Chapter - 10
Electric Current

We know that heat flows from higher temperature to lower tempferature and the rate of flow of heat is called heat current. Similarly charge flows in a conducting wire from high potential to low potential and the rate of flow of charges is called the electric current. The direction of current is given from positive charge to negative charge as per convention i.e. the direction is opposite to the direction of motion of electrons.

10.1 Electric current

In any electric circuit the amount of charge passed from a point per unit time is called electric current. If charge Q passes through a point in time t then

$$\text{electric current} = \frac{\text{Charge}}{\text{time}} \quad \text{or } I = \frac{Q}{t}$$

If n electrons pass from a point in t time then a total of ne charge will pass in t time from that point. Hence ne

$$\text{electric current (I)} = \frac{ne}{t}$$

Where e is the charge on electron whose value is 1.6×10^{-19} Coulomb.

10.2 Unit of electric current

From the formula of electric current

$$I = \frac{Q}{t} \qquad \textit{Unit of } I = \frac{\textit{Columb}}{\textit{second}} = \textit{Ampere}$$

Electric current is also given as

1 milli Ampere = 10^{-3} Ampere

1 micro Ampere= 10^{-6} Ampere

Definition of one ampere

When Q = 1 Coulomb and t = 1 second then

$$I = \frac{1}{1} = 1 \text{ Ampere}$$

If one coulomb charge passes from any point in one second time then the current in the circuit will be one Ampere.

We use an ammeter in series of the circuit to measure electric current

Example 1 : Find the number of electrons in 1 coulomb of charge

Solution :

$$Q = ne$$

$$1 = n \times 1.6 \times 10^{-19}$$

$$n = \frac{1}{1.6\times10^{-19}}$$

$$n = \frac{10^{19}}{1.6} = \frac{10\times10^{18}}{1.6} = 6.25\times10^{18}$$

10.3 Potential and potential difference

Electric potential is responsible for flow of electricity in a charged object. When two charged objects are placed in contact of each other then positive charge always flows from an object of high potential to the object of low potential. If both the objects are at same potential i.e. the potential difference is zero and if two are in contact with each other then no charge or current will flow between the two objects.

The potential difference between two points of an electric circuit is defined by work. Work done in taking unit positive charge from one point to another point in an electric circuit is equal to the potential difference between the two points.

Potential difference between points A and B is

$$(V_A - V_B) = \frac{\text{Work done (W)}}{\text{Charge (Q)}}$$

$V_A - V_B = \frac{W}{Q}$ Its unit is Joule/Coulomb (Volt)

Electric potential

If point B is at ∞ then

$$V_A - V_\infty = \frac{W}{Q}$$

potential at infinity is considered zero

$$\therefore V_A = \frac{W}{Q} \qquad (\because V_\infty = 0)$$

if $Q = 1$ unit charge then $V_A = W$

Electric potential at any point is equal to the work done in bringing a unit charge from infinity to that point.

Equipment used to measure the potential difference is called Voltmeter. It is placed parallel to two points where potential difference is to be measured.

Example : 2 How much work is required to be done to transfer a charge of 3 coulomb between two points with potential difference of 10 volts.

Solution : $V_A - V_B = 10$ V Given W=?

$V_A - V_B = 10$ V and Q = 3 coulomb

$$V_A - V_B = \frac{W}{Q}$$

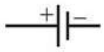
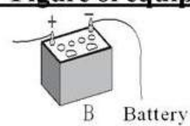
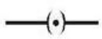
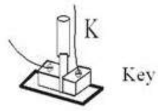
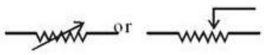
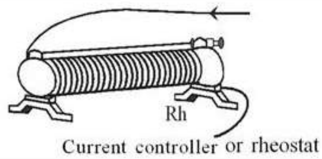
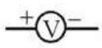
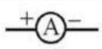
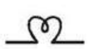
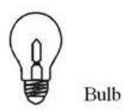
$$\therefore W = (V_A - V_B) \times Q$$

$W = 10 \times 3 \qquad W = 30$ Joule

10.4 Prevailing symbols of useful equipments in electrical circuits

While drawing electrical circuits different parts are reprsented by symbols for ease. Following table 10.1 shows a few of them -

Table 10.1 Symbols of common component and equipments used in different circuits

S.no.	Component	Symbol	Figure of equipment
1	Electric cell (Battery)		
2	Key or switch		
3	Variable resistance or rheostat or current controller		
4	Voltmeter		
5	Ammeter		
6	Electric bulb		

10.5 Ohm's law

German scientist Gerog Simon Ohm in 1826 observed a relation between the potential difference between two terminals of a conductor and the current flowing through the conductor. This rule is called Ohm's law and accroding to this law :

The potential difference between the terminals of a conductor is proportional to the current flowing through the conductor when physical states of the conductor like temperature, pressure, length and area etc remain constant

$$V \propto I, \quad V = RI$$

Where R is a constant and is called resistance of the conductor.

Unit of resistance

$$R = \frac{V}{I} \text{ Unit} \rightarrow \frac{\text{Volt}}{\text{Ampere}} = \text{Ohm}(\Omega)$$

Definition of 1 ohm

When a current of 1 amp is passed through a conductor and the developed potential difference is 1 volt then the resistance of that conductor will be 1 ohm.

Experimental verification of Ohm's law

Join a battery (B), a rheostat or current controller (R_h), an ammeter (A), a voltmeter (V) and a key (K) in series and a conducting wire PQ is joined parallel to a voltmeter as shown in the figure 10.1

By adjusting the current contraller (R_h) we change the current in the circuit and in conductor PQ. We note the current as well as corresponding voltage across PQ. Now we draw a graph between potential difference V and current I. We see that the graph is a straight line.

This proves that the potential difference across the terminals of conductor is proportional to the current flowing through it. This is ohm's law.

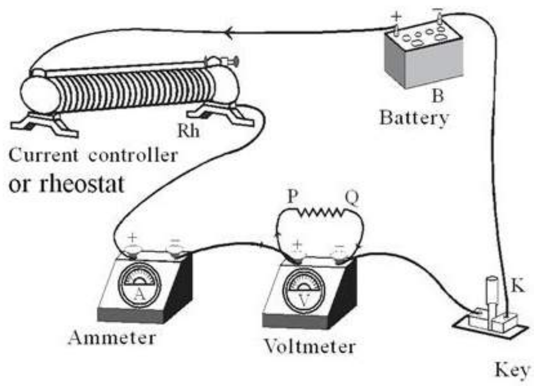


Fig. 10.1 Diagram for experimental verification of Ohm's law

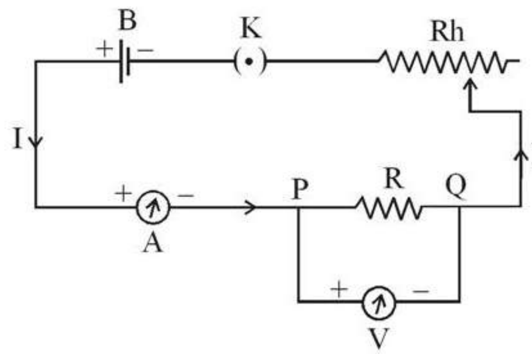


Fig 10.2 Circuit diagram to experimentally verify Ohm's law

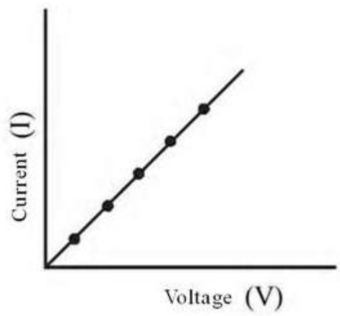


Fig 10.3 Graph between measured voltage and current

Example 3 : Find the resistance of a conducting wire in which potential difference of 2 volts is produced when 0.5 ampere current flows through it?

Solution :

Given I = 0.5 ampere

$V = 2\ V$

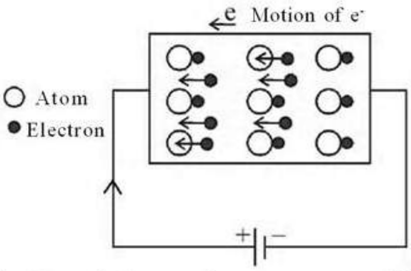
$R = ?$

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

$$R = \frac{2}{0.5} = 4\ \Omega$$

10.6 Resistance

Every conducting material is made of many molecules and these molecules are made of atoms. Electrons encircle around the nucleus in atoms. Electrons of the outermost orbit are relatvely loosely bound by the nucleus. These electrons move around freely in a conductor. When these conductors are connected to the battery then these free electons move towards the positive terminal of the battery. Atoms, molecules and ions in the conductor porvide hinderance to the movement of these electrons. This hinderrance is called resistance.



"The Restriction to the movement of charges in conductors is called Resistance".

As resistance is inversely proportional to the conductivity therefore when resistance of a conductor is low then its conductivity will be high.

10.6.1 Dependence of resistance

Resistance depends upon following factors

(a) On length - We take conducting wire of different lengths having same material and same diameter (cross-section) and find the resistances of these wires. Now we draw a graph between length of wire and its resistance. We find that the graph is a straight line. i.e. as the length of the conducting wire increases its resistance also increases or we can say that resistance (R) is proportional to its length

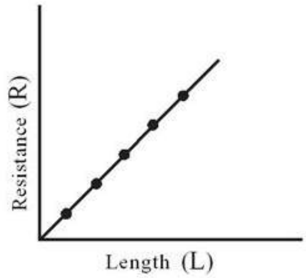


Fig. 10.4 Graph between R & L

$$R \propto L \qquad .....(10.1)$$

(b) On cross sectional area - Let us take different wires of the same material and same lenght but having different cross -sectional area and find their resistances. Now we draw a graph between the resistance and cross -sectional area A and between the resistance and inverse of cross -sectional are a $\left(\frac{1}{A}\right)$. We find that the graph is a strainght line i.e. as corss sectional area (A) or thickness of the wire is increased its resistance decreases.

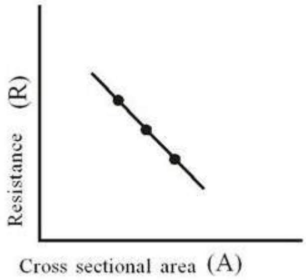


Fig. 10.5 Graph between R & A

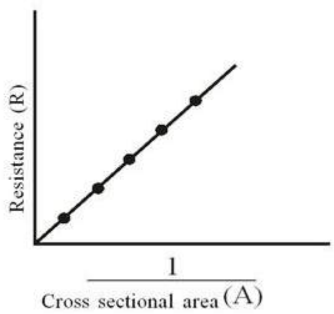


Fig. 10.6 Graph between R & 1/A

$$R \propto \frac{1}{A} \qquad .....(10.2)$$

From equation (10.1) and (10.2)

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

or $$R = K\frac{L}{A} \qquad ......(10.3)$$

Where K is a constant that is known as specific resistance of the conducting material or resistivity.

Unit of resistivity :

Solving equation (10.3) for K we get

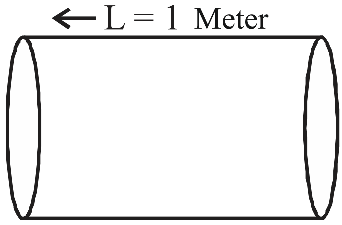
$$K = \frac{RA}{L}$$

$$\text{Unit of K} = \frac{\text{Ohm} \times \text{meter}^2}{\text{Meter}} = \text{Ohm} \times \text{Meter}$$

10.7 Resistivity

Assume a conducting wire with unit lenght and unit cross sectional area.

Thus resistance of wire of unit length and unit cross sectional area is known as specific resistance or resistivity, of the material.



Resistivity does not depend upon the lenght or cross sectional area of a conductor. It depends on the material of the conductor.

10.7.1 Dependence of resistance on temperature

As temperature is increased the resistance increases for metals like silver, copper and gold while for alloys like manganin and constantan the resistance very slightly with change in temperature. On the contrary for materials like silicon (Si) and germanium (Ge) the resistance decreases with increase in temperature. These are called semi-conductors.

L= 1 Meter A= 1 m^2

$$K = \frac{R \times 1}{1} \qquad \text{or} \qquad K = R \text{ Ohm x Meter}$$

Table 10.2 Specifice resistance of a few materials

Category	Material	Specific resistance (Ohm x meter)
Conductor	Silver	1.60×10^{-8}
	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.20×10^{-8}
	Nickel	6.84×10^{-8}
	Iron	10.0×10^{-8}
Alloys	Constantan [Cu & Ni Alloys]	49×10^{-8}
	Manganin [Cu, Mn, Cl or Ni Alloys]	44×10^{-8}
	Nichrome [Ni, Cr, Mn Fe Alloys]	100×10^{-8}
Insulators	Glass	$10^{10} - 10^{14}$
	Ebonite	$10^{15} - 10^{17}$
	Diamond	$10^{12} - 10^{13}$

When temperature is decreased in certain materials the resistance drops to zero at a certain temperature. These are called superconductors. For example at 4.2 K temperature the resistance of mercury suddenly drops to zero.

10.7.2 Dependence of resistance on material

If we take wire of four different conductors say silver, copper, gold and aluminum such that the length and cross sectional area of all of them is same. Now we find the resistances of all these wires. We find that the resistance of aluminum is highest and the resistance of silver is lowest.

$R_{,Yewfu;e} > R_{lksuk} > R_{rkack} > R_{pkanh}$

This silver is the best conductor and is followed by copper, gold and aluminium.

From the point of view of conductivity, the four metals are in the sequence

Silver > Copper> Gold>Aluminium

10.8 Combination of resistances

By combining known resistances in two different ways we obtain resistances of different values.

(a) Series combination

In this type of combination second end of the first wire is combined with the first end of the second wire and second end of the second wire is combined with the first end of the third wire etc. In figure 10.7 series combination of three conducting wires AB, BC & CD is shown. Lets R_1, R_2 and R_3 are their resistances. In series combination the same current flows from all resistances while the potential difference across their ends is different.

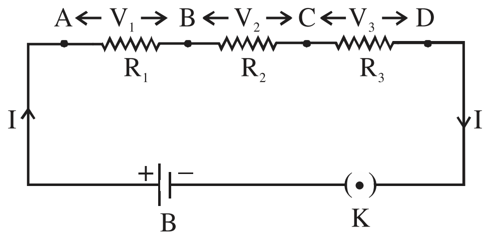


Fig 10.7 Series combination of resistance

Assume that a current I flows from the resistances R_1, R_2 and R_3 and the developed potential difference across the ends of resistances are V_1, V_2 and V_3

According to Ohm's law

Potential difference across the wire AB

R_1 $V_1 = IR_1$

Potential difference across the wire BC

R_2 $V_2 = IR_2$

Potential difference across the wire CD.

R_3 $V_3 = IR_3$

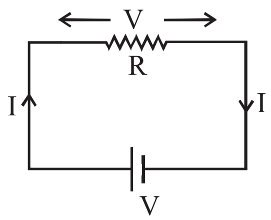
If the potential difference across the battery is V volt then

$$V = V_1 + V_2 + V_3$$

$$V = IR_1 + IR_2 + IR_3$$

$$V = I(R_1 + R_2 + R_3) \qquad .....(10.4)$$

If R is the effective resistance of the series combination of R_1, R_2 & R_3 then potential



Equivalent circuit of fig 10.7

difference across the equivalent resistance is

$V = IR$

Putting this value in equation 10.4 we get

$$IR = I(R_1 + R_2 + R_3)$$

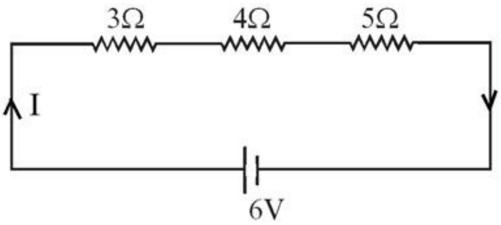
or $R = R_1 + R_2 + R_3$

Thus we can say that total resistance of a series combination of a number of resistances is equal to the sum of resistatnces of that combination.

Example 4 : Resistanaces of $3\Omega, 4\Omega$ & 5Ω are connected in series in a circuit in which a battery of 6 V is also connected. Find the following :

(a) current in each resistance

(b) Potential difference across each of the resistance



Solution

Equivalent resistance of three reistances in series is

$$R = R_1 + R_2 + R_3$$

$$R = 3 + 4 + 5 = 12\,\Omega$$

current will remain the same through all the resistances

$$I = \frac{V}{R} = \frac{6}{12} = 0.5 \text{ ampere}$$

Potential difference (P.D.) across all the three resistances can be found by equation V = IR

P.D. across $3\,\Omega$ resistance

$$V_1 = IR_1 = 0.5 \times 3 = 1.5 \text{ V}$$

P.D. across $4\,\Omega$ resistance

$$V_2 = IR_2 = 0.5 \times 4 = 2.0 \text{ V}$$

P.D. across $5\,\Omega$ resistance

$$V_3 = IR_3 = 0.5 \times 5 = 2.5 \text{ V}$$

(b) Parallel combination

In parallel combination, all the resistances are connected in such a way that the one end of each of them is connected to one point, say C, and the other end of each of them is connected to another point, say D, in the circuit. In figure 10.8 three conductors having resistances R_1, R_2 and R_3 are connected in parallel. In parallel combination the protendtial difference across all the resistances is same but current in each of the resistance is different. Let I_1, I_2 and I_3 are the currents flowing through R_1, R_2 and R_3 respectively then

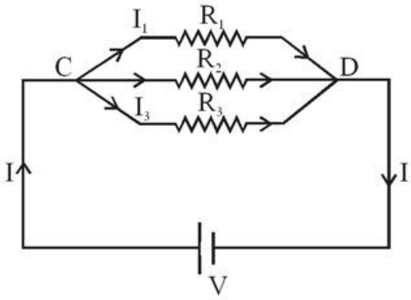


Fig 10.8 Parallel combination of resistances

According to Ohm's law

current in R_1 $\Rightarrow$ $I_1 = \frac{V}{R_1}$

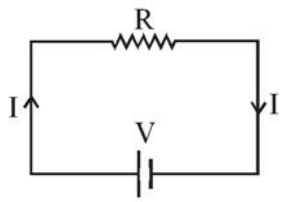
current in R_2 $\Rightarrow$ $I_2 = \frac{V}{R_2}$

current in R_3 $\Rightarrow$ $I_3 = \frac{V}{R_3}$

$$\because \; I = I_1 + I_2 + I_3$$

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

or $$I = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) \qquad .....(10.5)$$



Equivalent circuit of figure 10.8

If equivalent resistance of R_1, R_2 व R_3 in parallel combination is given by R then the current flowing in the equivalent circuit is $I = \frac{V}{R}$

Putting $I = \frac{V}{R}$ in equation 10.5

$$\frac{V}{R} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

or $$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Thus the inverse of the equivalent resistance of a parallel combination is equal to the sum of the inverse of each of the resistance in parallel combination. If there are two resistances in a parallel combination, say R_1 and R_2 then

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \quad \text{Or} \quad \frac{1}{R} = \frac{R_1 + R_2}{R_1 R_2}$$

or $$R = \frac{R_1 R_2}{R_1 + R_2}$$

Example 5 : Three resistances of $1\Omega, 2\Omega$ & 3Ω are connected in parallel in an electrical circuit. If this circuit is connected with a battery of 6V then find the follwoing -

(a) Equivalent resistance of the combination

(b) current in the circuit

(c) current in each resistance

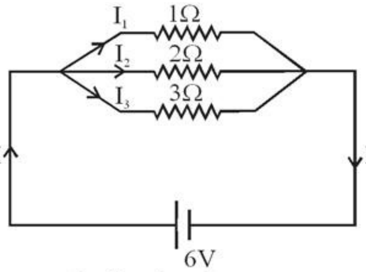
Solution (a) equivalent resistance

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \quad \begin{cases} R_1 = 1\Omega \\ R_2 = 2\Omega \\ R_3 = 3\Omega \\ R = ? \end{cases}$$

$$\frac{1}{R} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3}$$

$$\frac{1}{R} = \frac{6+3+2}{6}$$

$$\frac{1}{R} = \frac{11}{6} \quad \text{Or} \quad R = \frac{6}{11}\Omega$$



(b) current in the circuit

$$I = \frac{V}{R} \begin{cases} V = 6 \text{ volt} \\ R = \frac{6}{11}\Omega \\ I = ? \end{cases}$$

$$I = \frac{6}{6/11}$$

$$= 6 \times \frac{11}{6} = 11 \text{ ampere}$$

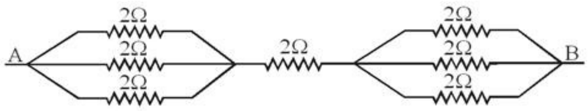
(c) current in each resistance

current in $R_1 = 1\Omega \Rightarrow I_1 = \frac{V}{R_1} = \frac{6}{1} = 6$ ampere

current in $R_2 = 2\Omega \Rightarrow I_2 = \frac{6}{2} = 3$ ampere

current in $R_3 = 3\Omega \Rightarrow I_3 = \frac{6}{3} = 2$ ampere

Example 6: Find the equivalent resistance between A and B in the given circuit.



Solution : In the given circuit three resistances of 2Ω are connected in parallel at two places. The equivalent resistance of each of them will be

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \Rightarrow \frac{1}{R} = \frac{1}{2} + \frac{1}{2} + \frac{1}{2}$$

$$\Rightarrow \frac{1}{R} = \frac{1+1+1}{2} \quad \text{or} \quad \frac{1}{R} = \frac{3}{2} \quad \text{or} \quad R = \frac{2}{3}\Omega$$

Thus equivalent circuit may be drawn as

We see that resistances and $\frac{2}{3}\Omega$ are connected in series between point A&B. Hence the equivalent resistance is given as

$$R = R_1 + R_2 + R_3$$

$$R = \frac{2}{3} + 2 + \frac{2}{3} = \frac{2+6+2}{3} = \frac{10}{3}\Omega$$

10.9 Thermal effect of current

When a battery is connected to a circuit and current flows through a conducting wire then the chemical energy stored in the battery is converted continuously into kinetic energy of free electrons. These free electrons collide with the atoms of conductor and in the process the kinetic energy of these electrons decreases and temperature of the conductor increases. Thus chemical energy of the battery changes into thermal energy of conductor. For example, when an electric fan runs continously then it becomes hot.

If we consider an electric circuit in which only a pure resistance is connected then all of the energy of the source decays in the form of thermal energy of conductor. This is known as thermal effect of current. It is used in electric heater, electric press and electric geyser.

To find the heat generated from thermal effect in a pure resistor let us assume a pure reistance wire connected to a battery. Let R is the reistance of the wire and I is current flowing through the circuit and the potential difference across the terminals of resistance is V.

If charge Q passes through the resistance in time t and the potential difference developed is V then the work done = charge x potential difference.

$$W = QV$$

$$W = I\,t\,V$$

In time t the energy given (VI t) by the source is converted to thermal energy and thus the heat developed in time t will be H = VI t

$$H = IR \times It \qquad \left[\text{From Ohm's law } V = IR\right]$$

$$H = I^2Rt$$

From the above equation we see that the heat generated in the resisance wire is

(a) proportianl to the square of the current flowing in the wire

$$H \propto I^2$$

(b) proportional to the reistance

$$H \propto R$$

(c) proportional to the time t of flow of current

$$H \propto t$$

All the three rules are called Joule's law of heating.

Electric power

Work done per second when current flows through an electrical circuit is called electric power

$$\text{Electric power (P)} = \frac{\text{Work done (W)}}{\text{Total Time (t)}}$$

As we know that energy given to a pure resistor = VI t

Thus the power given to the resistor

$$P = \frac{W}{t} = \frac{VI\,t}{t}$$

$$P = VI$$

$$P = IR \times I \qquad [\;V = IR]$$

$$P = I^2R$$

Unit of Power is Joule/second . This is also called Watt.

Watt is a small unit to measure power. Other units to measure power are

1 kilowatt (1 kW) = 1000 Watt = 10^3 Watt

1 megawatt (1 MW) = 1000000Watt = 10^6 Watt

1 horse power (1 hp) = 746 Watt

Electrical energy is given as mulltiplication of electric power and time in hour.

Electrical energy = Electrical power (P) x time (t)

Therefore unit of electrical energy is Watt hour (Wh).

When one Watt power is used for one hour then used energy is one Watt hour. The commercial unit of electrical energy is kilo Watt hour (kWh) and is generaly called a 'unit' :

Relation in 1 kWh and Joule

1 kiloWatt hour = $10^3 \times 60 \times 60$ Watt $\times$ second

$$= 36 \times 10^5 = \frac{\text{Joule}}{\text{Second}} \times \text{Second}$$

$$= 36 \times 10^5 \text{ Joule}$$

To calculate consumed electrical energy in 'unit' we use following relation

Electrical energy consumed =

$$\frac{\text{Electrical Power P (Watt)} \times \text{time (hour)}}{1000}$$

For example when two bulbs of 100 watt each are used 8 hours per day then energy consumed in a month (30 days) will be

$$= \frac{\text{p (watt)} \times \text{time(hour)}}{1000} = \frac{(100 \times 2) \times (30 \times 8)}{1000}$$

= 48 unit

Example 7 : A 10 volt storage cell is connected to a nicrome resistance coil of 50 ohm so that current flows for one hour. Calculate the heat generated in resistance coil.

Solution : current in the circuit

$$I = \frac{V}{R} = \frac{10}{50} = 0.2 \text{ ampere}$$

V = 10 Volt

R = 50Ω

t = 1 hour

= 60 × 60 second

= 3600 second

H = ?

$H = I^2 R t$

$H = (0.2)^2 \times 50 \times 3600 = 7200$ Joule

Example 8 : An electric bulb is connected to a source of 220 volt and the current flowing through the circuit is 0.5 ampere. What will be the power of the bulb?

Solution : Given

P = VI	V = 220 volt
P = 220 × 0.5	I = 0.5 ampere
P = 110 watt	P = ?

10.10 Magnetic effect of current

In 1820 Orsted performed an experiment in which he observed that when electric current passes through a conducting wire then magnetic field is produced around the conducting wire and thus the magnetic needle placed near the wire is deflected. Experiment performed by Orsted can be understood by following way

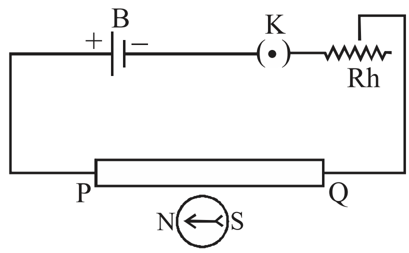


Fig. 10.9 (a)

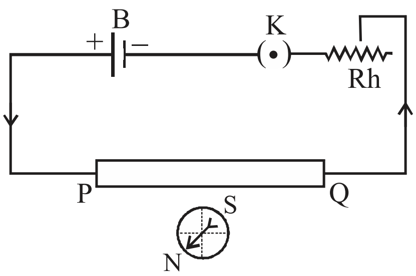


Fig. 10.9 (b)

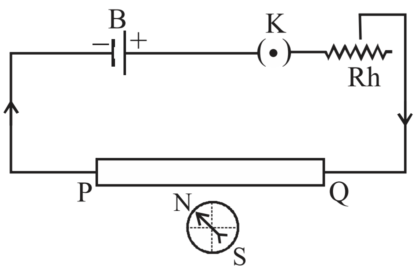


Fig. 10.9 (c)

Fig 10.9 Experiment of Orsted

(i) When there is no current flowing through the conductor then magnetic field is not produced around the conductor and the magnetic needle does not deflect [fig 10.9 (a)]

(ii) When current flows through the conductor then magnetic field is produced around the conductor and deflects the magnetic needle [fig 10.9(b)]

(iii) If we change the direction of the current through the conductor then the direction of deflection of magnetic needle also changes [fig 10.9(c)]

Deflection of magnetic needle during current flow in the conductor shows that magnetic field is produced around the conductor. If we increase the current in the conductor or if we take the needle near to the conductor then the deflection in the needle increases.

10.11 Direction of magnetic field

Two laws are used to find the direction of the produced magnetic field during current flow in a conductor :

(a) Right handed cork-screw law :- According to this law when a right handed screw is rotated circularly and the point of the screw goes towards direction of electic current then the direction of rotation of screw will show the direction of magnetic field.

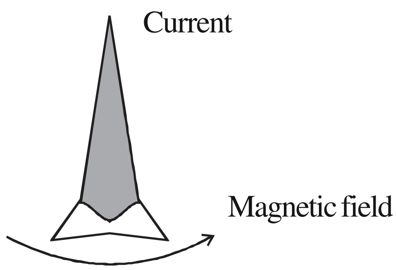


Fig 10.10(a) Right handed screw law

(b) Right hand law

According to this law if conductor wire is held by the right hand such that the thumb is in the direction of the flow of current then the curved fingers will represent the direction of magnetic field.

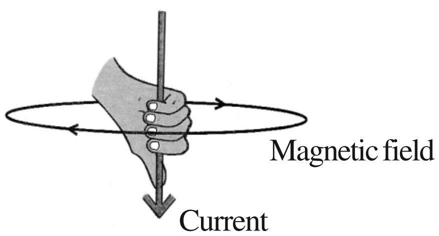


Fig 10.10(b) Right hand law

10.12 Magnetic field and field lines

In Orsted's experiment we observed that a conductor rod behaves like a magnet when current flows through it and compass needle is deflected when brought near to this conductor rod. Actually, the compass needle is also a small magnetic rod . When no outside magnetic field is near this compass needle then it rests in north-south direction The point of the needle directed towards the north is called north facing pole and the end point of the compass needle directed towards the south is called south facing pole.

To represent the magnetic field around a magnet, imaginary lines are drawn around the magnet. These lines are called field lines.

Area around the magnet where we can feel the effect of magnet is known as magnetic field.

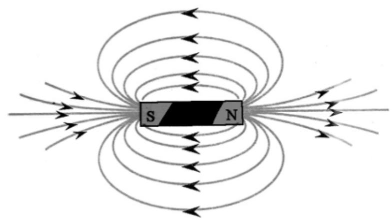


Fig 10.11

Magnetic field has both the direction and the magnitude and the direction of magnetic field is always from north pole to south pole. Figure 10.11 represents magnetic field lines.

10.13 Electromagnetic induction

A coil is connected to a galvanometer as shown in the figure 10.12 and a bar magnet is brought near the coil. We observe that galvanometer gives deflection i.e. current flows through the coil. The value of current depends upon the relative speed of magnet and coil.

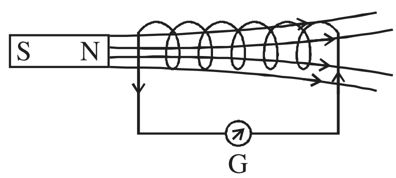


Fig 10.12

Production of electric effect (or electromotive force) in the coil (or an electrical conductor) because of relative motion of a coil and magnet (or changing magnatic field) is called electromagnetic induction.

Explanation

When coil and magnet are in relative motion then the field lines passing through the cross section of the coil changes continously and thus magnetic flux changes. According to Faraday, when magnetic flux associated with the coil changes then induced current is produced.

10.13.1 Magnetic flux

The number of field lines passing through a cross section area placed in a magnetic field is called magnetic flux associated to that cross-sectional area. Unit of magnetic flux is Weber.

10.14 Electric current generator

Generator is a device in which mechanical energy is given to a coil placed in a magnetic field and electrical energy is obtained. It works on elctromagnetic induction.

Current generators are of two types :

(a) Alternating Current generator

Different appliances at our home like bulb, fan, elctric iron, toaster, refrigerator etc operate with alternating source. During marriages you might have seen that when electricity is stopped beacuse of fault then light decorations are operated with a diesel based alternating current generators usually placed outside the hall or garden.

Thus alternating current generator is a device that transforms mechaincal energy to alternating electric energy.

It has four inportant components

(a) Field magnet (b) Armature or coil

(c) Slip rings (d) Brushes

(a) Field magnet - Generallly it is powerful magnet in horseshoe shape. In figure, it is shown as NS.

(b) Armature or coil - It is a copper coil ABCD wound around a structrue of cast iron.

c) Slip ring - End A & D of the armature coil are connected separately to two slip rings S_1 & S_2. These slip rings, insulated from each other,. rotate along with the coil.

(d) Brushes - Brushes are made of graphite or carbon and one end of them is in contact with slip rings and the other end is connected to outer circuit. They rotate with the armature coil.

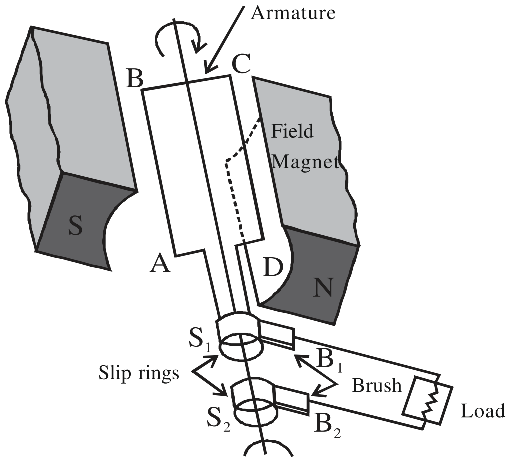


Fig 10.13 Alternating current generator

Working

When armature is rotated by providing mechanical energy then the magnetic flux through the coil ABCD continuously changes and current flows through the coil.

When the coil is rotated clockwise then the plane of the coil alternately become parallel and perpendicular to the magnetic field. In the first half cycle the flux decreases and thus in first half rotation the direction of current in the outer circuit is clockwise and it is anticlockwise in the next half rotation. So in the first half cycle the current flows from B_1 to B_2 in outer circuit and in the next half cycle the current flows from B_2 to B_1. In this way during the full rotation of armature the direction of current changes after a fixed phase difference. During the full rotation, magnitude of current also changes continuously. Such current is called alternating current.

In India, the frequency of alternating current through home elecrtricity is 50 hertz and therefore to obtain alternating current of 50 hertz from the generator the coil is rotated 50 times in a second. Magnitude of the current produced through alternating current generator depends upon the number of turns in the coil, area of the coil, rotation, velocity and intensity of magnetic field .

(b) Direct current generator

This device also converts mechanical energy to electrical energy but the direction of the current obtained from electrical energy remains constant

Construction:- It is also similar to alternating current generator. The only difference is that instead of two slip rings it has a single split ring commutator

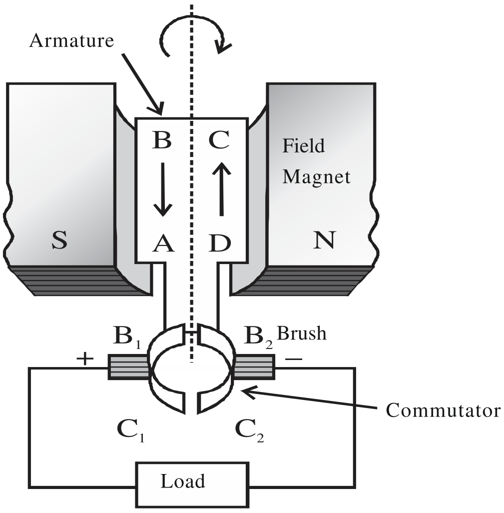


Fig 10.14 Direct current generator

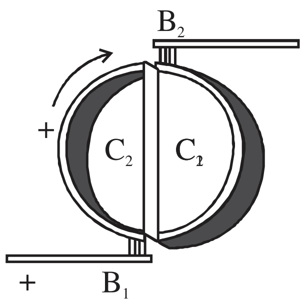


Fig 10.15 Position of commutator after half rotation

Split ring commutator is a metal ring having two halves C_1 and C_2 . One end of the armature is connected to C_1 and the other end is connected to C_2 . Two carbon brushes touch these two split rings. Commutator ring rotates with the armature.

Working

When armnature is rotated in the magnetic field then the magnetic flux through the coil continously changes and induced current flows through it. Brushes B_1 & B_2 are adjusted such that when the direction of current changes in the coil the contact of the brushes also changes from one part of commulator C_1 to other part of commulator C_2 and thus the direction of current in the outer circuit remains constant.

Let us assume that during the first half cycle the direction of induced current is such that the end of the coil connected to C_1 is positive and the end connected to C_2 is negative. Let B_1 is connected to C_1 and B_2 is connected to C_2 during this cycle. Thus B_1 will be positive & B_2 will be negative. Now when the direction of current changes at the begining of next half cycle then C_1 becomes negative and C_2 becomes positve. At the same time because of rotation of the coil the C_1 reaches to the place of C_2 and C_2 reaches at the place of C_1. Now the C_1 comes in contact with B_2 while the C_2 comes in contact with B_1. Thus B_1 always remains positive and B_2 remains negative. In this way the curent flows from B_1 to B_2 in outer circuit.

Important Points

1. Rate of flow of charge is called current. Its direction is always taken from positive to negative and it is measured in amperes.
2. Restriction in the flow of charge is called resistance. It depends upon lenght, cross section area, temperature and the material.
3. When physical states of a conductor are constant then the potential difference produced across the conductor is proportional to the current flowing through it. It is called Ohm's law.

   $V = IR$ Where R is a constant and is known as resistance of conductor
4. Ammeter measures current in the circuit and is used in series in the circuit.

5. Voltmeter measures the potential difference across the conductor and is placed parallel to it in a circuit.
6. Resistance of a conducting wire of 1 meter length and 1 square meter cross sectional area is called specific resistance of the material of the wire. Its unit is ohm x meter. It does not depend on length or cross-sectional area of the wire but depends on the material of the wire.
7. Equivalent resistance in series combination

$$R = R_1 + R_2 + R_3 \ldots\ldots$$

8. Equivalent resistance in parallel combination

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots$$

9. A pure resistor is connected to an electric source. The energy given to the pure resistor by electric source (W = VIt) fully transforms into heat energy.
10. When electric current is passed through a conductor then magnetic field is produced around the conductor. This effect is called magnetic effect of currrent
11. Number of magnetic lines of force passing through a surface, kept in a magentic field, is called magnetic flux associated with that surface.
12. Electric generator is a device that transforms mechanical energy to electrical energy. It is based on the concept of electromagenetic induction. Generators are of two types.

    (i) Alternating current generator

    (ii) Direct current generator

Practice questions

Objective type questions

1. 2 ampere current flows in a conductor connected with a 5V battery. Find the resistance of the conductor

   (a) 3Ω (b) $2.5\ \Omega$
   (c) 10Ω (d) $2\ \Omega$
2. Resistivity depends on which of the following?

   (a) Length of the conductor
   (b) Cross section area of the conductor
   (c) Material of the conductor
   (d) None of these
3. Volt is a unit of

   (a) current (b) potential difference
   (c) charge (d) work
4. Three conducting wires of $1\Omega, 2\Omega\ \&\ 3\Omega$ are connected in series in an electrical circuit. What will be the equivalent resistance?

   (a) Less than 1 Ohm (b) Less than 3 Ohm
   (c) More than 1 Ohm (d) More than 3 Ohm
5. The frequency of alternating current in India is

   (a) 45 Hertz (b) 50 Hertz
   (c) 55 Hertz (d) 60 Hertz
6. Resistances of different values are connected in parallel and connected with an electrical source. In each of the resistor -

   (a) current and potential difference will be differenct
   (b) current and potential difference will be same
   (c) current will be different but potential difference will be same
   (d) current will be same but potential difference will be different
7. 2 coulomb charge passes through an electrical circuit in 0.5 second. Find the value of electric current in ampere.

   (a) 1 ampere (b) 4 ampere
   (c) 1.5 ampere (d) 10 ampere
8. Which of the device does not depend on thermal effect of current

   (a) Heater (b) Electic iron
   (c) Toaster (d) Refrigerator

Very short type questions

9. What is the unit of specific resistance or resistivity?
10. Define the electric current

11. What is potential difference?
12. What is 1 ohm resistance?
13. How resistance depends upon cross section area?
14. Define resistivity.
15. What do you mean by electric power?
16. 100W – 220V is written on an electric bulb what does it means?
17. How electrical combination is made at home?

Short type questions

18. What is the difference between series combination and parallel combination of resistances?
19. What is electic power? Write the necessary formula for it.
20. Two resistances are of same material and are having same length. If the ratio of their cross-sectional area is 2 :11 then what will be the ratio of their resistances?
21. Define electric potential and potential difference.
22. What is the difference between alternating current generator and direct current generator?
23. Write the right hand rule.
24. Find number of Joules in 1 kilowatt hour.
25. Write Joule's law of heating.
26. Give circuit diagram of experimental verification of ohm's law.

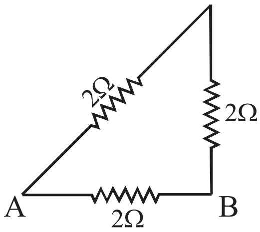
Essay type questions

27. Explain construction and working of alternating current generator. Draw necessary diagram.
28. Derive necessary formula for equivalent resistance of a series combination of resistances giving proper circuit diagram
29. Derive necessary formula for equivalent resistance of a parallel combination of resistances along with proper circuit diagram.

Numerical questions

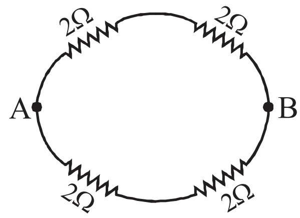
30. Find the highest and lowest resistance from combination of resistances of 1Ω, 2Ω and 3Ω [6Ω, $6/11\ \Omega$]
31. What will be resistance of a conductor wire when the potential difference across its terminals is 2.5 volt when 10 milliampere current flows through it? [250Ω]
32. Find equivalent resistance between A& B in the following circuits

(a)



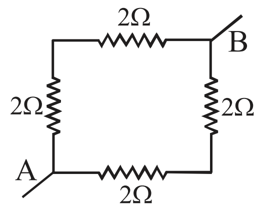
(Ans. $4/3\ \Omega$)

(b)



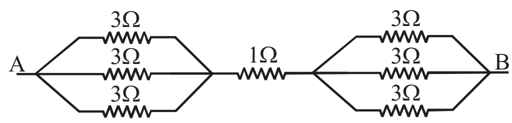
(Ans. 2Ω)

(c)



(Ans. 2Ω)

(d)



(Ans. 3Ω)

33. An electric rod of 1500 watt is used 3 hours daily to heat water. If the rate of consuming one electrical unit energy is Rs. 5.00 then how much be the value of consumed electrical energy in 30 days (Rs. 675)

Answer key

1. (b) 2. (c) 3. (b) 4. (d) 5. (b)
6. (c) 7. (b) 8. (d)