

MAGNETIC EFFECTS OF CURRENT

Q1. What is a magnet? What are its types?

Ans. A magnet is a substance that attracts pieces of iron, cobalt, nickel, etc and aligns itself in the north-south direction when suspended freely. The Greeks knew the phenomenon of magnetism, as early as around 800 BC. They discovered that certain stones, now called magnetite (Fe_3O_4), attract pieces of iron. The Chinese called it the Lodestone i.e. the leading stone. In 1269 Pierre de Maricourt found that magnet has two poles, North Pole and South Pole. Subsequent experiments showed that every magnet, regardless of its shape, has two poles. In 1600 William Gilbert extended these experiments to a variety of materials. Using the fact that a compass needle orients in preferred directions, he suggested that the earth itself is a large permanent magnet. It was Oersted who in 1819 gave the first evidence of the connection between electricity and magnetism. The cause of magnetism is the motion of charges.

All magnets can be classified into two types (i) Natural and (ii) Artificial or man made

Natural Magnets: The natural magnets are the one, which occur naturally in nature e.g. Magnetite ore (Fe_3O_4) is a natural magnet. It is also called lodestone. A lodestone occurs in all types of shapes and has a weak magnetic field strength.

Artificial Magnet: An artificial magnet is one, which is made by man by magnetising small pieces of iron or nickel. The artificial magnets are usually made of an alloy called Alnico (Aluminium, Nickel, Cobalt and Iron) and Nipermag (Iron, Nickel, Aluminium and Titanium). They are of various shapes: Bar Magnet, U-Shaped Magnet, Horse-Shoe Magnet, Magnetic Compass Needle, etc.

Bar Magnet: A magnet in the form of a rectangular bar or has a circular cross section is called bar magnet. A bar magnet has two poles, North Pole and South Pole. These poles are situated a small distance inwards from the two faces. The distance between the two poles is called the magnetic length. The face-to-face distance is called geometric length. The magnetic length is $7/8$ of the geometric length.

Q2. What are the properties of a magnet?

A magnet possesses the following properties.

Directive property: When a magnet is suspended freely, it always orients itself in the north-south direction. If the bar magnet is free to rotate, one end points north. This end is called the North Pole or N-pole; the other end is the South Pole or S-pole. The north pole of a magnet is usually coloured red or a red dot is placed on its side. Actually the north and south poles of a magnet point towards the south and north magnetic poles of the earth and not towards the earth's geographic poles.

Attractive property: A magnet can attract small pieces of magnetic substances like Iron, Steel, Cobalt, Alnico etc. The attraction is a maximum at the two ends called the poles. It is minimum or zero at the centre of the magnet.

Isolated poles do not exist: The magnetic poles always exist in pairs. i.e., magnetic monopoles don't exist. If a magnet is cut into small pieces each piece by itself is a magnet. If a magnet is cut parallel to its length then its pole strength becomes half. If the magnet is cut perpendicular to its length there is no change in its pole strength.

Like poles repel each other and unlike poles attract each other: When a south and a north pole are brought closer they attract each other, whereas when two north or two south poles are brought closer they repel each other.

Every magnet possesses some magnetic dipole moment directed from South Pole to North Pole inside the magnet.

6. The cause of magnetism of a magnet is the motion of charges.

The magnetism of a magnet can be destroyed by heating the magnet above a particular temperature called Curie's Temperature.

Q3. What is Magnetic Compass? What are its uses?

Magnetic Compass is a device used to find the direction of magnetic field at a point. It consists of a tiny magnet called Magnetic Needle pivoted on a spindle at the centre so that it can turn freely. The Magnetic needle is enclosed in a box covered by plastic or glass on both sides. The arrow head of the needle is the north pole of the compass and the tail acts as the South Pole. The North Pole is usually coloured red.

Magnetic Compass Needle is used:

- i. to find the direction of earth's magnetic field
- ii. to test the polarity of another magnetic pole.
- iii. to find the strength of magnetic field of a magnet.

Q4. What is a magnetic field? What are its units?

Ans. **MAGNETIC FIELD:** According to Faraday a magnet modifies the space around itself in such a manner that if any other magnetic substance moves into this space it experiences a force. This is termed as the magnetic force. The region around a magnet in which its magnetic force can be experienced by another magnetic substance is called magnetic field of the magnet. Magnetic field is a vector quantity. A magnetic field around a magnet can be visualised by drawing magnetic field lines around the magnet. The SI unit of magnetic field is Tesla (T). Thus, $1 \text{ Tesla} = 1 \text{ Newton / Ampere-metre} = 1 \text{ NA}^{-1} \text{ m}^{-1}$. It has been found that tesla is a fairly large unit. The other smaller unit of magnetic field is gauss (G) which is related to Tesla as $1 \text{ Tesla} = 10^4 \text{ gauss}$.

Q5. What are magnetic field Lines? What are the properties of magnetic field Lines?

Ans. **MAGNETIC FIELD LINES:** The concept of magnetic field lines was put forward by Michael Faraday in order to explain the interaction between the poles separated by some distance. A magnetic field line is a pictorial representation of the magnetic field around a magnet. Magnetic field lines possess the following properties:

The path along which unit North Pole moves in a magnetic field if it is allowed to move freely is called magnetic field line or Magnetic Line of Force.

Magnetic field lines travel from the north to the south pole of a magnet outside the magnet and from South to the North Pole inside the magnet. Thus, they form continuous closed curves.

Do You Know

1. A magstripe on a credit card contains millions of tiny magnetic domains held together by a resin.

The tangent drawn at any point of the magnetic lines of force represents the direction of the magnetic field at that point. Two magnetic field lines do not intersect each other. This is because if they do so then the magnetic field at that point will have two directions which is not possible.

The field lines of a uniform magnetic field are parallel to each other and the field lines of a non-uniform magnetic field are non-parallel to each other.

The relative closeness of the magnetic field lines represents the magnetic field strength. The more crowded the magnetic field lines the stronger is the field and farther the field lines, lesser is the magnetic field strength.

They contract longitudinally and exert pressure on each other laterally.

Q6. With the help of an activity, explain how magnetic field of a magnet can be plotted.

Ans. The magnetic field lines of a magnetic field can be plotted as follows:

Place the bar magnet NS on a sheet of paper and mark its boundary.

Mark a point A near the North Pole of the given magnet.

Place the compass needle so that one of its ends (south) lies exactly over point A as in Fig.

Mark point B on the paper at the opposite (north) end of the compass needle.

Move the compass needle so that the south end of the compass needle lies over B and mark point C at the north end of the needle and so on. Go on doing so till a point is reached near the south pole of the given magnet.

Join all these points with a free hand curve so as to form a smooth dotted curve.

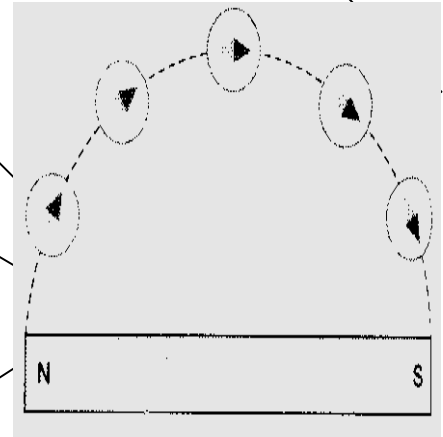
Mark an arrow head to show the direction of magnetic line of force; which will be North Pole to South Pole outside the magnet.

This dotted curve marked with an arrow head represents a magnetic field line. Similarly starting from other points near the North Pole of the magnet, draw other magnetic lines of force.

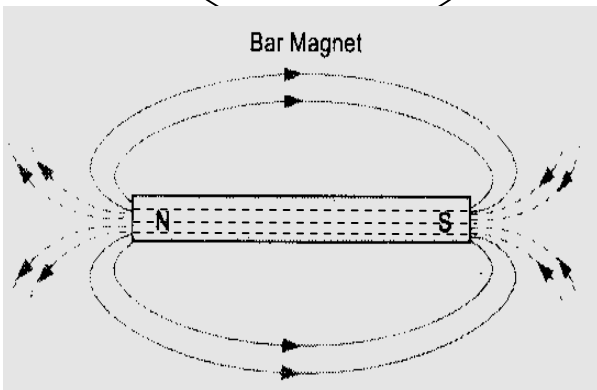
Q7. Explain the pattern of magnetic field of a bar magnet.

Ans. We can visualise the magnetic field lines around a bar magnet by sprinkling some iron filings near a bar magnet and tapping the sheet on which the magnet is placed. The iron filings will orient themselves and the magnetic field lines plotted for a bar magnet are as shown in figure.

The magnetic field lines around a bar magnet are not parallel and hence the magnetic field around a bar magnet is not uniform. The magnetic field lines inside the bar magnet are in the form of parallel straight lines and hence this indicates that the strength of magnetic field is the same at all the points inside the bar magnet. Thus, the magnetic field is uniform inside a current-carrying solenoid.



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Do You Know

1. Theoretical physicists have speculated about possible existence of magnetic monopoles but so far all the attempts have failed to find magnetic monopoles.
2. Kids! This field of finding magnetic monopoles

Q8. Explain Oersted's discovery. What were the observations and conclusions made from the experiment?

Ans. In 1819, Oersted performed an experiment to show that an electric current flowing through a wire produces a magnetic field around it. Oersted's observation was the first that indicated a connection between electricity and magnetism. The phenomenon due to which a magnetic field is produced around a current carrying conductor is called electromagnetism or magnetic effect of current. The Oersted's experiment was performed as follows:

A wire was connected to a battery in such a way that a current flows through the wire placed parallel to the magnetic compass kept directly over the wire.

The compass needle shows no deflection when no current flows through the wire.

When a current is passed through the wire, the needle shows deflection in one direction.

When a current is passed through the wire in opposite direction, the needle shows deflection in opposite direction.

When the compass is placed directly below the wire the needle deflections are reversed.

When the magnitude of the current is increased, the deflection of the magnetic needle increases.

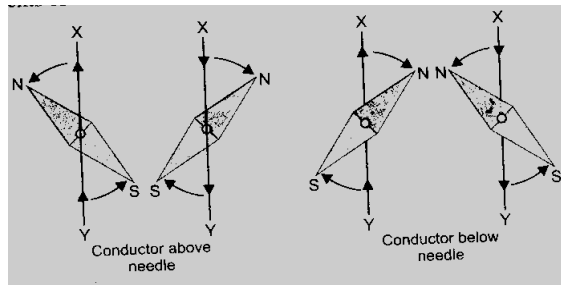
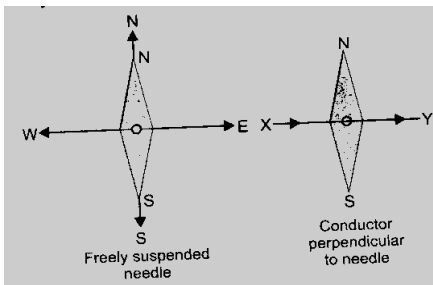
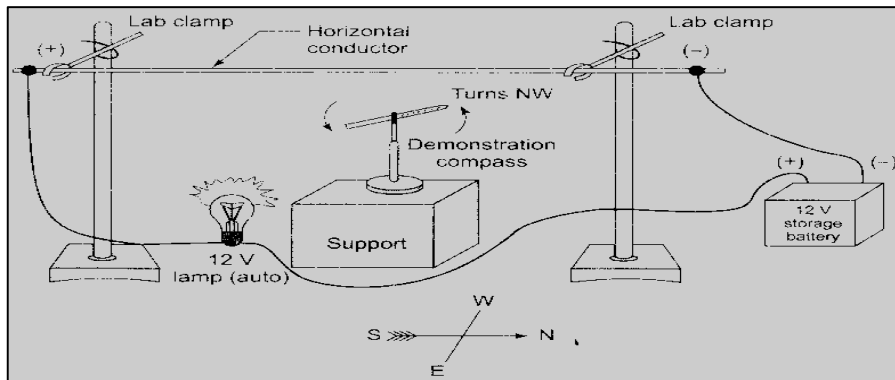
Conclusions: These observations led Oersted to conclude that:

A magnetic field is produced around the current carrying wire because a magnetic needle can be deflected only due to the presence of a magnetic field.

When no current flows through the wire, magnetic field is not produced around the wire.

When direction of current is reversed, the direction of magnetic field is also reversed.

When the magnitude of the current is increased, the strength of the Magnetic field also increases.



The direction of the deflection of the needle can be determined by:

Ampere's swimming Rule: Imagine a man swimming along a wire in the direction of the current with his face towards the needle so that the current enters at his feet and leaves at his head. The north pole of the needle will be deflected towards his left.

SNOW Rule: If the direction of the current flowing through the wire is from south (S) to north (N) and the wire is placed over the needle, the North Pole of the Needle is deflected towards the west.

- Describe an activity to explain the pattern of magnetic field due to a straight current carrying conductor.
- What are the factors on which magnetic field due to a straight current carrying conductor depends?
- How can we find the polarity or direction of magnetic field due to a straight current carrying conductor?

a) The Pattern of Magnetic Field: The pattern of magnetic field due to a straight current carrying conductor can be explained with the help of following activity:

Take a copper wire AB. Pass it through a cardboard as shown in figure.

Connect the wire to a battery through a key.

Sprinkle some iron filings on the cardboard.

Switch on the key and tap the cardboard gently.

You will find that the iron filings arrange themselves in the form of concentric circles.

Reverse the direction of current by changing the polarity of the battery.

You will find that this time too, the iron filings arrange themselves in concentric circles but in opposite direction.

Note that the same experiment can be carried out by plotting magnetic field lines using a compass.

Hence, the magnetic field lines of force around a straight conductor carrying electric current are concentric circles with the conductor at the centre. The direction of magnetic field changes when the direction of current is reversed. As we move away from the straight current carrying conductor the distance between the magnetic field lines increases continuously. This shows that as we move away the magnetic field decreases continuously.

b) Factors on which Magnetic Field Depends: It is found that the magnitude of magnetic field around a straight wire carrying current is:

directly proportional to the strength of current passed through the wire. i.e., $B \propto I$

inversely proportional to the distance of the point of observation from the straight current carrying wire i.e. $B \propto 1/d$

Thus, $B \propto I/d$

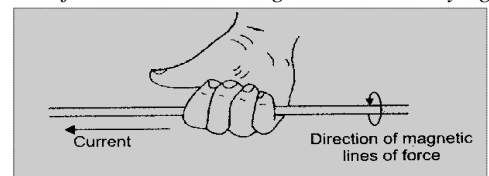
$$B = \mu_0 I/d$$

where μ_0 is called magnetic permeability of free space and $\mu_0 = 4\pi \times 10^{-7} \text{ Tm/A}$

This shows that as we move away the magnetic field decreases continuously.

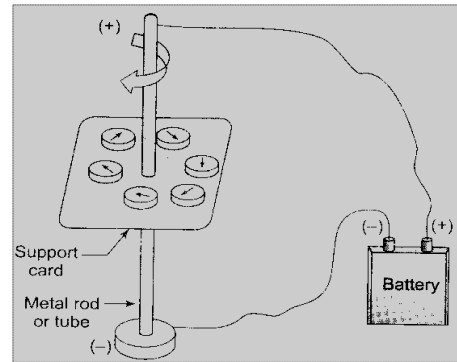
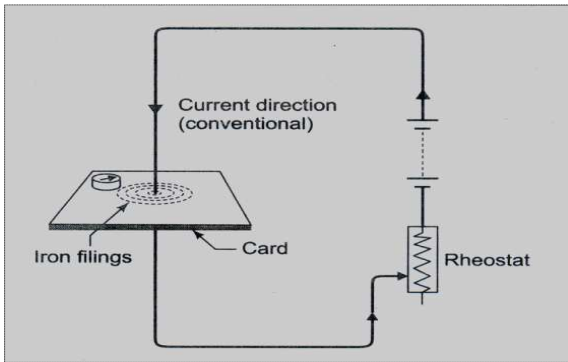
c) Polarity or Direction of Magnetic Field: The polarity or direction of magnetic field due to a straight current carrying conductor can be found as follows:

Right Hand Thumb Rule or Right Hand Palm Rule: The right hand thumb rule or palm rule gives the direction of magnetic field due to a straight current carrying conductor. According to the rule, "Grasp the conductor in the right hand with the thumb pointing in the direction of current, and then the direction in which the fingers curl gives the direction of the magnetic field."



Maxwell's Cork Screw Rule or Right Hand Screw Rule: According to this rule, 'Imagine a right handed screw to be rotated in the direction of current, and then the direction of rotation gives the direction of magnetic field lines'.

By using Magnetic Compass Needle: When a Magnetic compass is placed at a point near a straight current carrying conductor, the direction in which the Magnetic Compass Needle points gives the direction of the magnetic field at that point.



- a) Describe an activity to explain the pattern of magnetic field due to a current carrying circular coil.
 b) What are the factors on which magnetic field due to a current carrying circular coil?
 c) How can we find the polarity or direction of magnetic field due to a current carrying circular coil?

a) **The Pattern of Magnetic Field:** The pattern of magnetic field due to a current carrying circular coil can be explained with the help of following activity:

Let us bend the wire into a circular shape.

Pass the coil through a cardboard as shown in figure.

Connect the free ends of the coil to a battery and a key.

Sprinkle some iron filings on the cardboard.

Put on the key you will find that the iron filings arrange themselves in the form of concentric circles as shown in the figure.

Reverse the direction of current by changing the polarity of the battery.

You will find that this time too, the iron filings arrange themselves in concentric circles but in opposite direction.

The same experiment can be performed by using a magnetic compass and plotting the lines of forces.

Thus, The magnetic lines of forces near each segment of wire are circular and form concentric circles with ever increasing radii as we move away from the wire, whereas the lines of force near the centre of the coil are in the form of big arcs appearing almost as straight lines.

Thus, at the centre of the coil, the magnetic field is uniform and perpendicular to the plane of the coil.

It is to be noted that every point on the circular current carrying wire gives rise to the magnetic field appearing as straight lines at the centre. By applying the right hand thumb rule, we find that every section of the wire contributes to the magnetic field lines in the same direction within the loop. Thus, if there is a circular coil having n turns, the magnetic field produced by this current-carrying circular coil will be n times as large as that produced by a circular loop of a single turn of wire. This is because the current in each circular turn of coil flows in the same direction and magnetic field produced by each turn of circular coil then just adds up.

b) **Factors on which Magnetic Field Depends:** It is found that the magnitude of magnetic field due to a current carrying circular coil is:

directly proportional to the strength of current passed through the wire. i.e., $B \propto I$

Inversely proportional to the radius of the coil i.e., $B \propto 1/r$

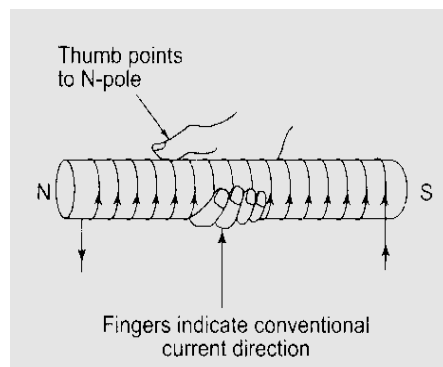
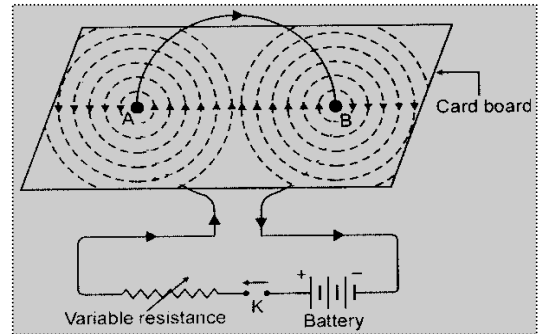
directly proportional to the number of turns of the wire. i.e., $B \propto n$.

Thus, $B \propto nI/r$

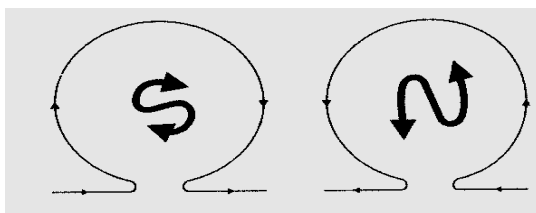
where r is the radius of the coil.

c) **Polarity or Direction of Magnetic Field:** The polarity of the current carrying coil is found by:

Right Hand Palm Rule: Curl the palm of your right hand around a circular wire with the fingers pointing in the direction of current, then the right hand thumb gives the direction of the magnetic field.



Clock Rule: The face or end of the coil behaves as North Pole when the direction of current in the coil is anticlockwise and the end of the coil behaves as South Pole when the direction of current in the coil is clockwise.

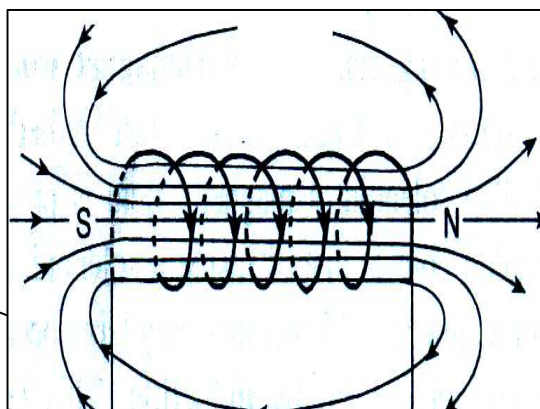


By using a bar magnet: When North Pole of a bar magnet is brought near one end of the coil such that there is repulsion, then this end of the coil is the North Pole of the bar magnet.

- a) What is a solenoid? Explain the pattern of magnetic field due to a current carrying circular coil.
- b) What are the factors on which magnetic field due to a current carrying circular coil?
- c) How can we find the polarity or direction of magnetic field due to a current carrying circular coil?

Ans. a) A solenoid is a long cylindrical coil of many tightly wound turns of insulated wire such that its length is greater than its diameter and it behaves like a magnet when current is passed through it. When a current is passed through a solenoid, a magnetic field is developed in and around it. As the electric current in each circular coil flows in the same direction, the magnetic field of the loop makes one end of a solenoid act as a North Pole and the other end as the South Pole.

The Pattern of Magnetic Field: The magnetic field around a current carrying solenoid is similar to the magnetic field produced by a bar magnet as shown in figure. The magnetic field lines around the solenoid are not parallel and hence the magnetic field around the solenoid is not uniform. The magnetic field lines inside the solenoid are in the form of parallel straight lines. This indicates that the strength of magnetic field is the same at all the points inside the solenoid. Thus, the magnetic field is uniform inside a current-carrying solenoid and acts along the axis of the solenoid.



b) **Factors on which Magnetic Field Depends:** Experiments show that the magnitude of the magnetic field inside a solenoid is: directly proportional to the number of turns in the coil i.e., $B \propto n$ directly proportional to the strength of the current. i.e., $B \propto I$ depends upon the nature of the core material. When a soft iron core is used as a core material, a very strong magnetic field is produced. Commonly an insulated wire is coiled over a non conducting hollow cylindrical tube. An iron rod is usually placed inside the hollow tube. This iron rod is called the core.

The current in each turn of a current-carrying solenoid flows in the same direction due to which the magnetic field produced by each turn of the solenoid adds up, giving a strong magnetic field inside the solenoid. The strong magnetic field produced inside a current-carrying solenoid can be used to magnetise a piece of magnetic material like soft iron, when placed inside the solenoid. The magnet thus formed is called an electromagnet. So, a solenoid is used for making electromagnets.

d) **Polarity or Direction of Magnetic Field:** The polarity of the current-carrying solenoid is found by:

Right Hand Palm Rule: Curl the palm of your right hand around current-carrying solenoid with the fingers pointing in the direction of current, then the right hand thumb gives the direction of the magnetic field.

Clock Rule: The face or end of the solenoid behaves as North Pole when the direction of current in the solenoid is anticlockwise and the end of the solenoid behaves as South Pole when the direction of current in the solenoid is clockwise.

By using a bar magnet: Bring the north pole of a bar magnet near both the ends of a current-carrying solenoid. The end of solenoid which will be repelled by the north pole of bar magnet will be its north pole, and the end of solenoid which will be attracted by the north pole of bar magnet will be its south pole.

Q12. What is Electromagnet? What are the factors Affecting the Strength of an Electromagnet?

Ans. An electromagnet is a coil of wire wound around a soft iron core. It behaves as a permanent magnet except that it can be turned off. It is a temporary magnet. It begins to behave as a magnet when an electric current is passed through it. It usually contains a soft iron core. The purpose of the core is to increase the intensity of the magnetic field. In fact an electromagnet is a solenoid with an iron core at its centre. The strength of the magnetic field of an electromagnet depends upon the same factors as that of a solenoid. An electromagnet works on the magnetic effect of current.

FACTORS AFFECTING THE STRENGTH OF AN ELECTROMAGNET: The strength of an electromagnet depends on:

The number of turns: If we increase the number of turns in the coil, the strength of electromagnet increases. i.e., $B \propto n$.

The current flowing in the coil: If the current in the coil is increased, the strength of electromagnet increases. i.e., $B \propto I$.

The length of air gap between its poles: If we reduce the length of air gap between the poles of an electromagnet, then its strength increases. For example, the air gap between the poles of a straight, bar type electromagnet is quite large, so a bar type electromagnet is not very strong. On the other hand, the air gap between the poles of a U-shaped electromagnet is small, so it is a very strong electromagnet.

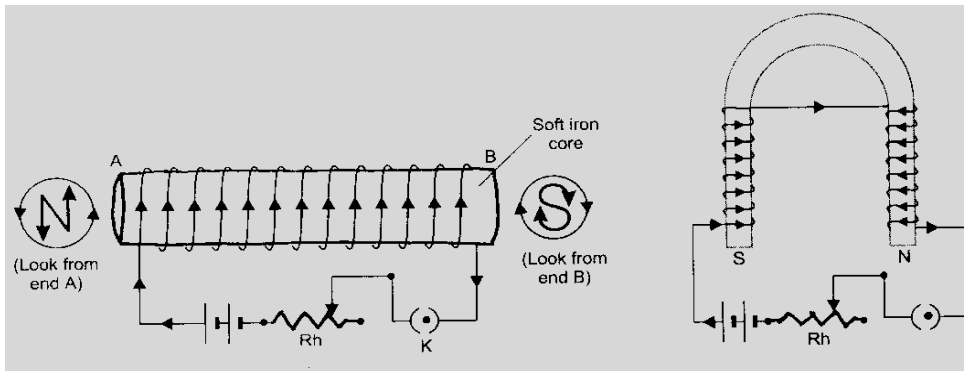
The core of an electromagnet must be of soft iron because soft iron loses all of its magnetism when current in the coil is switched off. On the other hand, if steel is used for making the core of an electromagnet, the steel does not lose all its magnetism when the current is stopped and it becomes a permanent magnet. This is why steel is not used for making electromagnets. Electromagnets can be made in different shapes and sizes depending on the purpose for which they are to be used.

It should be noted that in many respects an electromagnet is better than a permanent magnet because it can produce very strong magnetic fields and its strength can be controlled by varying the number of turns in its coil or by changing the current flowing through the coil.

Q13. What is the difference between differences between a bar magnet and an electromagnet? (OR) How is An electromagnet is better than a permanent magnet?

Ans. An electromagnet is better than a permanent magnet as follows:

Bar Magnet	Electromagnet
1. The bar magnet is a permanent magnet.	1. An electromagnet is a temporary magnet. Its magnetism is only for the duration of current passing through it.
2. A permanent magnet produces a weak magnetic force	2. An electromagnet can produce very strong magnetic force.
3. The strength of a permanent magnet cannot be changed.	3. The strength of an electromagnet can be changed by changing the number of turns in its coil or current passing through it.
4. The polarity of a permanent magnet is fixed.	4. Its polarity can be changed by changing the direction of current.
5. It cannot be readily demagnetized.	5. It can be readily demagnetized by stopping current.



Q14. Describe that a current conductor placed in a magnetic field experiences a mechanical force

Ans. Oersted found that an electric current flowing through a conductor produces a magnetic field around itself. The field so produced exerts a force on a magnet placed in the vicinity of the conductor. French scientist Andre Marie Ampere (1715-1836) suggested that the magnet must also exert an equal and opposite force on the current-carrying conductor in accordance with third law of motion. The force due to magnetic field acting on a current carrying conductor can be demonstrated through the following activity.

Take a small aluminium rod AB (of about 5 cm). Using two connecting wires suspend it horizontally from a stand, as shown in Fig.

Place a strong horse-shoe magnet in such a way that the rod lies between the two poles with the magnetic field directed upwards. For this put the North Pole of the magnet vertically below and South Pole vertically above the aluminium rod.

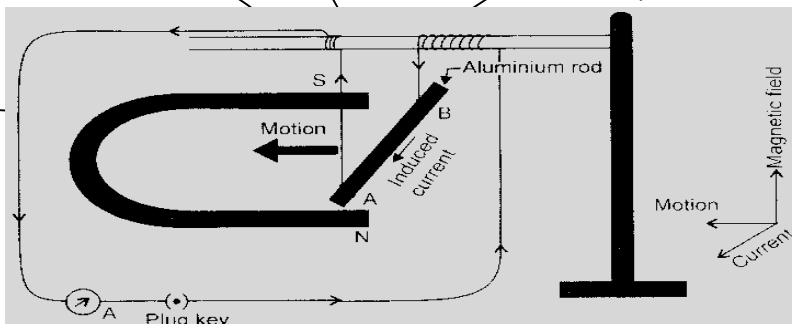
Connect the aluminium rod in series with a battery, a key and a rheostat.

Now pass a current through the aluminium rod from end B to end A.

It is observed that the rod is displaced towards the left.

Reverse the direction of current flowing through the rod and observe the direction of its displacement. It is now towards the right.

The displacement of the rod in the above activity suggests that a force is exerted on the current-carrying aluminium rod when it is placed in a magnetic field. It also suggests that the direction of force is also reversed when the direction of current through the conductor is reversed. Now change the direction of field to vertically downwards by interchanging the two poles of the magnet. It is once again observed that the direction of force acting on the current-carrying rod gets reversed. It shows that the direction of the force on the conductor depends upon the direction of current and the direction of the magnetic field. Experiments have shown that the displacement of the rod is largest (or the magnitude of the force is the highest) when the direction of current is at right angles to the direction of the magnetic field. The direction of force experienced by a current carrying conductor placed in a magnetic field can be found by Fleming's left hand rule.



an activity to show carrying

Q15. What are the factors on which the force experienced by the current carrying conductor placed in a magnetic field depends?

Ans. Experimentally it has been found that the force experienced by the current carrying conductor, in a magnetic field is directly proportional to:

the magnitude of current flowing through the conductor i.e., $F \propto I$. This means more the strength of current, more is the force experienced by the current carrying conductor and hence more is the displacement of the rod.

the magnitude of the magnetic field of the magnet i.e., $F \propto B$. This means more the Magnetic field, more is the force experienced by the current carrying conductor and hence more is the displacement of the rod.

the length of the conductor inside the magnetic field i.e., $F \propto L$. This means more the length of the conductor inside the magnetic field, more is the force experienced by the current carrying conductor and hence more is the displacement of the rod.

the sine of the angle between the conductor and the magnetic field i.e., $F \propto \sin\theta$. The force experienced by the current carrying conductor and hence displacement of the rod is largest when the direction of current is at right angles to the direction of the magnetic field ($\theta = 90^\circ$) and The force experienced by the current carrying conductor and hence displacement of the rod is largest when the direction of current is parallel to the direction of the magnetic field ($\theta = 0^\circ$).

Thus, $F = BIL \sin \theta$

if $\theta = 90^\circ$ i.e., the rod is perpendicular to the direction of the magnetic field, then $F = BIL$

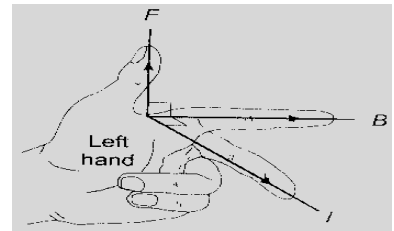
if $\theta = 0^\circ$ i.e., the rod is parallel to the direction of the magnetic field, then $F = 0$

Q16. State Fleming's Left Hand Rule

Ans. **FLEMING'S LEFT HAND RULE:**

According to Fleming's Left Hand Rule, "Stretch the thumb, forefinger and middle finger: of your left hand mutually perpendicular to each other such that the fore finger points in the direction of magnetic field and the middle finger in the direction of current, then the thumb will point in the direction of motion or the force acting on the conductor".

(Remember this rule by FBI).



Q17. What is electric Motor? What are its types?

Ans. **THE ELECTRIC MOTOR:** An electric motor is a device that converts electrical energy into mechanical energy (kinetic energy). Electric motor is used as an important component in electric fans, refrigerators, mixers, washing machines, computers, MP3 players etc. There are two kinds of motors that we use in our day to day life- DC Motor and AC Motor.

Construction: The construction of a dc motor is as follows:

Armature: An electric motor consists of a rectangular coil ABCD of insulated copper wire wound on a soft iron core. The coil and the core together form Armature, which is free to rotate about an axle.

Strong Field Magnet: The coil is placed between the two poles of a magnet which provides a strong magnetic field such that the arm AB and CD are perpendicular to the direction of the magnetic field.

Split Ring- Commutator: The free ends of the coil are connected to the two halves R_1 and R_2 of a ring called Split rings or half rings. The inner sides of these halves are insulated and attached to an axle. The split rings together form commutator. A device that reverses the direction of flow of current through a circuit is called a commutator. The function of the commutator is to reverse the direction of current in the armature coil after each half rotation.

Brushes: The external conducting edges of R_1 and R_2 touch (press against) two conducting stationary metal or carbon brushes B_1 and B_2 , respectively, as shown in the figure.

Source of electricity: The two brushes are connected to a source of electricity (Battery), which supplies the current to the coil.

Working: Electric Motor is based on the principle that when a current carrying conductor (coil) is placed in an external magnetic field, a force acts on it which makes it to rotate. The working of motor can be explained as follows.

Current in the coil ABCD enters from the source battery through conducting brush B_1 and flows back to the battery through brush B_2 . On applying Fleming's left hand rule for the direction of force on a current-carrying conductor in a magnetic field. We find that the force acting on arm AB pushes it downwards while the force acting on arm CD pushes it upwards. Both these forces constitute a couple which produce a torque on the coil and hence rotate the coil and the axle anti-clockwise.

When the Armature coil rotates, the contacts of the commutator and the brushes break for a moment and hence no force acts on the coil. But due to inertia of motion, the coil goes on rotating until the commutator again comes in contact with brushes B_1 and B_2 .

Thus, at half rotation, R_1 makes contact with the brush B_2 and R_2 with brush B_1 . Therefore the current in the coil gets reversed and flows along the path DCBA. In electric motors, the split ring acts as a commutator. The reversal of current also reverses the direction of force acting on the two arms AB and CD. Thus the arm AB of the coil is now pushed upwards and the arm CD is now pushed downwards. Both these forces again constitute a couple which rotates the coil and the axle anti-clockwise.

Therefore the coil and the axle rotate half a turn more in the same direction. The reversing of the current is repeated at each half rotation, giving rise to a continuous rotation of the coil and to the axle. Hence the electrical energy gets converted into mechanical energy.

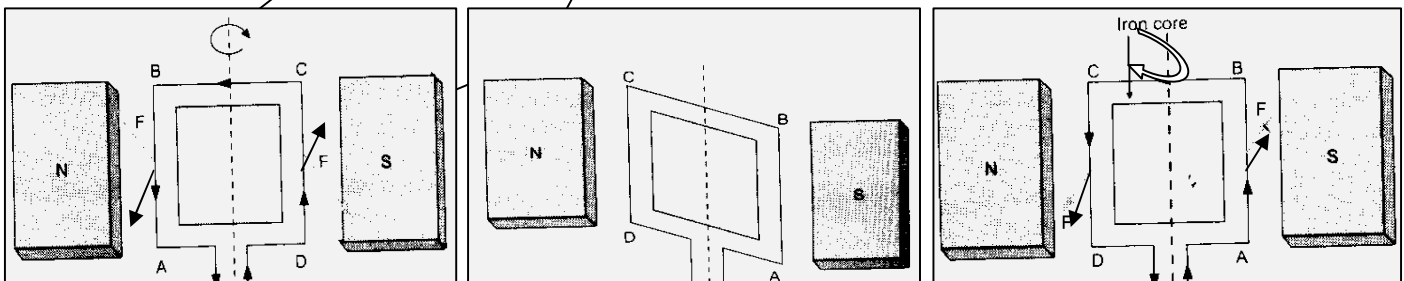
The turning effect or speed of rotation of the motor depends on :

a) the strength of the magnetic field, i.e., $\tau \propto B$

b) the current in the coil i.e., $\tau \propto I$

c) the number of turns in the armature coil. i.e., $\tau \propto n$

d) the Area of the coil i.e., $\tau \propto A$



The main difference between AC Motor and DC Motor is that:

DC Motor consists of half rings. DC motor uses dc supply e.g. motors of battery operated toys.

AC Motor consists of full rings called Slip Rings. AC motor uses AC supply e.g. Motor of a fan.

Q18. What is galvanometer?

Ans. **Galvanometer**: A galvanometer is an instrument that can detect the presence of a current in a circuit. The pointer remains 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.

Q19. What is meant by Electromagnetic Induction? State the rule used to find the direction of the induced current in the coil.

Ans. When magnetic field or magnetic flux through a closed circuit or coil changes due to relative motion of a magnet and a coil, an emf and hence current are induced in the circuit or coil. The emf induced in the coil is called induced emf and the current produced in the coil due to changing magnetic field is called induced current. The phenomenon of producing induced current in a closed circuit or coil due to the change in magnetic field in the closed circuit or coil is called electromagnetic induction. This phenomenon was first discovered by English physicist Michael Faraday in 1831. In practice we can induce current in a coil by:

moving a coil in a magnetic field or moving a magnet towards or away from the coil

by changing the magnetic field around a coil (secondary coil) by changing current in another coil (primary coil) it.

The value of the induced current depends on the following factors:

directly on the strength of the magnetic field, i.e., $I \propto B$

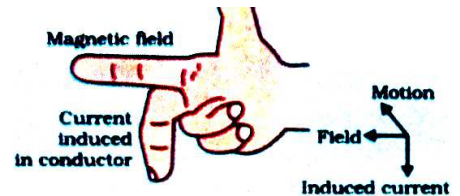
directly on the number of turns in the coil. i.e., $I \propto n$

directly on speed with which the magnet moves towards the coil.

The induced current is found to be the highest when the direction of motion of the coil is at right angles to the magnetic field. In this situation, we can use a simple rule to know the direction of the induced current called Fleming's Right Hand Rule.

FLEMING'S RIGHT HAND RULE:

Stretch the thumb, forefinger and middle finger of right hand so that they are mutually perpendicular to each other. If the forefinger indicates the direction of the magnetic field and the thumb shows the direction of motion of conductor, then the middle finger will show the direction of Induced current. This simple rule is called Fleming's right-hand rule.



Q20. Explain two ways to induce current in the coil.

Ans. **Moving a magnet towards or away from the coil (or) by moving a coil in a magnetic field:**

To observe this effect, let us perform the following activity:

Take a coil of wire AB having a large number of turns.

Connect the ends of the coil to a galvanometer as shown in Fig.

Take a bar magnet and move its north pole towards the end B of the coil.

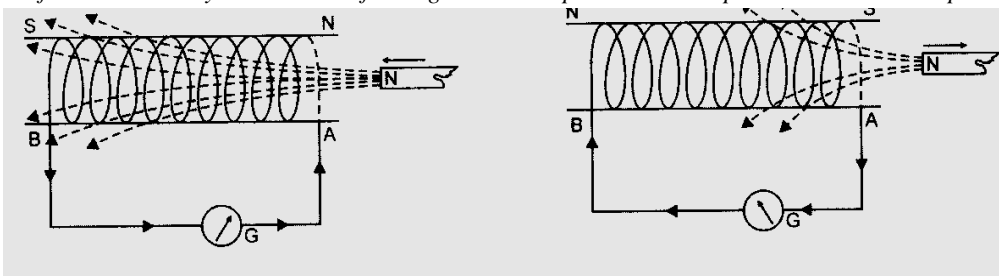
There is a momentary deflection in the needle of the galvanometer say to the right. This indicates the presence of a current in coil AB. The deflection becomes zero the moment the motion of the magnet stops.

Now withdraw the north pole of the magnet away from the coil. Now the galvanometer is deflected toward the left, showing that the current is now set up in the direction opposite to the first.

Place the magnet stationary at a point near to the coil, keeping its north pole towards the end B of the coil. We see that the galvanometer needle deflects toward the right when the coil is moved towards the north pole of the magnet. Similarly the needle moves toward left when the coil is moved away.

When the coil and the magnet are both stationary, there is no deflection in the galvanometer.

It is, thus, clear from this activity that motion of a magnet with respect to the coil produces an induced potential difference, which sets up an induced electric current in the circuit.



By Changing the Magnetic Field around a Coil (Secondary Coil) using Current carrying another Coil (Primary Coil).

Let us now perform a variation of above Activity in which the moving magnet is replaced by a current-carrying coil and the current in the coil can be varied.

Take two different coils of copper wire having large number of turns (say 50 and 100 turns respectively).

Insert them over a non-conducting cylindrical roll, as shown in Fig. (You may use a thick paper roll for this purpose.)

Connect the coil-1 called primary coil in series with a battery and a plug key.

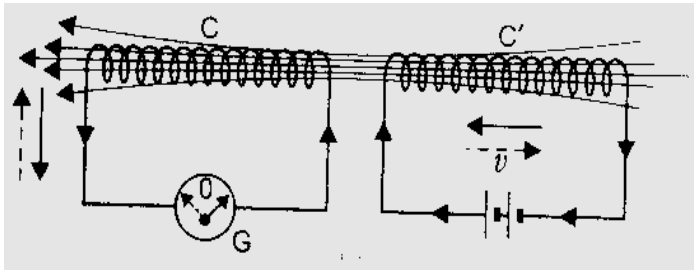
Also connect the coil-2 called secondary coil with a galvanometer as shown.

Plug in the key. Observe the galvanometer.

You will observe that the needle of the galvanometer instantly jumps to one side and just as quickly returns to zero, indicating a momentary current in coil-2.

Disconnect coil-1 from the battery. You will observe that the needle momentarily moves, but to the opposite side. It means that now the current flows in the opposite direction in coil-2.

We observe that as soon as the current in coil-1 reaches either a steady value or zero, the galvanometer in coil-2 shows no deflection. From these observations, we conclude that a potential difference is induced in the coil-2 whenever the electric current through the coil-1 is changing (starting or stopping). As the current in the first coil changes, the magnetic field associated with it also changes. Thus the magnetic field lines around the secondary coil also change. Hence the change in magnetic field lines associated with the secondary coil is the cause of induced electric current in it.



Q21. What is Electric generator? Explain the construction and working of Electric generator.

Ans. Electric generator is a device in which mechanical energy is used to rotate a conductor in a magnetic field to produce electricity. It is a device that converts mechanical energy (kinetic energy) into electrical energy. It is of two types namely AC Generator converts mechanical energy into electrical energy in the form of AC and DC Generator(Dynamo) converts mechanical energy into electrical energy in the form of DC

Construction: The construction of a dc generator is as follows:

Armature: An electric generator consists of a rectangular coil ABCD of insulated copper wire wound on a soft iron core. The coil and the core together form Armature, which is free to rotate about an axle.

Strong field Magnet: The coil is placed between the two poles of a strong magnet which provides a strong magnetic field such that the arm AB and CD are perpendicular to the direction of the magnetic field.

Split Ring- Commutator: The free ends of the coil are connected to the two halves R_1 and R_2 of a ring called Split rings or half rings. The inner sides of these halves are insulated and attached to an axle. The split rings together form commutator. A device that reverses the direction of flow of current through a circuit is called a commutator. The function of the commutator is to reverse the direction of current in the armature coil after each half rotation.

Brushes: The external conducting edges of R_1 and R_2 touch (press against) two conducting stationary metal or carbon brushes B_1 and B_2 , respectively, as shown in the figure.

Galvanometer: The Outer ends of the brushes are connected to the galvanometer to show the flow of current in the given external circuit.

The axle may be mechanically rotated from Brushes outside to rotate the coil inside the magnetic field.

Principle: Electric generator works on the principle of electromagnetic induction i.e., when magnetic field or magnetic flux through a closed circuit or coil changes due to relative motion of a magnet and a coil, an emf and hence current are induced in the circuit or coil. The direction of the induced current is determined by the Fleming's right-hand rule.

Working:

When the axle attached to the two rings is rotated such that the arm AB moves up and the arm CD moves down in the magnetic field produced by the permanent magnet. Let us say the coil ABCD is rotated clockwise in the arrangement shown in Fig.

By applying Fleming's right-hand rule, the induced currents are set up in these arms along the directions AB and CD. Thus an induced current flows in the direction ABCD.

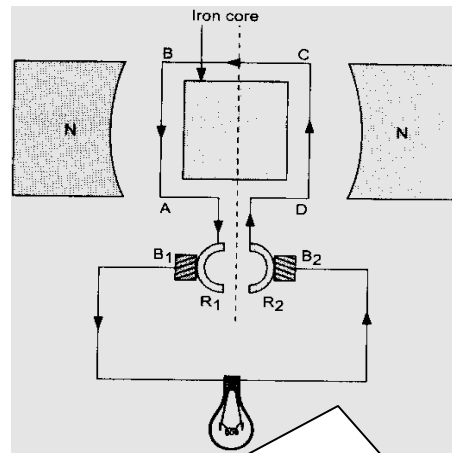
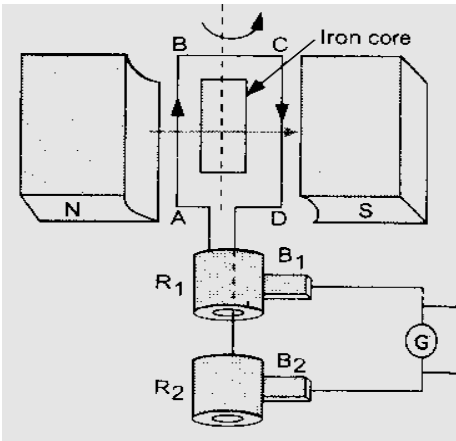
If there are larger numbers of turns in the coil, the current generated in each turn adds up to give a large current through the coil. This means that the current in the external circuit flows from B_2 to B_1 .

After half a rotation, arm CD starts moving up and AB moving down. As a result, the directions of the induced currents in both the arms change, giving rise to the net induced current in the direction DCBA. The current in the external circuit now flows from B_1 to B_2 . Thus after every half rotation the polarity of the current in the respective arms changes. Such a current, which changes direction after equal intervals of time, is called an alternating current (abbreviated as AC). This device is called an AC generator.

The main difference between AC Motor and DC Motor is that:

DC generator consists of half rings or a split-ring commutator. With this arrangement, one brush is at all times in contact with the arm moving up in the field, while the other is in contact with the arm moving down.

AC generator consists of full rings called Slip Rings. With this arrangement, one brush is at all times in contact with the one slip ring while the other brush is in contact with other slip ring. The brushes in an ac generator always remain in contact with the same brush. The emf in an ac generator changes direction after every half cycle of the armature



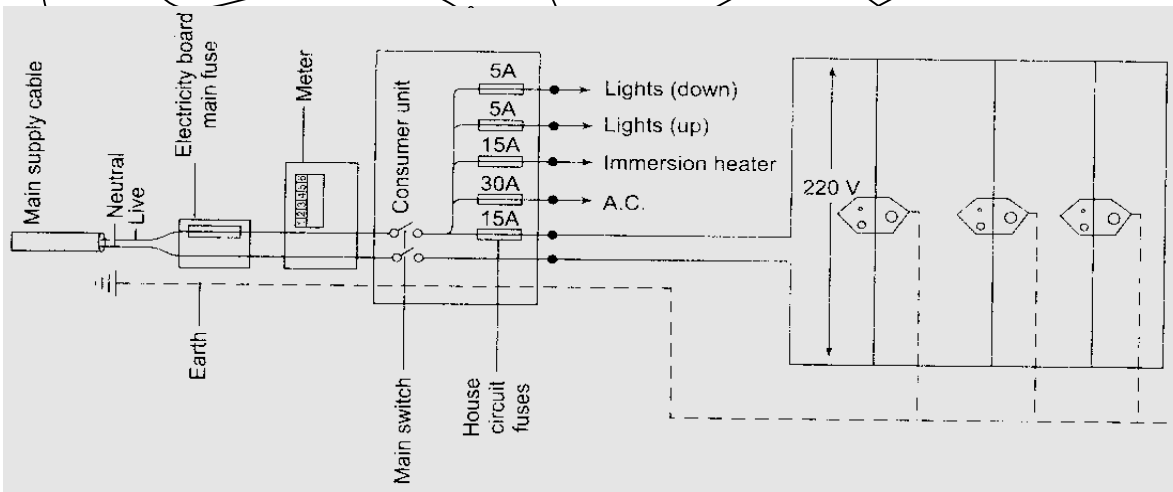
Q22. Write a short note in domestic electric circuits.

Ans. **DOMESTIC ELECTRIC CIRCUITS**

In our homes, we receive supply of electric power through a main supply (also called mains), either supported through overhead electric poles or by underground cables. One of the wires in this supply, usually with red insulation cover is called live wire (or positive). Another wire, with black insulation, is called neutral wire (or negative). In our country, the potential difference between the two is 220 V.

At the meter-board in the house, these wires pass into an electricity meter through a main fuse. Through the main switch they are connected to the line wires in the house. These wires supply electricity to separate circuits within the house. Often, two separate circuits are used, one of 15 A current rating for appliances with higher power ratings such as geysers, air coolers, etc. The other circuit is of 5 A current rating for bulbs, fans, etc. The earth wire, which has insulation of green colour, is usually connected to a metal plate deep in the earth near the house. This is used as a safety measure, especially for those appliances that have a metallic body, for example, electric press, toaster, table fan, refrigerator, etc. The metallic body is connected to the earth wire, which provides a low resistance conducting path for the current. Thus, it ensures that any leakage of current to the metallic body of the appliance keeps its potential to that of the earth, and the user may not get a severe electric shock.

In each separate circuit, different appliances can be connected across the live and neutral wires. Each appliance has a separate switch to 'ON/OFF' the flow of current through it. In order that each appliance has equal potential difference, they are connected parallel to each other.



Q23. What is the difference between short-circuit and overloading?

Ans. **SHORT CIRCUITING** : Short circuit means the coming together of the live and the neutral wire. This can happen due to the (i) damage to the appliance or (ii) wearing out of the wires carrying current. When a circuit is short circuited the resistance of the circuit becomes very small as the current follows the shortest circuit. This results in a large current flowing in the circuit. This large current, at times, may heat up the wires to such an extent that a fire may break out due to the intense heat. The damage due to Short circuit can be prevented by:

- Using proper insulated wires
- Using proper rating electric fuse
- By earthing

OVERLOADING Every electrical circuit in the house is designed to carry a certain maximum value of current. If the current in the circuit exceeds the predetermined value, then the circuit is said to be overloaded. This may be due to the connection of a large number of appliances to the same circuit. Overloading also makes a large current flow through the wires and may also be a cause of electrical fire. It can be prevented by:

- Using proper insulated wires
- Using proper rating electric fuse
- Using less number of high power devices simultaneously.

Q24. What is electric fuse? How does it work?

Ans. **ELECTRIC FUSE**: Electric fuse is an important safety device of all domestic circuits. An electric fuse is a short length of easily fusible wire put into an electrical circuit for protection purposes. The use of an electric fuse prevents the electric circuit and the appliance from a possible damage due to overloading or short-circuits by stopping the flow of unduly high electric current. The Joule heating that takes place in the fuse melts it to break the electric circuit.

It is usually made of an alloy of lead and tin (63 % tin + 37 % lead). It has a high resistivity and low melting point. As soon as the safe limit of current exceeds the fuse "blows" and the electric circuit is cut off. A fuse is always connected to the live wire in the beginning of a circuit in series before an appliance is connected. A copper wire cannot be used as a fuse wire because it has low resistance.

The 'fuse rating' is the maximum safe current permitted to flow in a fuse before it breaks. For lighting purpose, the current required in a lamp is 0.5 A only. So, with a few lamps in a circuit the maximum current may be about 3 or 4 A. The protective fuse wire in a lighting circuit is usually rated at 5 A. For heating purposes large currents are needed. So, fuse wire of 10 to 15 A rating may be used.

There are different types of fuses. The old type of fuse is made of two metal clamps fixed on a porcelain base with a groove in between. The fuse wire is connected in between the metal clamps which are inserted in the appropriate section of the circuit. These days' costly appliances are fitted with a cartridge type fuse. It consists of a length of fuse wire connected to metal caps at the end of a short glass tube. Nowadays miniature circuit breaker (MCB's) are being utilised for lighting circuits.

- Fuses blow off due to the following reasons.
- Short circuit due to worn out insulation on connecting wires.
- Overloading of an electrical circuit.

Q25. What is meant by earthing? Explain why earthing is important?

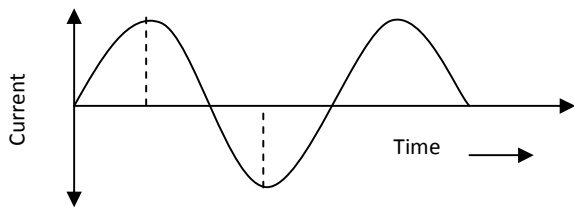
Ans. **EARTHING: (GROUNDING)**: By earthing we mean the connecting of a device (or a system) to the earth. To ensure good contact with the earth, a large metal plate is buried under the earth at a depth where the soil is moist. The plate is surrounded by a mixture of charcoal and common salt to ensure good contact with the wet soil and hence the ground. The earthing wire is usually bare and thick. It provides a safe and easy path for the electric charge to flow down to the earth which acts as a very large sink.

Earthing the circuit or appliance is a very important safety precaution. If the metal casing of the appliance is connected to the earth with the help of a conductor, the metal casing will be then at the same potential as the earth i.e. zero volt. The metal cases of all electrical appliances used in the home, such as room heater, electric stove, electric iron, are connected by the earth cable to the earth. In case, the insulation inside the appliance breaks down, or the live wire becomes loose and touches the case (body of the appliance), the case becomes 'live' and the user gets a severe shock, if the case is not earthed.

The power line used for operating high power gadgets such as oven, heater etc. has in addition to the two line wires - live (L) and neutral (N) - a third wire E which is the earthing wire. It is connected to the third terminal post.

Q26. What is the difference between AC and DC?

Alternating Current(A.C)	Direct Current(D.C)
The electric current which changes its direction (or polarity) after certain fixed interval of time is called A.C or alternating current. Thus in A.C, the polarity (+ or -) is not fixed The source of AC is AC generator, Inverter, etc.	The electric current which always flows in the same direction is called direct current or D.C. Thus in DC, the polarity (+ or -) is fixed. The sources of DC are current DC generator, battery or a cell, solar cell, etc.
In AC, the magnitude of the current changes periodically with time. The variation of AC with time can be represented as:	In DC, the magnitude of the current either remains constant or changes with time. The variation of DC with time can be represented as

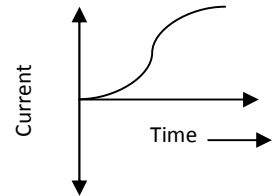
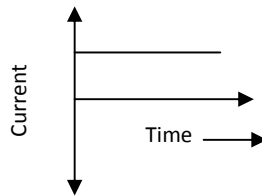


Advantages:

AC can be easily transmitted over long distances using step up transformers because there is less loss of energy during its transmission.
 AC can be controlled without much loss of electric power.
 The frequency of AC cannot be zero. The frequency of AC supply in India is 50Hz.

Disadvantages:

AC is more fatal than DC because it is usually produced at higher potential.
 AC cannot be used in the process of electrolysis.



Disadvantages:

DC cannot be transmitted over long distances using step up transformers because there is more loss of energy during its transmission.
 DC can also be controlled but loss of electric power is more.
 The frequency of DC can be zero.

Advantages:

DC is less fatal than AC because it is usually produced at lower potential.
 DC can be used in the process of electrolysis.

In India, the AC changes direction after every $1/100$ second, that is, the frequency of AC is 50 Hz.

TEXT BOOK QUESTIONS

Q1. Why does a compass needle get deflected when brought near a bar magnet?

Ans. A compass needle get deflected when brought near a bar magnet because Compass needle is itself a small magnet and hence experiences a force in the magnetic field of a bar magnet.

Q2. Draw magnet filed lines around a bar magnet.

Ans. Already done

Q3. List the properties of magnetic lines of force.

Ans. Already done

Q4. Why don't two magnetic lines of force intersect each other?

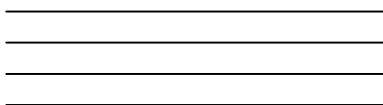
Ans. The tangent drawn at any point of the magnetic lines of force represents the direction of the magnetic field at that point. Two magnetic field lines do not intersect each other. This is because if they do so then the magnetic field at that point will have two directions which is not possible.

Q5. Consider a circular loop of wire lying in the plane of the table. Let the current pass through the loop clockwise. Apply the right hand rule to find out the direction of magnetic field inside and outside the loop.

Ans. According to Right Hand thumb Rule, Magnetic field inside the loop is perpendicular to the plane of table and in the downward direction. However, outside the loop, magnetic field is perpendicular to the plane of the table and in the upward direction.

Q6. The magnetic field in a given region is uniform. Draw a diagram to represent it.

Ans.



Q7. The magnetic field inside a long straight solenoid carrying current is :

- (a) zero
- (b) decreases as we move towards its ends
- (c) increases as we move towards its ends
- (d) is the same at all points.

Ans. (b).

Q8. Which of the property a proton can change when it moves freely in a magnetic field?

- (a) mass
- (b) speed
- (c) velocity
- (d) momentum.

Ans. A force acts on a proton when it moves freely in a magnetic field. Hence its velocity and momentum can change.

Ans. (c) and (d).

Q9. In activity 13-7, how do we think the displacement of rod AB will be affected if (i) current in rod AB is increased (ii) a stronger horse shoe magnet is inserted (iii) length of the rod AB is increased.

Ans. Force acting on a current carrying conductor of length l placed perpendicular to magnetic field B is given by $F = BIl$

- i. When I increase, F also increases. Hence the displacement of the rod increases.
- ii. When a stronger horse shoe magnet is inserted, magnetic field at B increases. So force also increases. Hence displacement increases.
- iii. When l increases, force increases and hence displacement increases.

Q10. A positively charged particle (alpha particle) projected towards west is deflected towards north by a magnetic field. The direction of magnetic field is

(a) towards south (b) towards east

(c) downward (d) upward.

Ans. (d).

Q11. State Fleming's left hand rule.

Ans. Already done

Q12. What is the principle of electric motor?

Ans. Already done

Q13. What is the role of the split ring in an electric motor?

Ans. The split-ring in an electric motor reverses the direction of current in the armature coil of motor. Therefore, the direction of the force acting on the two arms of the coil is also reversed. As a result of this, the coil of d.c. motor continues to rotate in the same direction.

Q14. Explain different ways to induce current in a coil.

Ans. Already done

Q15. State the principle of electric generator.

Ans. Already done

Q16. Name some sources of direct current.

Ans. A dry cell, a battery, a solar cell, d.c. generator etc. are some sources of direct current.

Q17. Which source produces alternating current?

Ans. AC generator (which converts mechanical energy into alternating current or electricity) and an oscillator (a device which converts D.C. into A.C.) are the sources which produce alternating current.

Q18. A rectangular coil of copper wires is rotated in a magnetic field. The direction of the induced current changes once in each

Ans. (a) two revolutions (b) one revolution

(c) half revolution (c) $1/4^{\text{th}}$ revolution

Ans. (c).

Q19. Name two safety measures commonly used in electric circuit and appliances.

Ans. (i) Electric fuse and (ii) earthing.

Q20. An electric oven of 2 kW power rating is operated in a domestic electric circuit (220 V) that has a current rating of 5 A. What result do you expect? Explain.

Ans. $P = 2 \text{ kW} = 2000 \text{ W}$ and $V = 220 \text{ V}$

$I = P/V = 2000/220 = 9.09 \text{ A}$.

This shows that current flowing through the oven is more than the current rating (5 A). Hence, the fuse in the circuit melts and oven is saved from damage.

Q21. What precautions should be taken to avoid the overloading of domestic electric circuit?

Ans. (i) We should not connect many appliances in the same socket.

(ii) Electrical appliances of high power rating should not be switched on simultaneously.

CHAPTER END EXERCISES

Q1. Which of the following correctly describes the magnetic field near a long straight wire?

(a) the field consists of straight lines perpendicular to the wire

(b) the field consists of straight lines parallel to the wire

(c) the field consists of radial lines originating from the wire

(d) the field consists of concentric circles centered on the wire.

Ans. (d).

Q2. The phenomena of electromagnetic induction is :

(a) the process of charging a body

(b) the process of generating magnetic field due to current passing through a coil

(c) producing induced current in a coil due to relative motion between a magnet and the coil

(d) the process of rotating a coil of an electric motor.

Ans. (c).

Q3. The device used for producing electric current is called a
(a) generator (b) galvanometer (c) ammeter (d) motor.

Ans. (a).

Q4. The essential difference between an AC generator and a DC generator is that
(a) AC generator has an electromagnet while a DC generator has permanent magnet
(b) DC generator will generate a higher voltage
(c) AC generator will generate a higher voltage
(d) AC generator has slip rings while the DC generator has a commutator.

Ans. (d).

Q5. At the time of short circuit, the current in the circuit
(a) reduces substantially (b) does not change
(c) increases heavily (d) vary continuously.

Ans. (c).

Q6. State whether the following statements are true or false:
(a) an electric motor converts mechanical energy into electrical energy
(b) an electric generator works on the principle of electromagnetic induction
(c) the field at the centre of a long circular coil carrying current will be parallel straight lines
(d) a wire with a green insulation is usually the live wire.

Ans. (a) False. It converts electrical energy into mechanical energy. (b) True. (c) True. (d) False. Live wire has red insulation cover.

Q7. List three sources of magnetic fields.

Ans. Three sources of magnetic fields are;

- (i) a permanent magnet
- (ii) a current carrying conductor
- (iii) a current carrying solenoid.

Q8. How does a solenoid behave like a magnet? Can you determine the north and south poles of a current carrying solenoid with the help of a bar magnet. Explain.

Ans. When electric current flows through a solenoid, magnetic field is set up around the solenoid. The pattern of the magnetic field is same as that of the magnetic field of a bar magnet. One end of the solenoid behaves as North Pole and the other end of the solenoid behaves as South Pole. To determine the north and south poles of a current carrying solenoid with the help of a bar magnet, suspend it with a strong thread. Now bring the north pole of a bar magnet towards one end of the solenoid. If the solenoid attracts towards the magnet, then that face of the solenoid is South Pole. If the solenoid moves away from the bar magnet, then that face of the solenoid is the North Pole.

Q9. When is the force experienced by a current carrying conductor placed in magnetic field is largest?

Ans. The force experienced by a current carrying conductor placed in magnetic field is largest when current carrying conductor is placed perpendicular to the magnetic field.

Q10. Think you are sitting in a chamber with your back to one wall. An electron beam moving horizontally from back wall towards the front wall, is deflected by a strong magnetic field to your right side. What is the direction of magnetic field?

Ans. Movement from electron beam from back wall to the front wall is equivalent to the flow of electric current from front wall to the back wall. The deflection of the beam means, the force is acting towards our right side. According to Fleming's Left Hand Rule, the direction of magnetic field is vertically downward. That is, the magnetic field is perpendicular to the plane of the paper and directed inward. Such magnetic field is shown by \otimes

Q3.

A fuse is inserted with each gadget which needs protection, it is inserted in modern power plugs and it is of course there in each branch circuit and at the main supply input point to provide safety everywhere. These are essential for the safety of the person and building as well as for the protection of the electrical gadgets in use. Whenever there is high current (in excess of some predetermined value) the fuse "blows" (melts) and that part of the circuit is turned off. This prevents damage to the gadget and any fire that could have resulted from over heating due to excess current.

Q. AC can be transmitted over long distances using step up transformers whereas dc cannot be transmitted as such.

R. The ac voltages can be easily varied by using a transformer.

S. The ac can be easily converted into dc.

T. The magnitude of ac can be reduced by using a choke coil.

U. The ac is easier and cheaper to generate than dc. The ac generators are usually more robust and their efficiency is high.

The only disadvantage that ac has is that it flows on the outer surface of a conductor and is more fatal than dc.

Note : The electric current which changes its direction (or polarity) after certain fixed interval of time is called ac or alternating current. Thus in ac, the polarity (+ or -) is not fixed and its current vs time graph is as shown in Fig 4.35a. Frequency of ac is the number of cycles of ac per second. One cycle of ac consists of one positive and one negative half cycles. In India the ac we receive at our homes has a frequency of 50 Hz, and a voltage of 220 V.

The electric current which always flows in the same direction is called direct current or dc. Thus in dc the polarisation (+ or -) are fixed. The current obtained from the battery or a cell is dc. The current vs time graph of dc is as shown in figure

4.35b.

4.16.1 Advantages of AC over DC The following are the advantages of ac over dc.

1. *Ac can be transmitted over long distances using step up transformers whereas dc cannot be transmitted as such.*
2. *The ac voltages can be easily varied by using a transformer.*
3. *The ac can be easily converted into dc.*
4. *The magnitude of ac can be reduced by using a choke coil.*
5. *The ac is easier and cheaper to generate than dc. The ac generators are usually more robust and their efficiency is high.*

Note- The only disadvantage that ac has is that it flows on the outer surface of a conductor and is more fatal than dc.

The difference between the direct and alternating currents is that the direct current always flows in one direction, whereas the alternating current reverses its direction periodically. Most power stations constructed these days produce AC. In India, the AC changes direction after every $1 / 100$ second, that is, the frequency of AC is 50 Hz. An Important advantage of AC over DC is that electric power can be transmitted over long distances without much loss of energy.

4.13.1 Faraday's Experiment and Laws

During the 1830s, several pioneering experiments with magnetically induced emf were carried out in England by Michael Faraday and in the United states by Joseph Henry.

There are a number of ways a magnetic field can be used to generate an electric current; figure 4.27 illustrates one of them. This figure shows a bar magnet and a helical coil of wire to which a galvanometer is connected. When there is no relative motion between the bar magnet and the coil, as in

~part a of the figure, the galvanometer reads zero, indicating there is no current. However, when the

magnet moves towards the coil, as in part *b*, a

current appears in the coil. As the magnet approaches, the magnetic field that it creates at the location of the coil becomes stronger and stronger, and it is this changing magnetic field that produces the current. When the magnet moves away from the coil, as in part *c*, a current also exists, but the direction of the current is reversed. Now the magnetic field at the coil becomes weaker as the magnet moves away. Once again, it is **the changing magnetic field at the coil that generates the current.**

A current would also be created in Figure 4.27 if the magnet were held stationary and the coil were moved, because the magnetic field at the coil would be changing as the coil approached or receded from the magnet. **Only relative motion between the magnet and the coil is needed to generate a current; it does not matter which one moves.**

The current in the coil is called an induced current, because the current is brought about (or "induced") by a changing magnetic field. Since a source of emf is always needed to produce a current, the coil itself behaves as if it were a source of emf. The emf is known as an induced emf. Thus, a changing magnetic field induces an emf in the coil, and the emf leads to an induced current.

The common element in all these experiments is changing magnetic field (flux) through the coil.

This led Faraday to conclude that an electric current can be produced by changing the magnetic field (flux). A current cannot be produced if the magnetic flux does not change.

Based on the observations of the above experiments Faraday put forward the following laws called Faraday's laws of electromagnetic induction.

1. Whenever the magnetic field (flux) linked with a coil changes an induced emf is produced.
2. The induced emf lasts as long as the change in magnetic field (flux) continues.
3. The induced emf in the closed loop equals the negative rate of change of magnetic field (flux) through the loop.

Thus it can be concluded that

The strength of the induced current depends directly upon the following factors.

(i) Strength of the magnetic field. (ii) Number of turns in the coil.

(iii) Relative speed between the coil and the magnet.