greek word electron, which means “amber.” Amber is petrified tree resin and it was well known to the ancients that if we rub an amber rod with a piece of cloth, the amber attracts small pieces of dry leaves or paper. A piece of hard rubber, a glass rod or a plastic comb rubbed with cloth also display this “amber effect” or static electricity or frictional electricity as we call it today.
Experiments show that there are exactly two kinds of electric charges :
(i) Negative charge (ii) Positive charge
This also shows that unlike charges attract each other while like charges repel each other.
The S.I. unit of electric charge is coulomb. It is denoted by symbol **C**

1.1 (a) Conductors and Insulators :

In some substances, the electric charges can flow easily while in other they cannot. S, all the substances can be divided mainly into two electrical categories: Conductors and insulators.

(i) **Conductors :** Those substances through which electric charges can flow, are called conductors. But the flow of electric charges is called electricity. All the metals like silver copper and aluminum etc., are conductors. Carbon, in the form of graphite, is a conductors an the aqueous solution (water solution) of salts are also conductors. The human body is a fairly good conductor. All the conductors (like metals) have some electrons which are loosely held by the nucleus of their atoms. These electrons are called “free electrons” and can move from one atom to another atom throughout the conductor. The presence of “free electrons” in a substance makes it a conductor of electricity.

(ii) **Insulators :** Those substances through which electric charges cannot flow, are called insulators. In other words, those substances through which electricity cannot flow are called insulators. Glass, ebonite, rubber, most of the plastics, paper, dry wood, cotton, mica, bakelite, and dry air, are all insulators because they do not allow electric charges (or electricity) to flow through them. In the case of charged insulators like glass, ebonite etc., the electric charges remain bound to them and do not move away.

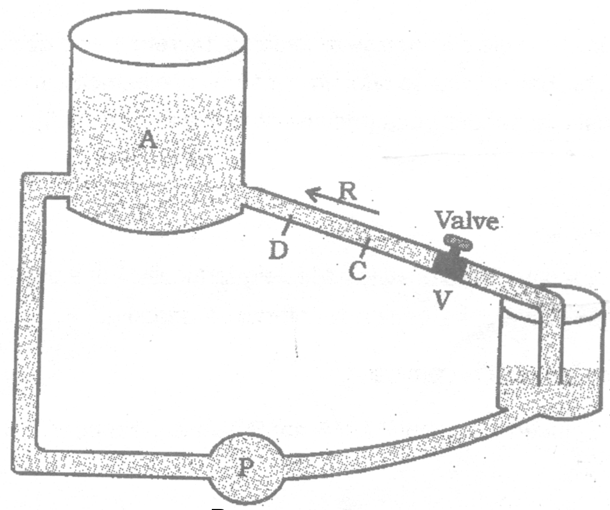
The electrons present in insulators are strongly held by the nuclei of their atoms. Since there are “no free electron” in an insulator which can move from one atom to another, so insulator does not allow electric charges (or electricity) to flow through it.

NOTE : Those substance whose conductivity lies in between the conductors and insulators are called semi-conductors.

For e.g. : Silicon, germanium are semi - conductors.

1.2 ELECTRIC FIELD AND ELECTRIC POTENTIAL :

The flow of electricity in a circuit can be regarded very mush similar to the flow of water in a pipe. The water pipe is analogous to the electric conductor, while the amount of water flowing through a given point per second corresponds to electric current. Figure below show how the pump (P) builds up and maintains pressure by lifting water from a tank (B) to the reservoir (A) through the pipe (R).Note that along the pipe, different points are at different pressure. Water in the pipe flow from say, a point C to D only when the pressure at C is greater than that at D. Thus, when the value (V) is open, water start flowing into the reservoir.



Pump

In the same manner electrons will move along a wire only if there is a difference of electric pressure called potential difference along the conductor. This difference of potential produced by the cell or a battery, which acts like a water pump in the circuit.
The chemical action within the cell generates the difference in potential between the electrodes, which sets the electrons in motion and produces the current We define the electric potential difference between the two points, A and B, on a conductors carrying current, as the work done to move a unit charge from A to B. Potential difference (V) between the points A and B = work done (**W)**/charge (**Q**). The unit of potential is volt, named after a scientist Alessandra (1745 - 1827).
One volt is the potential difference when 1 joule of work is done to move a charge of 1C.

1.2 (a) Electric Field :

Electric field due to a given charge is defined as the space around the charge in which electrostatic force of attraction or repulsion due to charge can be experienced by any other charge. If a test charge experiences no force at a point, the electric field at that point must be zero.
Electric field intensity at any point is the strength of electric field at that point/ It is defined as the force experienced by unit positive charge placed at that point.

If $\vec{F}$ is the force acting on a test charge **+q$_0$** at any point **r**, then electric field intensity at this point is given by

$$\vec{E}(r) = \frac{\vec{F}}{q_0}$$

Electric field is a vector quantity and its S.I. unit is Newton per coulomb or N/C.

1.2 (b) Electric Potential :

The electric potential at a point in an electric field is defined as the amount of work done in moving a unit +ve charge from infinity to that point, without acceleration or without a change in K.E., against the electric force due to the electric field.

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

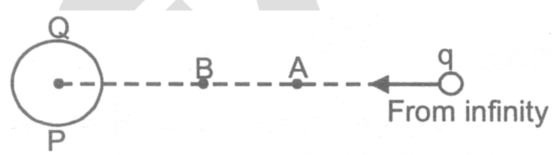
Since work is measured in joule and charge in coulomb, therefore electric potential is measured in joule per coulomb (**J/C**). This unit occurs so often in our study of electricity, so it has been named as volt, in honour of the scientist Alessandra Volta (the inventor of the voltaic cell).

$$1\,\text{Volt} = \frac{1\,\text{joule}}{1\,\text{coulomb}}$$

Potential is a scalar quantity, therefore it is added algebraically. For a positively charged body potential is positive and for a negatively charged body potential is negative.

1.2 (c) Electric Potential Difference :

Consider a charge Q placed at a point P. Let A and B be two other point (B being closer to A) as shown



If a charge q is brought from infinity to A, a work W_A will be done.

The potential at A will then be, $V_A = \frac{W_A}{q}$

If charge q is brought from infinity to B, the work done will be W_B.

The potential at B will the be, $V_B = \frac{W_B}{q}$

The quantity V_B - V_A is called the potential difference between points A and B in the electric field of charge Q.

Mathematically we have,

$$V_B - V_A = \frac{W_B}{q} - \frac{W_A}{q}$$

Electric potential difference is also measured in volt.

1.3 ELECTRIC CURRENT :

The electric current is a flow of electric charges (called electrons) in a conductor. The magnitude of electric current in a conductor is the amount of electric charge passing through a given point of the conductor in one second. If a charge of **Q** coulombs flow through a conductor in time **t** seconds, then the magnitude of the electric current **I** flowing through it is given by :

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

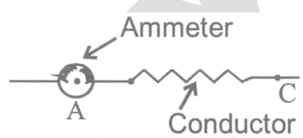
The nit of charge, in S.I. system is coulomb, which is equivalent to the charge of nearly 6.25×10^{18} electrons.
If charge is measured in coulomb, then the flow of 1 coulomb/second gives us the unit of current, which is called ampere named in the honour French scientist, Andre - Marie Ampere (1775 - 1836).

Definition of ampere :

When 1 coulomb of charge flows through any cross - section of a conductor 1 second, the electric current flowing through it, is said to be 1 ampere.

$$1 \text{ mA} = \frac{1}{1000} \text{ A}$$

Current is measured by an instrument called ammeter. The ammeter is connected in series with the circuit through which the current is to be measured. An ammeter should have very low resistance.

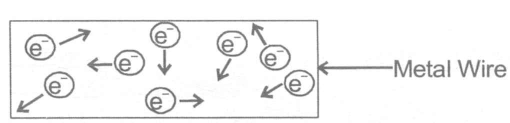


1.3 (a) Direction of Electric Current :

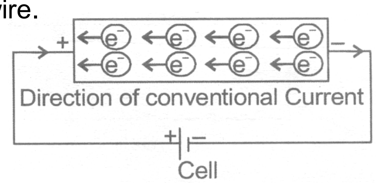
When electricity was invented a long time back, it was known that there are two types of charges : positive charges and negative charges, but the electron had not been discovered at that time. So, electric current was considered to be a flow of positive charges and the direction of flow of the positive charges was taken to be the direction of electric current. Thus, the conventional direction of electric current is from positive terminal of a cell (or battery) to the negative terminal through the circuit.

1.3 (b) How the Current Flows in a Wire :

As electric current is the flow of electrons in a metal wire (or conductor) when a cell or battery is connected across its ends. A metal wire has plenty of free electrons in it. When the metal wire has not been connected to a source of electricity like a cell or a battery, then the electrons present in it move at random in all the directions between the atoms of the metal wire as shown in figure below.



When a source of electricity like a cell or a battery is connected between the ends of the metal wire, then and electric force acts on the electrons present in the wire. Since the electrons are negatively charged, they start moving from negative end to the positive and of the wire and this flow of electrons constitutes the electric current in the wire.



1.3 (c) How to get a Continuous flow of Electric Current :

It is due to the potential difference two points that an electric current flows between them. The simplest way to maintain a potential difference between the two ends of a conductor so as to get a continuous flow of current is to connect the conductor between the terminals of a cell or a battery. Due to the chemical reactions going on inside the cell or battery, a potential difference is maintained between its terminals and this potential difference drives the current in a circuit.

1.4 ELECTRICAL SYMBOLS :

The various electrical symbols used in electric circuits are given below :

(i) Cell 

(ii) Battery 

(iii) Connecting wire

(vi) A wire joint 

(v) Wire crossing without contact 

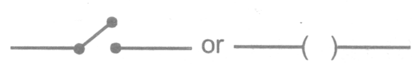
(vi) Fixed resistance (or Resistor) 

(vii) Variable resistance (or Rheostat) 

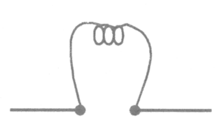
(viii) Ammeter 

(ix) Voltmeter 

(x) Galvanometer 

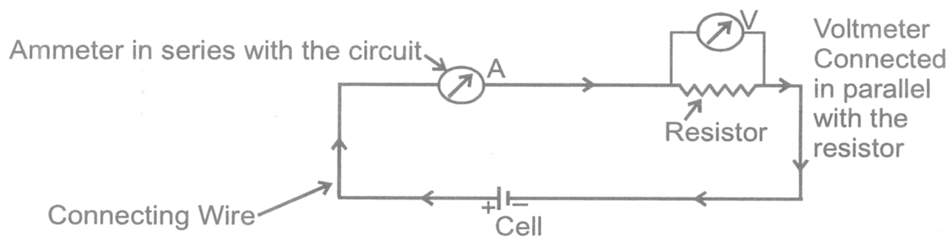
(xi) An open switch (An open plug key) 

(xii) A closed switch (A closed plug key) 

(xiii) Electric bulb 

1.4 ELECTRICAL CIRCUITS :

A continuous path consisting of conducting wires and other resistances (like lamps, bulbs etc.) between the terminal of a battery, along which an electric current flows, is called a circuit.



1.4 (a) Open Electric Circuit :

An electric circuit through which no electric current flows is known as open electric circuit. The electric circuit will be open circuit if the plug of the key is taken out or if the connecting wire break from any point.

1.4 (b) Closed Circuit :

An electric circuit through which electric current flows continuously is known as closed circuit.

DAILY PRACTIVE PROBLEMS # 1

OBJECTIVE DPP - 1.1

1. How many electrons constitute a current of
(A) 6.25×10^{18} (B) 6.25×10^{12} (C) 6.25×10^{11} (D) 6.25

2. 1 Coulomb is equal to :
(A) 1 amp × 1 sec (B) 1 amp / 1 sec (C) 1 joule × 1 amp (D) 1 joule / 1 sec

3. When a body is negatively charged by fraction, it means :
(A) the body has acquired excess of electrons (B) the body has acquired excess of protons
(C) must be zero (D) many be negative or positive or zero

4. If a charged body attracts another body, the charge on the other body :
(A) must be negative (B) must be positive
(C) must be zero (D) may negative or positive or zero

5. A suitable unit for expressing the strength of electric field is :
(A) V/C (B) C/m (C) N/C (D) C/N

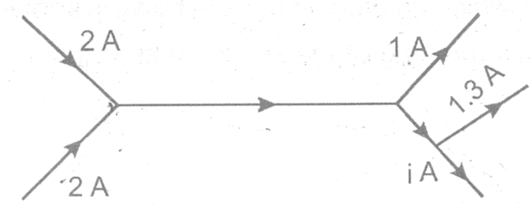
6. One ampere equal :
(A) $10^{6}\ \mu A$ (B) $10^{-6}\ \mu A$ (C) $10_{-3}\ \mu A$ (D) 10 mA

7. What constituted current in a metal wire ?
(A) Electrons (B) Protons (C) Atoms (D) Molecules

8. If **I** is the current through a wire and e is the charge of electron, then the number of electrons in **t** seconds will be given by-
(A) $\frac{Ie}{t}$ (B) e/It (C) It/e (D) Ite

9. Conventionally, the direction of the current is taken as -
(A) the direction of flow of negative charges (B) the direction of flow of atoms
(C) the direction of flow of positive charges (D) the direction of flow of molecules

10. Figure shows, current in a part of electrical circuit, then the value of current is -



(A) 1.7 A (B) 3.7 A (C) 13 A (D) 1.0 A

SUBJECTIVE DPP - 1.2

1. What is conventional current ?

2. A wire is carrying current. is it charged ? If yes then, why ?

3. One coulomb of charge flows through any cross section of a conductor in 1 second. What is the current flowing through the conductor ?

4. Which of the two is connected in series, ammeter or voltmeter ?

5. What is the potential difference between the terminals of battery is 250 joules of work is required to transfer 20 coulombs of charge from one terminal of the battery to the other ?

ELECTRICITY

2.1 ELECTRICAL RESISTANCE :

2.1 (a) Ohm's Law :

It states that the current passing through a conductor is directly proportional to the potential difference across its ends, provided the temperature and other physical conditions (mechanical stain etc.), remain unchanged i.e.,

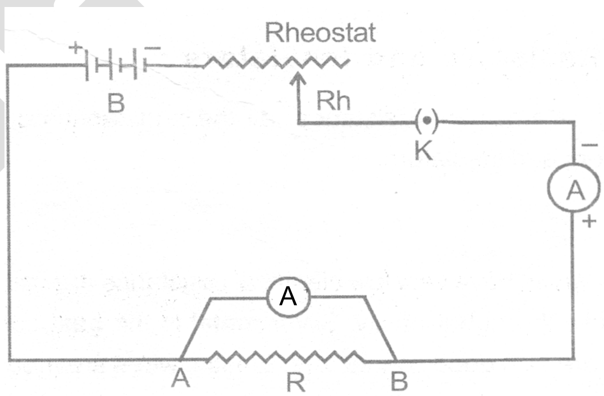
Where R is a content called resistance of the conductor.
The relation R = V/I is referred to an Ohm's law, after the German physicist George Simon Ohm (1789 - 1854), who discovered it.
It is quite clear from the above equation that

(i) The current **I** is proportional to the potential difference **V** between the ends of the resistor.

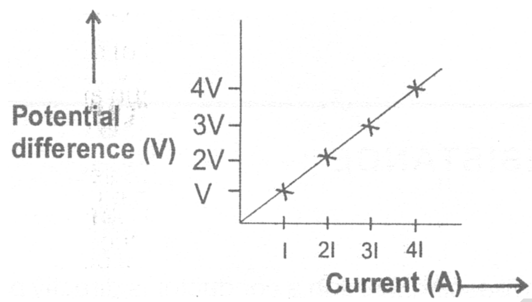
(ii) Current **I** is inversely proportional to the resistance.

Experimental verification of ohm's law :

Set up a circuit as shown in the figure below consisting of a wire AB, a current measuring instrument called ammeter, an instrument measuring the potential difference called voltmeter and a number of cells, each of which provided some constant potential difference across the two point of a conductor. First, use one cell and note the current in the circuit and the potential difference across the wire AB. Suppose potential difference due to the cell produces a current **I** in the circuit and a potential difference (**V**) across the wire AB. Repeat this experiment with two cells, three cells and four cells.



Note the successive readings in the ammeter and the voltmeter. WE will find that with two cells in the circuit, the current would be **2I** and the potential difference **2v.** Similarly, with three cells the current is **3I** and potential difference **3v** and so on. [The important precaution to observe here is not allow the current of flow in the wire continuously. This can be done by taking off the plug key and closing it only when the current is to be drawn.]
Now, plot a graph between the current and the potential difference. we will be a straight line graph.



2.1 (b) Resistance of a Conductor :

The electric current is a flow of electrons through a conductor. When the electrons move from one part of the conductor to the other part, they collide with other electrons and with the atoms and ions present in the body of the conductor. Due to these collisions, there is some obstruction or opposition to the flow of electrons through the conductor.
The property of a conductor due to which it opposes the flow of current through it, is called resistance. The resistance of conductor is numerically equal to the ratio of potential difference across its ends to the current following through it.

$$\Rightarrow \quad \text{Resistance} = \frac{\text{Potential difference}}{\text{Current}}$$

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

2.1 (c) Unit of Resistance :

The S.I. unit of resistance is **ohm**, which is denoted by the symbol Ω .
When a potential difference of 1 volt is applied to its ends and a current of 1 ampere flows through it, then resistance f the conductor will be 1 ohm.

2.1 (d) Conductors, Resistors and Insulators :

On the basis of their electrical resistance, all the substances can be divided into three groups: conductors, resistors and insulators.

(i) Conductors :

Those substances which have very low electrical resistance are called conductors. A conductor allows the electricity to flow through it easily. Silver metal is the best conductor of electricity. Copper and aluminum metals are also conductors. Electric wires are made of copper or aluminum because they have very low electrical resistance.

(ii) Resistor :

Thos substances which have comparatively high electrical resistance, are called resistors. The alloys like nichrome, manganin and constantan (or ureka), all have quite high resistances, so they are used to make those electrical devices where high resistance is required. A resistor reduces the current in the circuit.

(iii) Insulators :

Those substances which have infinitely high electrical resistance are called insulators. An insulator does to allow electricity to flow through it. Rubber is an excellent insulator. Electrician wear rubber hundgloves while working with electricity because rubber in an insulator and protects them from electric shocks. Wood is also a good insulator.

2.1 (e) Factors affecting the Resistance of a Conductor :

Resistance depends upon the following factors :

(i) length of the conductor.

(ii) Area of cross - section of the conductor (or thickness of the conductor).

(iii) Nature of the material of the conductor.

(iv) Temperature of the conductor,

Mathematically : it has been found by experiments that :

(i) The resistance of a given conductor is directly proportional to its length i.e.

$$R \propto \ell \qquad \text{……….(i)}$$

(ii) The resistance of a given conductor is inversely proportional to its area of cross-section i.e.

$$R \propto \frac{\ell}{A} \qquad \text{……..(ii)}$$

From (i) and (ii)

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

$$R = \frac{\rho \times \ell}{A} \qquad \text{………..(iii)}$$

Where ρ (rho) is a constant known as resistively of the material of the conductor. Resistivity is also known as specific resistance.

Dependency of resistance on temperature :

If R_0 is the resistance of the conductor at 0^0C and R_t is the resistance of the conductor at t^0C then the relation between R_0 and R_t is given by.

$R_t = T_0\,(1+ \alpha\Delta T)$ [Here $\Delta t = t - 0 = t$]

or $\alpha = \frac{R_t R_0}{R_0 t}$

Here, α = Coefficient of Resistivity, t= temperature in ^{0}C

2.1 (r) Resistivity :

Resistivity, $\rho = \frac{R \times A}{\ell}$ ....(iv)

By using this formula, we will now obtain the definition of resistivity. Let us take a conductor having a unit area of cross - section of 1 m^2 and a unit length of 1 m. So, putting A = 1 and ℓ = 1 in equation (iv), we get:
Resistivity, ρ = R

The resistivity of a substance is numerically equal to the resistance of a rod of the substance which is 1 metre long and 1 metre square in cross - section.

$$'\rho' = \frac{\text{ohm} \times (\text{metre})^2}{\text{metre}} = \text{ohm - metre}$$

The S.I. unit of resistivity is ohm-metre which is written in symbols as Ω-m.
Resistivity of a substance does not depend on its length or thickness. It depends only on the nature of the substance. The resistivity of a substance is its characteristic property. So, we can use the resistivity values to compare the resistances of two or more substances.

(i) Importance of resistivity :

A good conductor of electricity should have a low resistivity and a poor conductor of electricity should have a high resistivity. The resistivities of alloys are much more higher than those of the pure metals. It is due to their high resistivities that manganin and constantan alloys are used to make resistance wires used in electronic appliances to reduced the current in an electrical circuit.
Nichrome alloy is used for making the heating elements of electrical appliances like electric irons, room-heaters, water-heaters and toasters etc. because it has very high resistivity and it does not undergo oxidation (or burn) even when red-hot.

(ii) Effect of temperature of resistivity :

The resistivity of conductors (like metals) is very low. The resistivity of most of the metals increases with temperature. On the other hand, the resistivity of insulators like ebonite, glass and diamond is very high and does to changes with temperature. The resistivity of semi-conductors like silicon and germanium is in between those of conductors and insulators and decreases on increasing the temperature. Semi-conductors are proving to be of great practical importance because of their marked change in conducting properties with temperature and impurity concentration.

Que.: Why alloys do not oxidize (burn) readily at high temperature ?

Ans. Because with the change in temperature their resistivity changes less rapidly.

2.1 (g) Combination of Resistances (or Resistors):

Apart from potential difference, current in circuit depend or resistance of the circuit. So, in the electrical circuits of radio, television and other similar things, it is usually necessary to combine two or more resistances to get the required current in the circuit. We can combine the resistances lengthwise (called series) or we can put the resistances parallel to one another. Thus, the resistances can be combined in two ways : (i) series combination (ii) parallel combination

(i) Series combination of resistors :

Consider three resistors of resistances R_1, R_2 and R_3 connected in series to cell of potential difference V as shown in figure. Since the three resistors are connected in series therefore the current **I** through each of them is same.

Then by Ohm's law the potential drop across each resistor is given by $V_1 = IR_1$, V_2 and $V_3 = IR_3$.
Since V is the total potential in the circuit therefore by conservation of energy we have

$$V = V_1 + V_2 + V_3$$

Substituting for V_1, V_2 and V_3 in above equation we have,

$$V = IR_1 + IR_2 + IR_3 \quad \text{........... (i)}$$

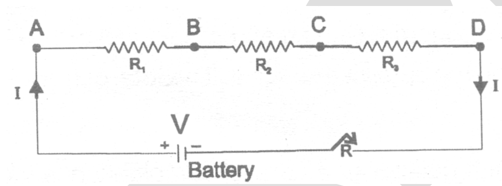
If R_S is the equivalent resistance of the series combination, then by Ohm's law we have

$$V = IR_s \quad \text{........... (ii)}$$

Therefore from equations (i) and (ii) we have

$$IR_s = IR_1 + IR_2 + IR_3$$

Hence $$R_s = R_1 + R_2 + R_3$$



Series comination of resistances

Thus in series combination the equivalent resistance is the sum of the individual resistances. For more resistors, the above expression would have been-
$R_s = R_1 + R_2 + R_3 + \text{............}$

NOTE :

In a circuit, if the resistors are connected in series :

(A) The current is same in each resistor of the circuit :

(B) The resistance of the combination of resistors is equal to sum of the individual resistors.

(C) The total voltage across the combination is equal to the sum of the voltage drop across the individual resistors.

(D) The equivalent resistance is greater than that of any individual resistance in the series combination.

(ii) Parallel combination of resistors :

Consider two resistors R_1 and R_2 connected in parallel as shown in figure. When the current I reached point 'a', it splits into two parts I_1 going through R_1 and I_2 going through R_2. If R_1 is greater than R_2, then I_1 will be less than I_1 i.e. the current will tend to take the path of least resistance.

Since charge must be conserved, therefore the current **I** that enters point 'a' must be equal to the current that leaves that point. Therefore we have

$$I = I_1 + I_2 \qquad ....(i)$$

Since the resistors are connected in parallel therefore the potential across each must be same, hence by Ohm's law we have

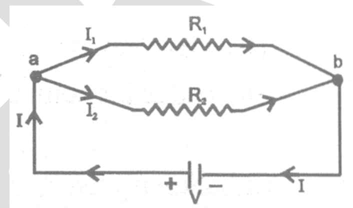
$I_1 = \frac{V}{R_1}$ and $I_2 = \frac{V}{R_2}$ substituting in equation (i) we have,

$$I = \frac{V}{R_1 + \frac{V}{R_2}} \qquad ....(ii)$$

Let R_P be the equivalent resistance of the parallel combination, they by Ohm's law we have,

$$I = \frac{V}{R_P} \qquad ....(iii)$$

Hence from equations (ii) and (iii) we have,



$$\frac{V}{R_P} = \frac{V}{R_1} + \frac{V}{R_2} \quad \text{or} \quad \frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$$

An extension of this analysis to three or more resistors in parallel gives the following general expression

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

NOTE :

(A) The sum of the reciprocals of the individual resistance is equal to the reciprocal of equivalent resistance, R_P.

(B) The currents in various resistors are inversely proportional to the resistances, higher the resistance of a branch, the lower will be the current through it. The total current is the sum of the currents flowing in the different branches.

(C) The voltage across each resistor of a parallel combination is the same and is also equal to the voltage across the whole group considered as unit.

NOTE : For n equal residences $\frac{R_s}{R_p} = n^2$

DIALY PRACTIVE PROBLEMS # 2

OBJECTVIE DPP - 2.1

1. When the temperature of metallic conductor is increased its resistance :
(A) always decrease
(B) always increase
(C) may increase or decease
(D) remain the same

2. Specific residence of a wire depends upon :
(A) its length
(B) its cross - sectional area
(C) its dimensions
(D) its material

3. The unit of resistivity is :
(A) ohm
(B) ohm meter
(C) ohm metre^{-1}
(D) mho metre^{-1}

4. A wire of resistance R is cut into n equal parts. These parts are then connected in parallel. The equivalent resistance of combination will be :
(A) nR
(B) R/n
(C) n/R
(D) R/n^2

5. A piece of wire of resistance $4\,\Omega$ is bent through 180^0 at its mid point and the two halves are twisted together, then resistance is :
(A) $1\,\Omega$
(B) $2\,\Omega$
(C) $5\,\Omega$
(D) $8\,\Omega$

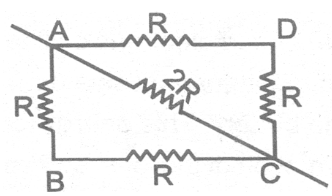
6. Three resistance each of $8\,\Omega$ are connected to a triangle. The resistance between any two terminal will be:
(A) $12\,\Omega$
(B) $2\,\Omega$
(C) $6\,\Omega$
(C) $\frac{16}{3}\,\Omega$

7. In how many parts(equal) a wire of $100\,\Omega$ be cut so that a resistance of $1\,\Omega$ is obtained by connecting them in parallel ?
(A) 10
(B) 5
(C) 100
(D) 50

8. The filament of an electric bulb is made of tungsten because :
(A) its resistance is negligible
(B) it is cheaper
(C) its melting point is high
(D) its filament is easily made

9. If a wire of resistance $1\,\Omega$ is stretched to double its length, then the resistance will become :
(A) $\frac{1}{2}\,\Omega$
(B) $2\,\Omega$
(C) $\frac{1}{4}\,\Omega$
(D) $4\,\Omega$

10. In the given circuit, the effective resistance between points A and C will be :



(A) $\frac{3}{2}R$ (B)6R (C) $\frac{2}{3}R$ (D) 3R

SUBJECTIVE DPP - 2.2

1. Does the value of resistance of a conductor depend upon the potential difference applied across it or the current passed through it ?

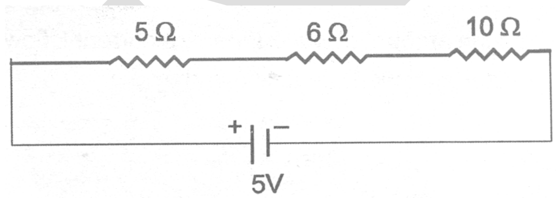
2. A wire of resistivity ρ is stretched to double its length. What will be its new resistivity ?

3. Two wires A and B of same metal have the same area of cross-section and have their lengths in the ratio 2 : 1. What will be the ratio of currents flowing through them, when the same potential difference is applied across length of each of them ?

4. Compare the resistance of two wires of same material. Their lengths are in the ratio 2 : 3 and their diameters are in the ratio 1 : 2.

5. If the current supplied to a variable resistor is constant, draw a graph between voltage and resistance.

6. Calculate the potential difference across each resistor in the circuit shown in figure below.



ELECTRICITY

3.1 HEATING EFECT OF CURRENT :

When the ends of a conductor are connected to a battery, then free electrons move with drift velocity and electric current flows through the wire. These electrons collide continuously with the positive ions of the wire an thus the energy taken from the battery is dissipated. To maintain the electric current in the wire, energy is taken continuously from the battery. This energy is transferred to the ions of the wire by the electrons. This increases the thermal motion of the ions, as a result the temperature of the wire rises. The effect of electric current due to which heat is produced in a wire when current is passed through it is called heating effect of current or Joule heating. In 1841 Joule found that when current is passed through a conductor the heat produced across it is :

(i) Directly proportional to the squire of the current through the conductor i.e. $H \propto I^2$

(ii) Directly proportional to the resistance of the conductor i.e. $H \propto R$

(iii) Directly proportional to the time for which the current is passed i.e. $H \propto t$

Combining the above three equations we have $H \propto I^2Rt$

or $H = \dfrac{I^2Rt}{J}$

Where J is called Joule's mechanical equivalent of heat and has a value of J = 4.18 cal^{-1}. The above equation is called Joule's law of heating.

In some cases, heating is desirable, while in many cases, much as electric motors, generators or transformers, it is highly undesirable. Some of the devices in which heating effect of an electric current is desirable, are incandescent lamps, toasters, electric irons and stoves. The tungsten filament of an incandescent lamp operates at a temperature of 2700^0 c. Here, we see electrical energy being converted into both heat and light energy.

3.1 (a) Electric Energy :

The fact that conductors offer resistance to the flow of current, means that work must be continuously done to maintain the current. The role of resistance in electrical circuits in analogous to that of friction in mechanics. To calculate the amount of work done by a current I, flowing through a wire of resistance R, during the time t, the amount of work done is given by-

$$W = QV$$

but as $Q = I \times t$

therefore, the amount of work done, W is

$$W = V \times I \times t$$

By substituting the expression for V from Ohm's law,

$$\mathbf{V = IR}$$

we finally get $\mathbf{W = I^2 Rt}$

This shows that the electrical energy dissipated or consumes depends on the product of the square of the current I. flowing through the resistance R and the time t.

(i) Commercial unit of electrical energy (Kilowatt - hour) :

The S.I. unit of electrical energy is joule and we know that for commercial purposes we use a bigger unit of electrical energy which is called **"kilowatt - hour".** One kilowatt - hour is the amount of electrical energy consumed when an electrical appliance having a power rating of 1 kilowatt and is used for 1 hour.

(ii) Relation between kilowatt hour and Joule :

Kilowatt-hour is the energy supplied by a rate of working of 1000 watts for 1 hour.
1 kilowatt-hour = 3600000 joules
$\Rightarrow$ 1 kWh = 3.3×10^6 J

3.1 (b) Electric Power :

The rate at which electric energy is dissipated or consumed, is termed as electric power. The power P is given by,

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

The unit of electric power is watt, which is the power consumed when 1 A of current flows at a potential difference of 1 V.
(i) Unit of power : The S.I. unit of electric power **'watt'** which is denoted by the letter W. The power of 1 watt is a rate of working of 1 joule per second.
A bigger unit of electric power is kilowatt.
1 kilowatt (kW) = 1000 watt.
Power of an agent is also expressed in horse power (hp).
1 hp = 746 watt.

(ii) Formula for calculating electric power :

We know, Power, $P = \dfrac{\text{Work}}{\text{Time}}$

and Work, $W = V \times I \times t$ joules

$\therefore$ $P = \dfrac{V \times I \times t}{t}$

$P = V \times I$

$P = V \times I$

Power P in timers of I and R :

Now from Ohm's law we have $\dfrac{V}{I} = R$

$V = I \times R$

$P = I \times R \times I$

$\therefore$ $P = I^2 \times R$

Power P in terms of V and R :

We know, $P = V \times I$

From Ohm's low $I = \frac{V}{R}$

$$P = V \times \frac{V}{R}$$

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

3.1 (c) Power - Voltage Rating of Electrical Appliances :

Every electrical appliance like an electric bulb, radio or fan has a label or engraved plate on it which tells us the voltage (to be applied) and the electrical power consumed by it. For example, if we look at a particular bulb in our home it may have the figures **220 V, 100W** written on it. Now **220 V** means that this bulb is to be used on a voltage of **220 volts** and **100 W** Which means it has a power consumption of 100 watts or 100 joules per second.

3.1 (d) Application of Heating Effect of Current :

Domestic electric appliances such as electric bulb, electric iron geyser, room heater etc work on heating effect of current and are rated in terms of voltage and wattage. The coils of these devices are made of a material of a very high resistance, (for instance, nichrome or tungsten) such that when a current passes through the coil, heat is generated. Generally the potential difference applied to the electrical appliance is the same as the of the mains i.e. **220-230 V** in India an d**110 V** is U.S.A. Canada etc.

3.1 (e) Electric Fuse :

An electric fuse in an easily fusible wire of short length put into an electric circuit for protection purpose. It is arranged to melt ("blow") at a definite current. It is an alloy of lead and tin (**37% lead + 63% tin**). It has a low resistivity and low melting point. As soon as the safe limit of current exceeds, the fuse "blows" and the electric circuit is cut off.
Consider a wire of length **L**, radius r and resistivity **p.** Let **I** be the current flowing through the wire. Now rate at which heat is produced in the wirem.

$$P = I^2 R = \frac{I^2 \rho L}{\pi r^2} \qquad \left[\therefore \frac{\rho L}{A} = \frac{\rho :}{\pi r^2}\right]$$

This heat increases the temperature of the wire. Due to radiation some heat is lost. The temperature of the fuse becomes constant when the heat lost due to the radiation becomes equal to the heat produced due to the passage of current. This given the value of current which can safely pass through the fuse. In other words we have,

$$I \propto r^{3/2}$$

Illustration :

1. 15 bulbs of 60W each, run for 6 hours daily and a refrigerator of 300 W runs for 5 hours daily. Work out per day bill at 3 rupees per unit.

Sol. Total wattage of 15 bulbs = 15 " 60 W = 900 W
$\therefore$ Electrical energy consumed by bulbs per day = P × t = 900 × 6 = 5400 Wh
And electrical energy consumed by refrigerator per day = 300 × 5 = 1500 Wh
Total electrical energy consumed per day = (5400 + 1500) Wh = 6900 Wh

$\therefore$ Electrical energy consumed per day = $\frac{6900}{1000}\text{KWh} = 6.9\text{KWh}$

Here, per day bill = Rs. 6.9 × 3 = Rs. 20.7

2. Two lamps, one rated 100 W at 220 V and other 60 W at 220 V are connected in parallel to a 220 V supply. What is current drawn from the supply line ?

Sol. Given that

V = 220 V

P_1 = 100W and P_2 = 60 W

$\therefore$ Current $I_1 = \frac{P_1}{V} = \frac{100}{220} = \frac{5}{11}$ A

Similarly,

Current $I_2 = \frac{P_2}{V} = \frac{60}{220} = \frac{3}{11}$ A

Hence, total current drawn from the supply line = $\frac{5}{11} + \frac{3}{11} = \frac{8}{11}\text{A} = 0.727$ A.

DAILY PRACTIVE PROBLEMS # 3

OBJECTVIE DPP - 3.1

1. Rate of heat generated by electrical current in a resistive circuit is expressed in :
(A) IR (B) IR^2 (C) I^2R (D) $\sqrt{IR}$

2. Two heater wires of equal length are first connected in series and then in parallel with a battery. They ratio of heat produced in the two cases in :
(A) 2 : 1 (B) 1 : 2 (C) 4 : 1 (D) 1 : 4

3. How much electrical energy in kilowatt hour is consumed in operating ten, 50 watt bulbs for 10 hours per day in a month of 30 days ?
(A) 15 (B) 150 (C) 1500 (D) 15000

4. An electric iron draws a current of 4A when connected to a 220 V mains. Its resistance must be :
(A) 40 Ω (B) 55 Ω (C) 100 Ω (C) None of these

5. The resistance of a conductors is reduced to half its initial value. In during so the heating effects in the conductor will become :
(A) half (B) one-fourth (C) four times (D) double

6. Laws of heating are given by :
(A) Faraday (B) Joule (C) Ohm (D) Maxwell

7. An electric iron is based upon the principle of :
(A) magnetic effect of current (B) heating effect of current
(C) chemical effect of current (D) none of these

8. A fuse wire is always connected to the :
(A) neutral wire (B) earth wire (C) live wire (D) none of these

9. Heating effete of a current conductor is due to :
(A) Loss of kinetic energy of moving atoms (B) Loss of kinetic energy of moving electrons
(C) Attraction between electrons and atoms (D) Repulsion between electrons and atoms

10. The correct relation between heat produce (H) and electric current following is :
(A) $H \propto I$ (B) $H \propto \frac{1}{I}$ (C) $H \propto I^2$ (D) $H \propto \frac{1}{I^2}$

SUBJECTIVE DPP - 3.2

1. An electric kettle is rated 500 W, 220 V. It is used to heat 400 g of water for 30 seconds. Assuming the voltage to be 220 V, calculate the rise in the temperature of the water. Specific heat capacity of water = 4200 J/kj^{0}C.

2. Three identical are connected in parallel with a battery. The current drawn from the battery is 6 A. If one of the bulbs gets fused, what will be the total current drawn from the battery ?

3. When two resistor are joined in series, the equivalent resistance is $90\,\Omega$. When the same resistors are joined in parallel, the equivalent resistance is $20\,\Omega$. Calculate the resistances of the two resistors.

4. Name of few practical applications of heating effect of current.

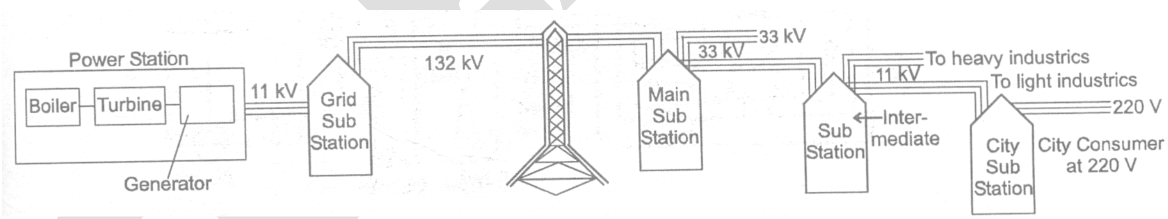
5. Out of the following bulbs rated 40 W, 220 V, 60 W, 220 V and 100 W, 220 V which one will glow the brightest when connected in series in series to a supply of 220 V ?

ELECTRICITY

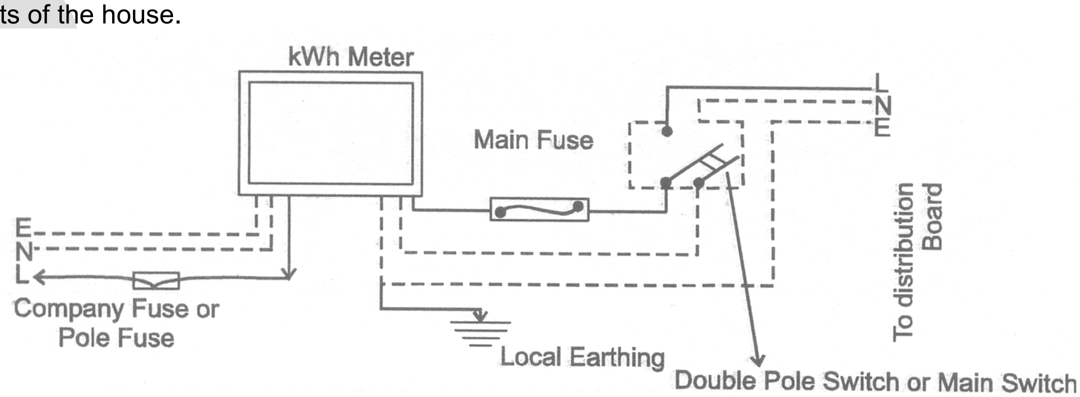
4.1 HOUSE - HOLD ELECTRICAL CIRCUIT :

Electric power is usually generated at placed which are very far from the placed where it is consumed. At the generating station, the electric power is generated at 11.000 volt (because voltage higher than this causes insulation difficulties, while the voltage lower than this involves high current). This voltage is alternating of frequency 50 Hz (i.e. changing its polarity 50 times in a second). The power is transmitted over long distances at high voltage to minimize the loss of energy in the transmission line wires. For a given electric power, the current becomes low at a high voltage and therefore the loss of energy due to heating ($=I^2$ Rt) becomes less. Thus, the alternating voltage is stepped up from 11 kV to 132 kV at the generating station (or called grid sub - station). It is then transmitted to the main sub-station. At the main sub-station, this voltage is stepped down to 33 kV and is transmitted to the switching transformer station or the city sub-station. At the city sub-station, it is further stepped down to 220 V for supply to the consumer as shown in figure.

To supply power to a house either the overhead wires on poles are used or an underground cable is used. Before the electric line is connected to the meter in a house, a fuse of high rating ($\approx$50 A) is connected at the pole or before the meter. This is called the company fuse. The cable used for connection has three wire : (i) live (or phase) wire, (ii) neutral wire and (iii) wire. The neutral and the earth wire are connected together at the local sub-station, so the neutral wire is at the earth potential. After the company fuse, the cable is connected to a kWh meter. From the meter, connections are made to the distribution board through a main fuse and a main switch.



The main switch is a double pole switch. it has iron covering. The covering is earthed. This switch is used to cut the connections of the live as well as the neutral wires simultaneously. The main switch and the meter and locally earthed (in the compound of house). From the distribution board, the wires go to the different parts of the house.

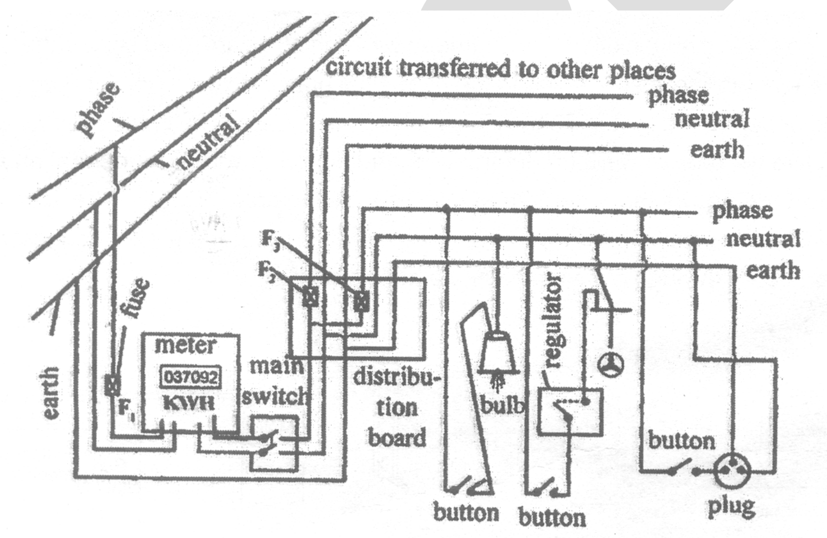


There are two systems of wiring which are in common use :

(i) the tree system (ii) the ring system

4.1 (a) Tree System :

In this system different branch lines are taken from the distribution board for the different parts of the house. These branch lines look like the different branches of a tree. Each branch line is taken to a room through a fuse in the live wire. The different circuits are connected in parallel so that if there is a short circuiting in one distribution circuit, its fuse will blow off, without affecting the electric supply in the other circuits. The neutral N and the earth E are common for all circuits. The connection to the neutral N is to complete the circuit. All the appliances in a room are connected in parallel so that they work at the same voltage. The line wires used for connections should be of proper current carrying capacity depending on the rating of the appliance to avoid their overheating. The overheating in line often results in fire. The switches and sockets should also have the proper current carrying capacity.



Disadvantages :

(i) It requires plugs and sockets of different sizes for different current carrying capacities.

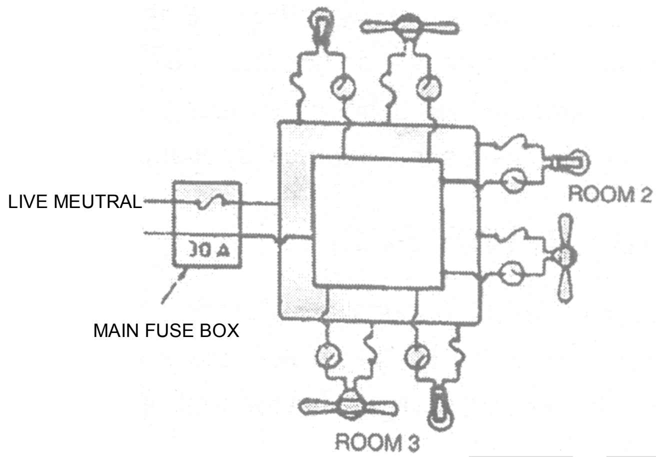
(ii) When the fuse in one distribution line blows, it disconnects all the appliances in the distribution line.

(iii) This wiring is expensive.

(iv) If a new appliance is to be installed requiring higher current say 15 A, white the original circuit in the room is for 5 A rating, then it is necessary to put new leads upto the distribution box. This could be quite expensive and inconvenient.

4.1 (b) Ring System :

The ring-system of electric wiring is now rapidly replacing the older tree system described above. It consists of a ring-circuit. Wires starting from the main fuse-box, run around all the main rooms o the house and then come back to the fuse-box again. The fuse box contains a fuse of rating about 30A. A separate connection is taken from the live wire of the ring for each appliance. The terminal of the appliance is connected to the live wire through a separate fuse and a switch. If the fuse of one appliance burns, it does not affect the other appliances. For each appliance, the wires used for connection should b of proper carrying capacity.



The fing system of witing

Advantages :

It can be noted that the current can travel to an individual appliance through two separate paths. Thus effectively the connection for each appliance is through double thickness of wire. Therefore the wire used for ring main is of a lower rating than that would be required for a direct connection to the mains. This reduces the cost of wiring considerably. Plugs and sockets of the same size can be used, Another advantage of this system is in installing a new appliance, since a new line up to the distribution box is not required. The appliance can be directly connected to ring main in the room. The only consideration is that the total load on the ring circuit should not exceed the main fuse viz. 30 A.

4.1 (c) Domestic Heating Applications :

Electric appliances like iron, heater radiator etc. depend on the fact that when a current is sent through a wire, the wire is heated up and it begins to radiate energy.
The most widely used material for making the heater wire is nichrome. It is an alloy of nickel and chromium in the ratio of 4 : 1. It is chosen because of the following reasons :
(i) It has high resistivity. A nichrome wire of ordinary length shows sufficient resistance.
(ii) It can withstand high temperature without oxidation.
(iii) Its melting point is very high.

4.1 (d) Hazards of Electricity :

We have seen earlier that touching a bare electricity wire with current flowing through it can give a dangerous electric shock. This is because electricity then flows through the body and damages the cells. The among of damage caused depends on the magnitude of current and the duration for which it flows is the body. The magnitude of current increases if the body is wet. That is why we are always advised not to touch any electrical appliances or a switch with wet hands.

A severe electric shock affects the muscles. Sometimes the shock may be so severe than the person may not be able to use his muscle to pull his hand away from the wire. In extreme cases, the heart muscles may get affected and may even lead to death.

4.2 EARTHING :

Earthling means to connect the metal case of electrical appliance to the earth (at zero potential) by means of a metal wire called “earth wire”. In household circuits, we have three wires, the live wire, the neutral wire and the earth wire. In household circuits. we have three wires, the live wire, the neutral wire an the earth wire. One and of the earth wire is buried the earth. We connect the earth wire to the metal case of the electrical appliance by using a three-pin plug. The mental casing of the appliance will now always remain at the zero potential of the earth. We say that the appliance has been earthed or grounded.

If, by chance, the live wire touches the metal cause of the electric iron (or any other appliance) which has been earthed, then the current passed directly to the earth through the earth wire. It does not need our body to pass the current and therefore, we do not get an electric shock. Actually, a very heavy current flows through the earth wire and the fuse of household wiring blows out or melts. And it cuts off the power supply. In this way, earthing also saves the electrical appliance from damage due to excessive current.

4.3 COLOUR CODING OF WIRES :

An electric appliance is provided with a three-core flexible cable. The insulation on the three wires is of different colours. The old convention is red for live, black for neutral and green for earth. The new international convention is brown for live, light blue for neutral and green (or yellow) for earth.

4.4 GALVANOMETER :

A galvanometer is an instrument that can detect the presence of a current is a circuit. The pointer remain at zero (the centre of the scale) for zero current flowing through it. It can deflect either to the left or to the right of the zero mark depending on the direction of current.

(i) Moving coil galvanometer (ii) Moving magnet galvanometer

it is used to make ammeter and voltmeter as follows :

4.4 (a) Ammeter :

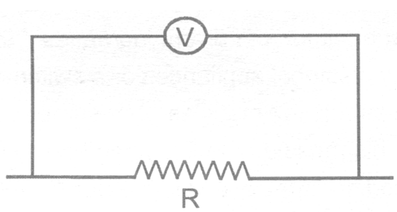
Ammeter is an electrical instrument which measures the strength of current in ‘ampere’ in a circuit which is always connected in series in circuit so that total current (to be measured) may pass through it. The resistance of an ideal ammeter is zero 9practically it should be minimum).

9.4 (b) Voltmeter :

it is an electrical instrument which measures the potential difference is ‘volt’ between two points of electric circuit. The only difference between ammeter and coltmeter is that ammeter has its negligible (approximately zero) resistance so that it may measure current of circuit passing through it more accurately giving the deflection accordingly, while the voltmeter passes negligible current through itself so that potential difference developed due to maximum current passing through circuit may be measured.

Voltmeter has very high resistance and the resistance of an ideal voltmeter is infinite.

A voltmeter is always connected in parallel.



DAILY PRATICE PROBLEMS # 4

OBJECTIVE DPP-4.1

1. The wire having a red plastic covering is a :
(A) live wire (B) neutral wire (C) earth wire (D) none of these

2. A switch is always connected to the
(A) earth wire (B) neutral wire (C) live wire (D) none of these

3. The wire having a black plastic covering is a
(A) live wire (B) neutral wire (C) earth wire (D) none of these

4. The wire having a green plastic covering is a
(A) live wire (B) neutral wire (C) earth wire (D) none of these

5. In three pin socket (shoe) the bigger hole is connected to :
(A) any wire (B) live wire (C) neutral wire (D) earth wire

6. Coming of live wire and neutral wire in direct contact cause :
(A) short-circuiting (B) over loading
(C) no damage (D) unknown effect

7. In electric fitting in a house :
(A) the live wire goes through the switch (B) the neutral wire goes through the switch
(C) the earth wire goes through the switch (D) no wire goes through the switch

8. High power electrical appliances are earthed to
(A) avoid shock
(B) avoid wastage
(C) Make the appliance look beautiful
(D) reduce the bill

SUBJECTIVE DPP - 4.2

1. Name two types of wiring system done for domestic wirings.

2. Why is earthing important for electrical appliance ?

3. Which colour wire used for earthing or grounding ?

4. Explain earthing.

ANSWERS

(DPP 1.1)

Q.	1	2	3	4	5	6	7	8	9	10
A.	A	A	A	D	C	A	A	C	C	A

(DPP 1.2)

2. No. **3.** 1A **4.** Ammeter **5.** 12.5 volt

(DPP 2.1)

Q.	1	2	3	4	5	6	7	8	9	10
A.	B	D	B	D	A	D	A	C	D	C

(DPP 2.2)

3. 1 : 2 **4.** 8 : 3 **6.** $\frac{25}{1}$ V, $\frac{30}{21}$ V, $\frac{50}{21}$ V

(DPP 3.1)

Q.	1	2	3	4	5	6	7	8	9	10
A.	C	D	B	B	D	B	B	C	B	C

(DPP 3.2)

1. 8.9^0C **2.** 4A **3.** **60 Ω , 30 Ω** **5.** 40W, 220V bulb will glow brightest.

(DPP 4.1)

Q.	1	2	3	4	5	6	7	8
A.	A	C	B	C	D	A	A	A