CHAPTER – 13
MAGNETIC EFFECTS OF ELECTRIC CURRENT

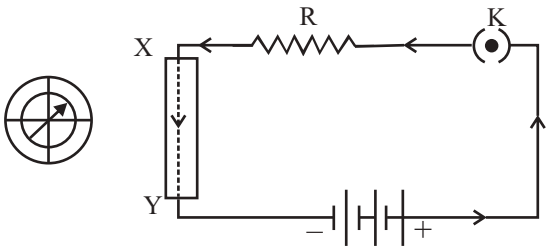
In this chapter, we will study the effects of electric current :

1. **Hans Christian Oersted (1777-1851)**

   Oersted showed that electricity and magnetism are related to each other. His research later used in radio, television etc.

   The unit of magnetic field strength is name Oersted in his honour.

2. **Oersted Experiment**



XY is conductor (Cu wire) through which current is passed

   On passing the current through the copper wire XY in the circuit, the compass needle which is placed near the conductor gets deflected. If we reverse the direction of current, the compass needle deflect in reverse direction. If we stop the flow of current, the needle comes at rest.

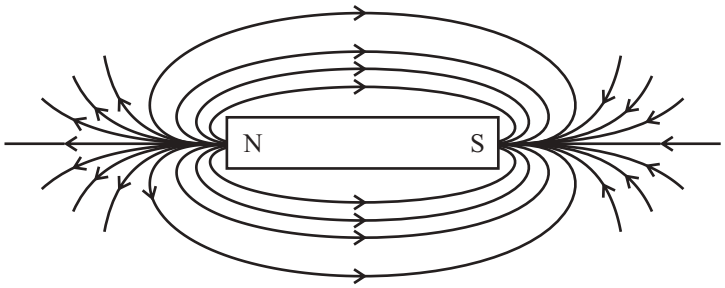
   Hence, it conclude that electricity and magnetism are linked to each other. It shows that whenever the current will flow through the conductor, then magnetic field around. it will developer

3. **Magnetic Field –** It is the region surrounding a magnet, in which force of magnet can be detected. It is a vector quantity, having both direction & magnitude.

4. Compass needle– It is a small bar magnet, whose north end is pointing towards north pole and south end is pointing towards south pole of earth.

5. **Magnetic field lines–**

   When a bar magnet is placed on a card board and iron fillings are sprinkled, they will arrange themselves in a pattern as shown below.



The lines along which the iron filling align themselves represent magnetic field lines.

Hence, magnetic field line is a path along which a hypothetical free north pole tend to move towards south pole.

6. **Characteristics of Magnetic field lines :**

(1) The direction of magnetic field lines outside the magnet is always from north pole to south pole of bar magnet and are indicated by an arrow.

Inside the magnetic, the direction of field lines is from its south pole to north pole

Thus magnetic field lines are closed curve

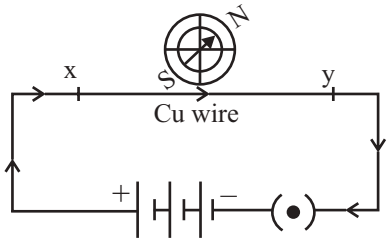
(2) The strength of magnetic field is expressed by the closeness of magnetic field lines. Closer the lines, more will be the strength and farther the lines, less will be the magnetic field strength.

(3) No two field lines will intersect each other.

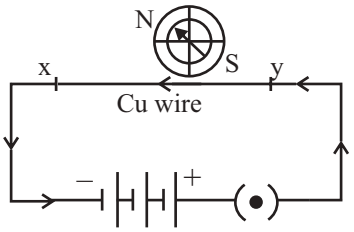
If they intersects, then at point of intersection the compass needle will show two direction of magnetic field which is not possible.

Tangent at the point of intersection shows two direction.

7. **Magnetic field due to Current Carrying Conductor**



(a)



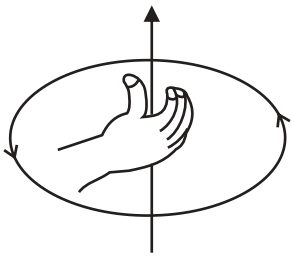
(b)

The above electric circuit in which a copper is placed paralled to a compass needle, shows the deflection in needle gets reversed, when the direction of current reversed. Hence electricity and magnetism are related to each other.

8. **Right Hand Thumb Rule :–**

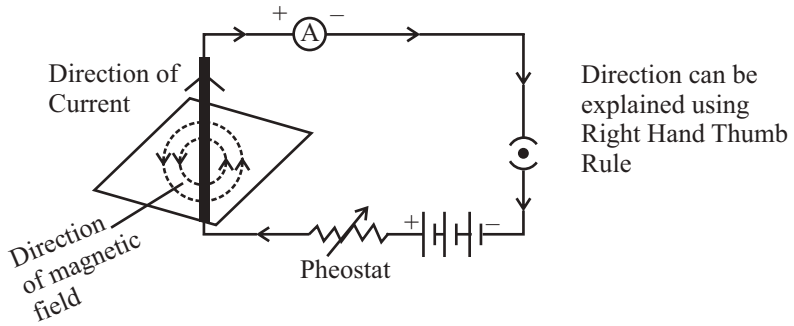
It is a convenient way of finding the direction of magnetic field associated with current carrying conductor.

Hold the straight were carrying current in your right hand such that thumb points towards the direction of current, then your folded fingers around the conductor will show the direction of magnetic field.

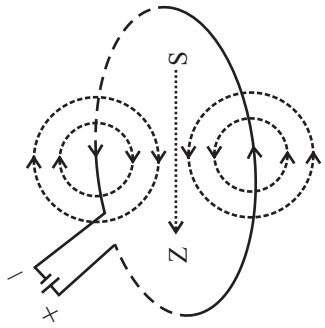


This rule is also called Maxwell's corkscrew rule.

9. **Magnetic Field due to Current through a Straight Conductor**



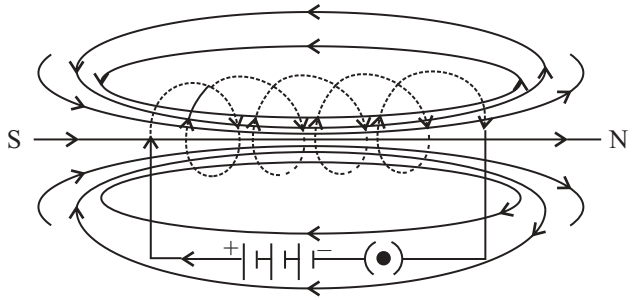
10. **Magnetic Field due to Current through a circular Loop**



Every point on the wire carrying current give rise to the magnetic field, appearing as a straight line at the centre of loop. By applying Right hand Thumb rule, we can find the direction of magnetic field at every section of the wire.

11. Solenoid– A Coil of many circular turns of insulated copper wire wrapped closely in the shape of a cylinder is called solenoid.

12. **Magnetic field due to a current in a solenoid–**



– Using R.H. Thumb Rule, we can draw the pattern of magnetic field lives around a current carrying solenod.

– One end of the solenoid behaves as a magnetic north pole, white the other end behave as the South Pole.

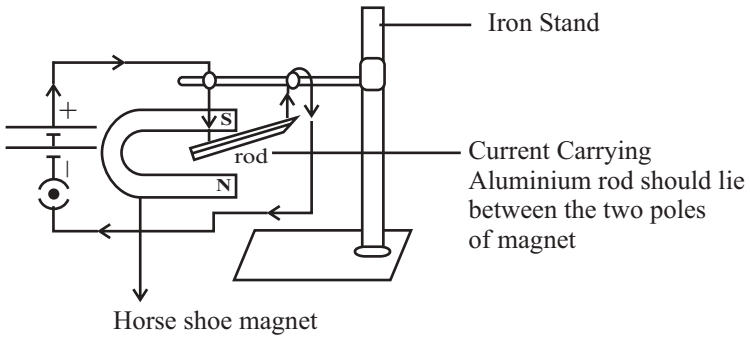
– The filed lines inside the solenoid are in form of parallel straigh lines, that implies that magnetic field inside the solenoid is same at all points i.e. Field is uniform.

13. **Electromagnet–** Strong magnetic field inside the solenoid can be used to magnetise a magnetic material for example soft iron, when it is placed inside the coil. The magnet so formed is called electromagnet.

14. **Force on a current carrying conductor in a magnetic field.**

Andre Marie Ampere (1775-1836) suggested that the magnet also exert an equal and opposite force on the current carrying conductor.

Experiment



We will observe that the rod will displace i.e. the rod will experience a force, when it is placed in magnetic field, in a perpendicular direction to its length.

– The direction of the exert force will be reversed if the direction of current through the conductor is reversed.

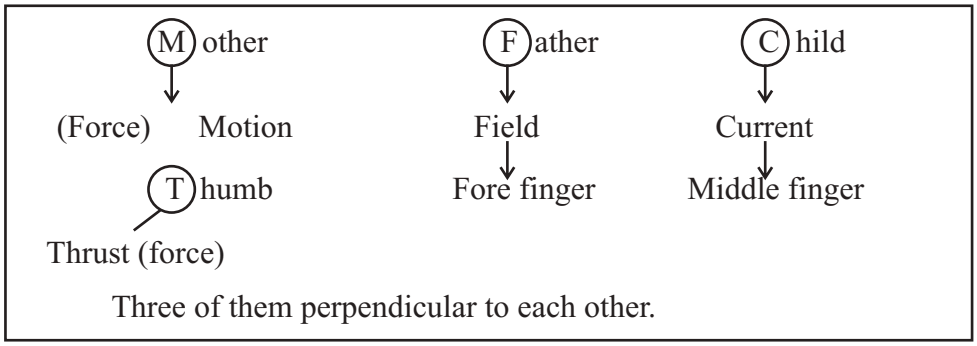
– If we change the direction of field by inter changing the two poles of the magnet, again the direction of exert force will change.

– Therefore the direction of exerted force depends on

(1) direction of current

(2) direction of magnetic field lines.

15. **Left Hand Fleming Rule**



– According to this rule, stretch thumb, forefinger and middle finger of your left hand such that they are mutually perpendicular to each other.

If fore finger represent direction of magnetic field & middle finger represent direction of current, then thumb will point in the direction motion or force acting on the conductor.

– Functioning of electric motor is based on this rule. It convert electrical energy into mechanical energy.

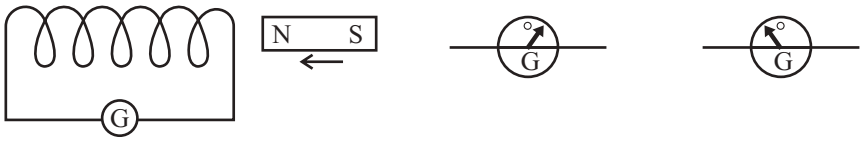
16. **Michael Faraday**– Gave the law of **Electro magnetic Induction**

17. **Galvanometer** It is an instrument that can detect the presence of a current in a circuit. If pointer is at zero (the centre of scale) the there will be no flow of current.

If the pointer deflect on either side right or left, this will show the direction of current. Represented by

18. **Electro Magnetic Induction –** Can be explained by two experiments

(a) FIRST EXPERIMENT "SELF INDUCTION"



In this experiment, when the north pole of bar magnet is brought closes to the coil or away from the coil, we see momentary deflection in the needle of galvanometer on either side of null point. First right and then left.

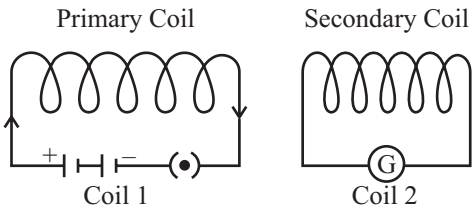
Similarly, if we keep the magnet stationary and coil is made to move towards or away from the north pole of magnet. Again we will observe deflection in the needle of galvanometer.

If both bar magnet and coil kept stationary, there will be no deflection in galvanometer.

This experiment can also be done with the south pole of magnet, we will observe the deflection in galvanometer, but it would be in opposite direction to the previous case.

It concludes that motion of magnet with respect to coil or vice-versa, changes the magnetic field. Due to this change in magnetic field lines, potential difference is induced in the same coil, which set up an induced current in the circuit.

(b) **SECOND EXPERIMENT – Mutual Induction**



In this experiment plug in the key that is connect coil with battery and observe the deflection in galvanometer. Now plug out the key that is disconnect the coil-1 from battery and observe the deflection in galvanometer, which will be in reverse direction.

Hence, we conclude that potential difference is induced in secondary coil (coil-2), whenever there is a change in current, in primary coil (coil-1) (by on and off of key).

This is because, whenever there is change in current in primary coil

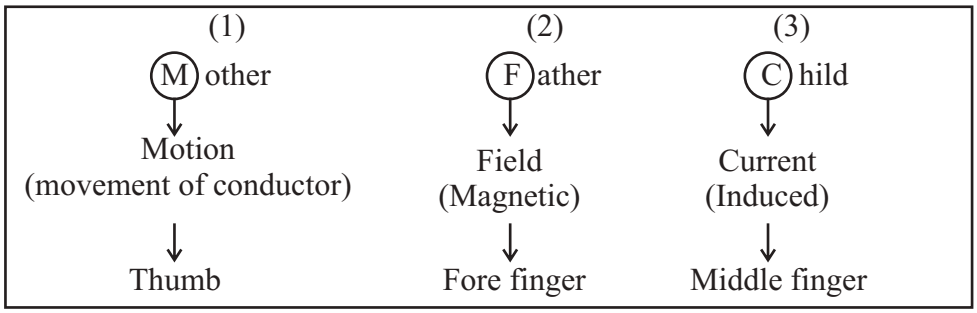
Magnetic field associated with it also changes

Now, magnetic field lines around the secondary coil (coil-2) will change and induces the electric current in it (observed by the deflectionof needle of Galvanometer in secondary circuit)

This process, by which changing of strength of current in primary coil, induces a current in secondary coil is called Electromagnetic Induction"

The induced current is found to be highest when the direction of motion of coil is at right angles to the magnetic field.

19. **Fleming's Right Hand Rule**

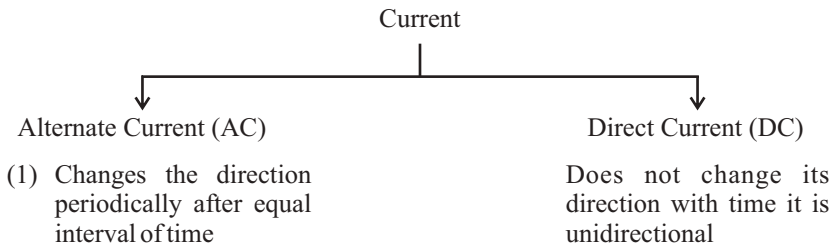


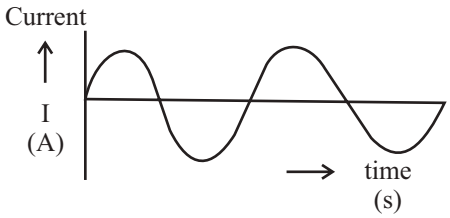
Three of them perpendicular to each other.

Rule can be defined at–

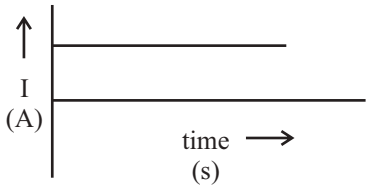
Stretch thumb, forefinger and middle finger of right hand, so that they are perpendicular to each other. The forefinger indicates direction of magnetic field, thumb shows the direction of motion of conductor, then the middle finger will shows the direction of induced current.

Electrical generator is based on the principle of electro magnetic induction. It convert mechanical energy into electrical energy.





It has frequency
50Hz in India
60 Hz in America



It has frequency
OHz

21. **Advantages of Alternate Current (AC) over Direct Current (DC)**

Electric power can be transmitted to longer distances without much loss of energy. Therefore cost of transmission is low.

In India the frequency of AC is 50Hz. It means after every 1/100 second it changes its direction.

22. **Domestic Electric Circuits :–**

In our homes, the electric power supplied is of potential difference V = 220V and frequency 50Hz.

It consist of three wires :–

(1) Wire with red insulation cover – LIVE WIRE (POSITIVE)

Live wire is at high potential of 220V

(2) Wire with black insulation cover – NEUTRAL WIRE (NEGATIVE)

Neutral wire is at zero potential

Therefore, the potential difference between the two is 220V.

(3) Wire with Green insulation cover – EARTH WIRE

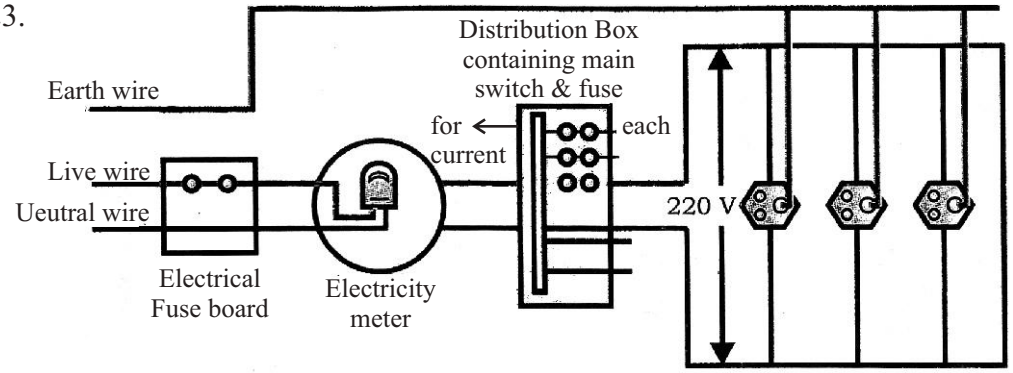
it is connected to a copper plate deep in the earth near house.

The metallic body of the appliances is connected with the earth wire as a safety measure.

Function–

Earth wire provide a low resistance to the current hence any leakage of current to the metallic body of the appliances, keep its potential equal to that of earth. That means zero potential and the user is saved from severe electric shock.

23.



Point to be noted in domestic circuit

(1) Each appliance has a seperate switch of ON/OFF

(2) In order to provide equal potential difference to each appliance, they should be connected parallel to each other. So that they can be operated at any time.

(3) We have two electric circuit in our home
- One consist of current of 15A for high power appliances
- Other circuit consist of current 5A for low power appliances.

24. **Short Circuiting –**

Due to fault in the appliances or damage in the insulation of two wires, the circuit will offer zero or negligible resistance to the flow of current. Due to low resistance, large amount of current will flow.

According to Joule's law of heating effect ($H \quad I^2$) heat is produced in live wire and produces spark, damaging the device and wiring.

25. **Overloading–**

Overloading can be caused by (1) Connecting too many appliances to a single socket or (2) accidental rise in supply voltage if the total current drawn by the appliances at a particular time exceeds the bearing capacity of that wire, it will get heated up. This is known as overloading.

Fuse a safety device can prevent the circuit from overloading and short circuiting.

EXERCISE

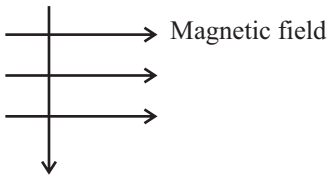
(Question Bank)

Very Short Answers (1 Mark)

1. What is the frequency of AC used in India?
2. Name the point where the iron filling are collected more?
3. Who discovered electro magnetic induction?
4. Why does a compass needle get deflected when brought near the bar magnet?
5. If both the coil and the magnet are stationary, will there be deflection in galvanometer?
6. Why magnetic field lines do not intersect each other?
7. What is the advantage of Alternate Current over Direct current?
8. What do you understand by short circuiting?
9. When the force experienced by a current carrying conductor placed in a magnetic field is maximum?
10. Write the factors affecting the magnetic field due to a straight conductor?

Short Answers (2 Marks)

1. A charged particles enters at right angles into a uniform magnetic field. What is the nature of charge particle, if it experiences a force in a direction pointing vertically out of the page.



Charge particle (use left hand flemings rule)

2. Name the Rule–
   (1) Force experience by a current - carrying conductor placed in a magnetic field.
   (2) Direction of magnetic field lines associated with a current carrying conductor.
   (3) Direction of induced current in a coil due to its rotation in magnetic field.

3. What is solenoid? Where the magnetic field is uniform in solenoid?

4. Draw the pattern of magnetic field lines due to current carrying straight conductor?

(5) Name two safety measures commonly used in electric circuit and appliances?

(6) What is overloading?

Long Answer (5 Marks)

1. Explain the phenomenon of Electro magnetic Induction with the help of an activity. Write its one application.

2. Draw the schematic diagram of domestic circuit. Write the colour and function of Neutral wire, Live wire and Earth wire.

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Chapter 13 Magnetic effects of electric current

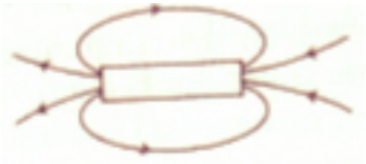
1. The phenomenon of electromagnetic induction is **(1)**
   a. the process of rotating a coil at an electric motor
   b. the process of charging a body
   c. the process of generating magnetic field due to a current passing through a coil
   d. producing induced current in a coil due to relative motion between a magnet and the coil
2. When a coil carries current in an anti clockwise direction what pole does it create? **(1)**
   a. South pole
   b. Zero pole
   c. North pole
   d. both South pole and North pole
3. Match the following with correct response. **(1)**

(1) Direction of induced current produced by motion of conductor in a magnetic field is given by	(A) Fleming's left hand rule
(2) Direction of force acting on a current carrying conductor kept in a magnetic field is given by	(B) Earthing
(3) Production of electricity from magnetism	(C) Electromagnetic induction
(4) High powered electrical appliances are connected to the earth	(D) Fleming's right hand rule

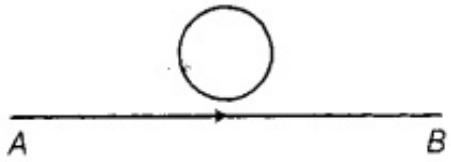
   a. 1-C, 2-B, 3-D, 4-A
   b. 1-D, 2-A, 3-C, 4-B
   c. 1-A, 2-C, 3-B, 4-D
   d. 1-B, 2-D, 3-A, 4-C
4. Which of the following involves electro magnetic induction? **(1)**
   a. A magnetic field exerts a force on a current- carrying wire

b. An electric current produces a magnetic field.
c. A rod is charged with electricity
d. The relative motion between a magnet and a coil produces an electric current.

5. The fuse wire should have **(1)**
   a. Low resistance, High melting point
   b. Low resistance, Low melting point
   c. High resistance, High melting point
   d. High resistance, Low melting point
6. What does the divergence of magnetic field lines near the ends of a current carrying straight solenoid indicate? **(1)**
7. Identify the poles of a magnet in the figure. **(1)**



8. Why is an alternating current considered to be advantageous over direct current for long range transmission of electric energy? **(1)**
9. Identify the region, where the magnetic field around a current carrying solenoid is uniform. **(1)**
10. i. Two circular coils P and Q are kept close to each other, of which, coil P carries a current. Will some current be induced in coil Q if coil P is moved towards Q ? Give a reason for your answer and name the phenomenon involved.
    ii. What happens, if coil P is moved away from Q?
    iii. State few methods of inducing current in a coil. **(3)**
11. Compare the permanent magnet and an electromagnet. **(3)**
12. A current carrying conductor is placed perpendicular to the uniform magnetic field. What happens to displacement of the conductor if
    (i) Amount of current increases
    (ii) If horse shoe magnet is replaced by a weak horse shoe magnet. **(3)**
13. A circular metallic loop is kept above the wire AB as shown below:



What is the direction of induced current produced in the loop, if the current flowing in the straight wire

i. is steady, i.e. does not vary?

ii. is increasing in magnitude?

Justify your answer in each case. **(3)**

14. What is the pattern of magnetic field due to a circular coil carrying current? **(5)**
15. Draw an appropriate schematic diagram showing common domestic circuits and discuss the importance of fuse. Why is it that a burnt out fuse should be replaced by another fuse of identical rating? **(5)**

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Chapter 13 Magnetic effects of electric current

Answers

1. d. producing induced current in a coil due to relative motion between a magnet and the coil

   Explanation: When a straight coil and a magnet are moved relative to each other, a current is induced in the coil. This phenomenon is known as electromagnetic induction.

2. c. North pole

   Explanation: According to clock rule if we look at the face of the coil which carries current in the clock wise direction then the face is called as south pole looking from the other side of coil we find that anti clock wise current flows that is called as north pole.

3. b. 1-D, 2-A, 3-C, 4-B

   Explanation:

   i. The direction of induced current in a straight conductor is given by Fleming's right hand rule.
   ii. It states that if we stretch the thumb, forefinger and the middle finger of right hand at right angles to one another in such a way that the forefinger points in the direction of magnetic field.
   iii. Then, thumb gives the direction of motion of conductor (force), forefinger indicates direction of magnetic field and the middle finger points the direction of induced current.
   iv. The direction of force which acts on the current-carrying conductor placed in a magnetic field is given by Fleming's left hand rule. It states that if the forefinger, thumb and middle finger of left hand are stretched mutually perpendicular and the forefinger points along the direction of external magnetic field, middle finger indicates the direction of current, then thumb points along the direction of force acting on the conductor.
   v. Electromagnetic induction is the process of generating electric current with

a magnetic field. It occurs whenever a magnetic field and an electric conductor, such as a coil of wire, move relative to one another.

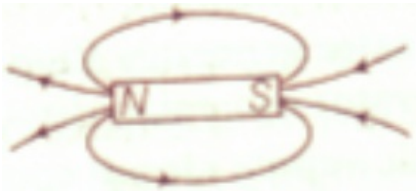
vi. High powered electrical appliances are connected to the earth by Earthing wire.

4. d. The relative motion between a magnet and a coil produces an electric current.
   Explanation: When a straight coil and a magnet are moved relative to each other, a current is induced in the coil. This phenomenon is known as electromagnetic induction.

5. d. High resistance, Low melting point
   Explanation: A fuse wire has high resistance and low melting point so that it will melt if a current of large magnitude passes through the wire.

6. The divergence of magnetic field lines indicates the decrease in strength of the magnetic field near the ends of the solenoid.

7. The poles of a magnet are marked in the figure as we know that out side magnet field lines moves N$\rightarrow$S and inside the Magnet field lines moves S$\rightarrow$N .



8. Alternating current can be transmitted without much loss of electric energy to the distant places. So AC is considered to be advantageous over DC.

9. The magnetic field is uniform inside the magnet.

10. i. When coil P is moved towards Q, then current will be induced in coil Q because the coil P will carry a magnetic field around it, so when it is moved towards coil Q it increases the magnetic flux around it, hence, current is induced. This phenomenon is called **electromagnetic induction.**

    ii. If P is moved away from Q, then the magnetic flux around Q will decrease and a current will be induced but in the opposite direction.

    iii. Some of the methods of inducing current in the coil are as below:
    a. Moving a magnet away or towards the coil.
    b. Moving a coil away or towards a magnet.
    c. Rotating a coil within a magnetic field.
    d. By changing the magnitude of current.

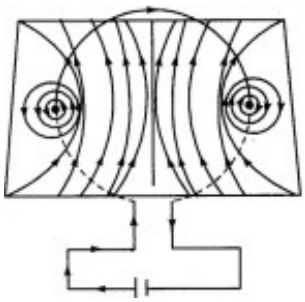
11.

Permanent Magnet	Electromagnet
(i) Very strong electromagnets cannot be produced.	(i) Very strong electromagnets can be produced.
(ii) Its strength is fixed.	(ii) Strength can be changed by changing the current through coil.
(iii) Polarities are fixed.	(iii) Polarities can be reversed by changing the direction of the current.
(iv) Cannot be immediately demagnetized.	(iv) Can be demagnetized immediately by stopping the current in the coil.
(v) Example of permanent magnet is a Bar Magnet	(v) Example of a temporary magnet is solenoid wounded across a nail and connected to a battery.

12. The displacement of the conductor
(i) will increase on increasing the current
(ii) Will decrease on using a weak horse shoe magnet.

13. i. The constant current flowing in the straight wire produces a constant magnetic field. Hence, no induced current is produced in the loop.
ii. Since current in the straight wire is changing, hence, induced current will be produced in clockwise direction.

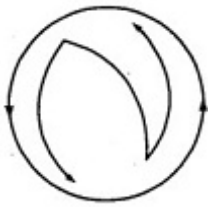
14. **Magnetic field due to circular conductor:** When a current is passed through a circular coil in clockwise direction, the magnetic field will be as shown in figure.



Here the current is passing clockwise when looked from front side. At the points where the conductor passes through horizontal plane, the lines of force are almost circular, their direction being given by right-hand grip rule. Near the central region, the lines are quite straight and at right angles to the plane of the coil.

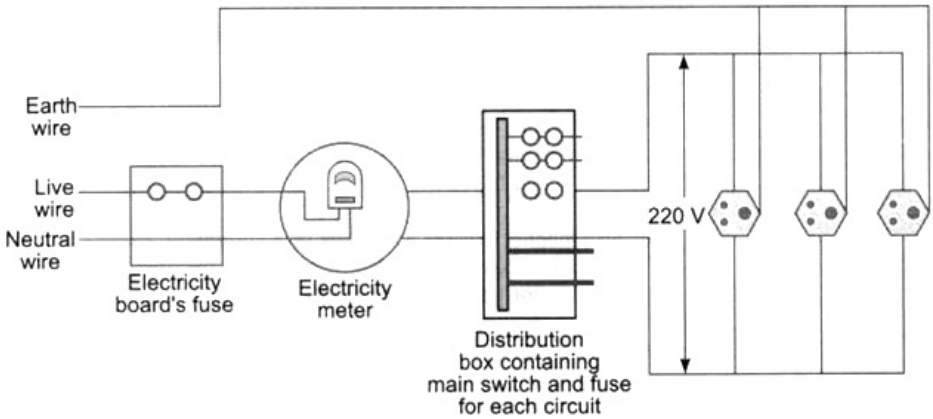
Further, it is clear from the figure that all the lines enter at the nearer face and leave at the farther face. Evidently, the lines of force due to the current flowing in circular loop closely resemble those produced by a magnetized circular disc of steel of same boundary as that of the coil, so that one face of it is north and other a south pole. The polarity of any face of coil can be determined by remembering a simple rule known as clock rule. If the current round any face of the coil flows in an anticlockwise direction it behaves like a north pole and if the current is in clockwise direction, the face acts as a south pole.

Clockwise current behaves like south pole.



Anti-clockwise current behaves like north pole.

15.



A fuse in a circuit prevents damage to the appliances and the circuit due to overloading. Otherwise, the appliances or the circuit may be damaged.

When current in the circuit exceeds the value of fuse rating, the fuse wire burns due to overloading. This causes a gap in the circuit and the current stops flowing in the circuit.

This is done due to the reason so that the circuit or the appliances to be connected in the circuit continue functioning without any damage in future.