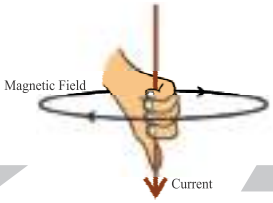


Chapter - 13

Magnetic Effects Of Electric Current

Magnet is any substance that attracts iron or iron-like substances.

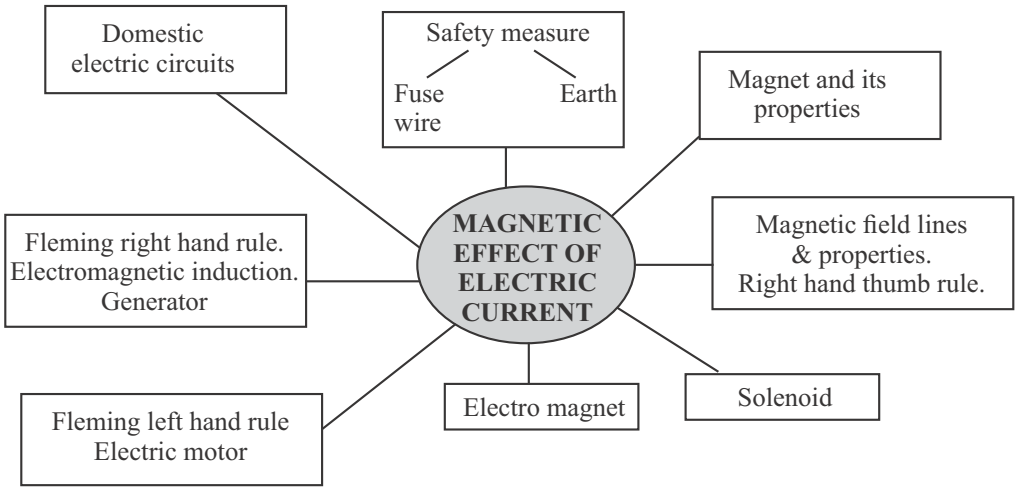
Properties of Magnet

(i) Every magnet has two poles *i.e.,* North and South.

(ii) Like poles repel each other.

(iii) Unlike poles attract each other.

(iv) A freely suspended bar magnet aligns itself in nearly north-south direction, with its north pole towards north direction.



Magnetic Field : The area around a magnetic in which its magnetic force can be experienced.

- Its SI unit is Tesla (T).

Magnetic field has both magnitude and direction.

Magnetic field can be described with help of a magnetic compass.

- The needle of a magnetic compass is a freely suspended bar magnet.

Characteristics of Field Lines

(i) Field lines arise from North pole and end into South pole of the magnet.

(ii) Field lines are closed curves.

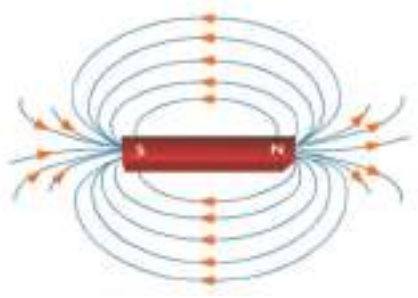
(iii) Field lines are closer in stronger magnetic field.

(iv) Field lines never intersect each other as for two lines to intersect, there must be two north directions at a point, which is not possible.

(v) Direction of field lines inside a magnet is from South to North.

(vi) The relative strength of magnetic field is shown by degree of closeness of field lines.

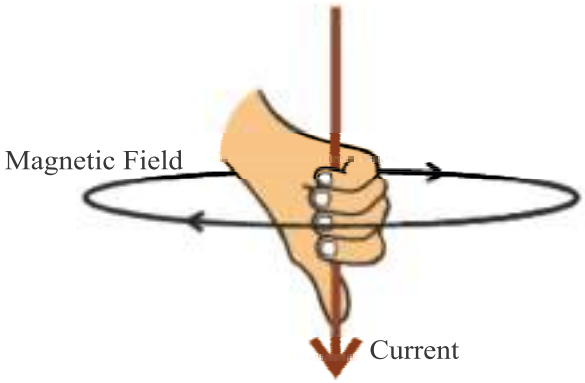
Magnetic Field of a Bar Magnet



- H. C. Oersted was the first person to state that electric current has magnetic field.

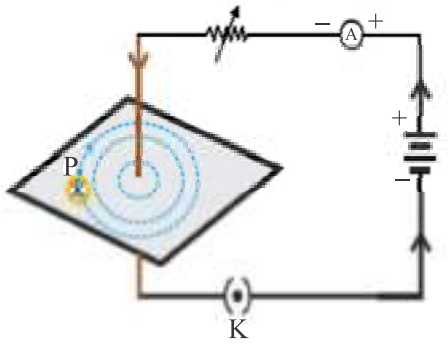
Right Hand Thumb Rule

Imagine you are holding a current carrying straight conductor in your right hand such that the thumb is pointing towards the direction of current. Then the fingers wrapped around the conductor give the direction of magnetic field.



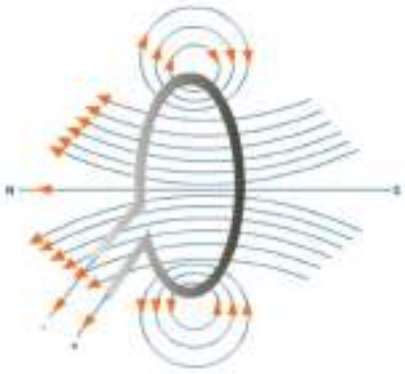
Magnetic Field Due to Current Through a Straight Conductor

- It can be represented by concentric circles at every point on conductor.
- Direction can be given by right hand thumb rule or compass.
- Circles are closer near the conductor.
- Magnetic field $\propto$ Strength of current
- $\text{Magnetic field} \propto \frac{1}{\text{Distance from conductor}}$



Magnetic Field Due to Current Through a Circular Loop

- It can be represented by concentric circle at every point.
- Circles become larger and larger as we move away.
- Every point on wire carrying current would give rise to magnetic field appearing as straight line at centre of the loop.
- The direction of magnetic field inside the loop is same.



Factors affecting magnetic field of a circular current carrying conductor

- Magnetic field $\propto$ Current passing through the conductor
- Magnetic field $\propto \frac{1}{\text{Distance from conductor}}$
- Magnetic field $\propto$ No. of turns in the coil

Magnetic field is additive in nature *i.e.,* magnetic field of one loop adds up to magnetic field of another loop. This is because the current in each circular turn has some direction.

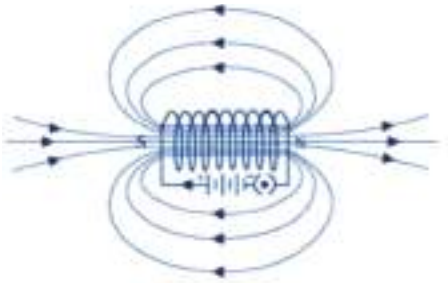
Solenoid

A coil of many circular turns of insulated copper wire wrapped closely in a cylindrical form.

- Magnetic field of a solenoid is similar to that of a bar magnet.
- Magnetic field is uniform inside the solenoid and represented by parallel field lines.
- Direction of magnetic field

  (i) Outside the solenoid : North to South

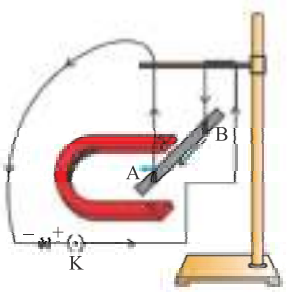
  (ii) Inside the solenoid : South to North
- Solenoid can be used to magnetise a magnetic material like soft iron.



Electromagnet	Permanent Magnet
1. It is a temporary magnet, so, can be easily demagnetised.	1. Cannot be easily demagnetised.
2. Strength can be varied.	2. Strength is fixed.
3. Polarity can be reversed.	3. Polarity cannot be reversed.
4. Generally strong magnet.	4. Generally weak magnet.

Force on a Current carrying Conductor in a Magnetic Field

Andre Marie Ampere suggested that the magnet also exerts an equal and opposite force on a current carrying conductor.

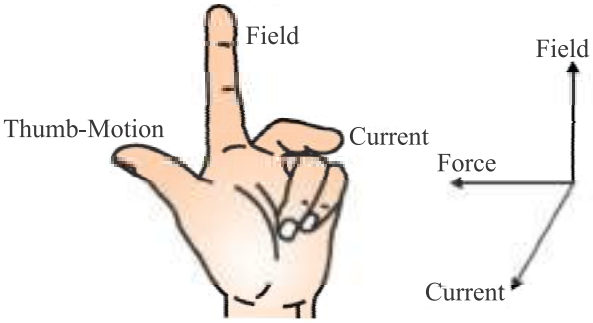


The displacement in the conductor is the maximum when the direction of current is at right angle to the direction of magnetic field.

Direction of force is reversed on reversing the direction of current.

Fleming□s Left Hand Rule

Stretch the thumb, fore finger and middle finger of your left hand such that they are mutually perpendicular. If fore finger points in the direction of magnetic field, middle finger in the direction of current then thumb will point in the direction of motion or force.



Electric Motor

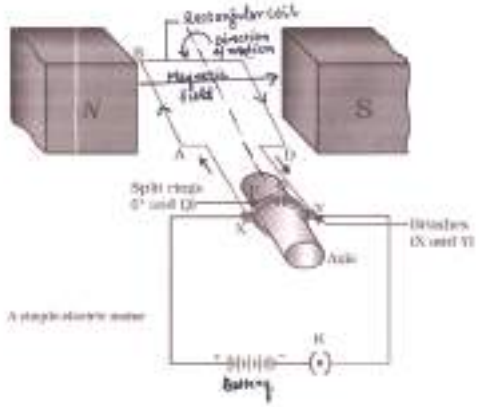
A motor is a device which converts electrical energy into mechanical energy. Electric motor is used in electric fans, washing machines refrigerators, mixer and grinder and other appliances.

Principle of a Motor :

An electric motor utilizes the magnetic effect of current. It works on the principle that when a rectangular coil is placed in a magnetic field and current is passed through it a torque acts on the coil which rotates it continuously. When the coil rotates the shaft to it also rotates and electrical energy supplied to the motor is converted into mechanical energy.

Construction of a Motor :

1. Armature Coil : An electric motor consists of an rectangular coil ABCD of insulated copper wire wound on a soft iron core called armature.
2. Strong Field magnet. : The coil (armature) is placed between two poles of a strong magnet such that arm AB and CD are perpendicular to the direction of the magnetic field.
3. Split ring type commutator : It consists of two halves of a metallic ring named as P and Q. The two ends of armature coil are connected to these two halves of ring. The function of commutators is that it reverses the direction of current in armature coil.



4. Brushes : Two carbon brushes X and Y press against the commutator. These brushes act as contact between commutator and terminal battery.
5. Battery : It is connected across the carbon brushes. It supplied current to the armature coil. Current in the coil ABCD enters from the source battery through conducting brush X and flows back to the battery through brush Y.

Working of a Motor :

1. When current flows through coil, arm AB and CD experiences magnetic force.
2. On applying Fleming left hand rule, the force acting on arm AB pushes it downwards and arm CD experiences force in upward direction.
3. Both these forces are equal and opposite. Two equal and opposite forces acting at different position of armature constitute a couple and rotate the coil in anti-clockwise direction.
4. At half rotation Q makes contact with brush X and P with brush Y. Now the current in the coil get reversed and flows along the path DCBA.
5. The arm AB of the coil that was earlier pushed down is now pushed up and the arm CD previously pushed up is now pushed down. These two equal and opposite forces constitute a couple, this couple now rotate the coil in clockwise direction.
6. 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 electric energy is converted into mechanical energy.

Commercial motor use :

(i) An electromagnet in place of permanent magnet.

(ii) Large number of turns of the conducting wire in the coil.

(iii) A soft iron core on which coil is wound plus the coils, is called the armature.

(iv) This enhances the power of the motor.

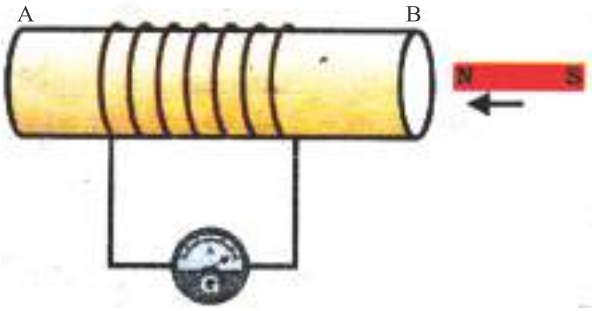
- Heart and brain in the human body have significant magnetic field.
- **MRI (Magnetic Resonance Imaging) :** Image of internal organs of body can be obtained using magnetic field of the organ.

Galvanometer : Instrument that can detect the presence of current in a circuit. It also detects the direction of current.

Electro Magnetic Induction

When a conductor is placed in a changing magnetic field, some current is induced in it. Such current is called induced current and the phenomenon is called electromagnetic induction.

Activity No. 1

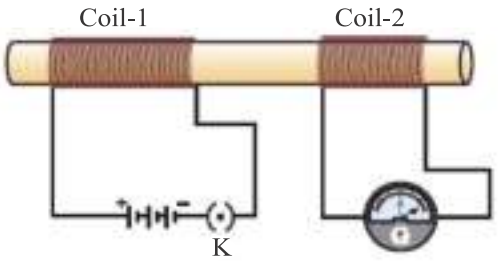


(i) **Magnet moved into the coil :** Momentary deflection in G indicating presence of current.

(ii) **Magnet kept stationary inside the coil :** No deflection.

(iii) **Magnet is withdrawn :** Momentary deflection in G but in opposite direction of first case.

Activity No. 2



Primary Coil **Secondary Coil**

(i) **Switched on :** Momentary deflection in G.

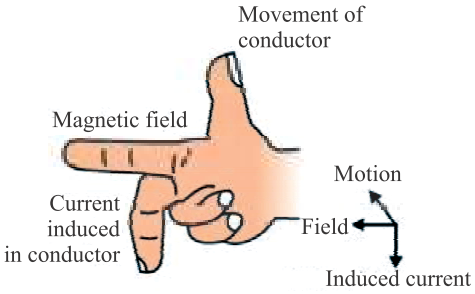
(ii) **Steady current :** No deflection.

(iii) **Switched off :** Momentary deflection in G but in opposite direction of the first case.

Fleming's Right Hand Rule

Hold the thumb, the fore finger and the middle finger of right hand at right angles to each other. If the fore finger is in the direction of magnetic field and the thumb points in the direction of motion of conductor, then the direction of induced current is indicated by middle finger.

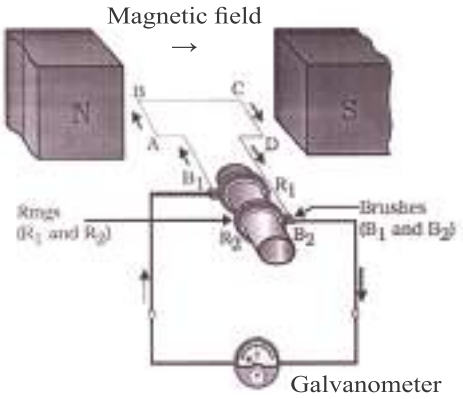
- Working principle of electric generator.
- Used to find direction of induced current.



Electric Generator

The electric generator is a machine for producing electric current or electricity. The electric generator converts mechanical energy (or kinetic energy) into electrical energy.

Principle of Electric Generator : (AC Generator) In an electric generator, mechanical energy is used to rotate a conductor in a magnetic field to produce electricity. Generator works on the principle of electromagnetic induction. When a closed coil is rotated in a uniform magnetic field with its axis perpendicular to the magnetic field, the magnetic field lines passing through the coil change and an induced emf is set-up. The principle behind the electric generator is based on Fleming's right hand rule.



Construction of Generator :

1. Field Magnet : It is strong horse-shoe shaped permanent magnet with concave poles.
2. Armature : ABCD is a rectangular armature coil. It consists of a large number of turns of insulated copper wire wound on a soft iron cylindrical core.
3. Slip rings : These are two brass rings, R_1 and R_2 rigidly connected to the two ends of the armature coil. As coil rotates slip rings also rotates.

4. Brushes : These are two graphite rods B_1 and B_2 which are kept pressed against the slip rings R_1 and R_2. Through these brushes, the current induced in the armature coil is sent to the external circuit.
5. Axle : The slip rings are placed on the axle which is made to rotate freely from an external source.
6. Galvanometer : To measure current the outer ends of the brushes are converted to the galvanometer.

Working of Generator :

1. The armature coil ABCD is in horizontal position.
2. Now, the coil is rotated clockwise.
3. The arm AB moves upwards while the arm CD moves downwards.
4. The coil cuts the magnetic lines of force.
5. According to Flemings' right hand rule, the induced current flows from A to B in arm AB and C to D in arm CD i.e. it flows along ABCD.
6. The induced current flows in the circuit through B_2 to B_1.
7. After half the rotation of the armature, the arm CD moves upwards and AB moves downwards. The induced current now flows in reverse direction i.e. along DCBA. The current now flows from B_1 to B_2.
8. Thus the direction of current in the external circuit changes after every rotation. Such a current which changes its direction after equal intervals of time is called alternating current.
9. This device is called AC Generator.

D.C. GENERATOR

DC Generator : It is a device which convert mechanical energy into electrical energy.

DC Generator has split ring commutator instead of slip rings.

Split ring commutator : It consists of two semi cylindrical brass rings R_1 and R_2 attached to the two ends of the armature coil. As the armature coil rotates, the two split rings also rotate about the same axis of rotation.

Alternate Current (A. C.) : The current which reverses its direction periodically.

- In India, A. C. reverses its direction in every $\frac{1}{100}$ second.

$$\text{Time period} = \frac{1}{100} + \frac{1}{100} = \frac{1}{50}\text{s}$$

$$\text{Frequency} = \frac{1}{\text{Time period}}$$

$$= \frac{1}{1/50} \quad \Rightarrow \quad 50 \text{ Hz}$$

Advantage

- A. C. can be transmitted over long distance without much loss of energy.

Disadvantage

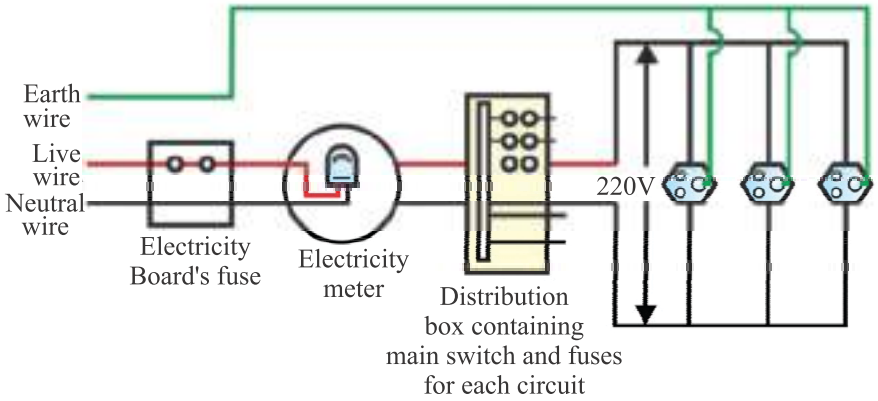
- A. C. cannot be stored.

Direct Current (D. C.) : The current which does not reverse its direction.

- D. C. can be stored.
- Loss of energy during transmission over long distance is high.
- Sources of D. C. : Cell, Battery, Storage cells.

Domestic Electric Circuits

- There are three kinds of wires used :
  (i) Live wire (positive) with red insulation cover.
  (ii) Neutral wire (negative) with black insulation cover.
  (iii)Earth wire with green insulation cover.
- The potential difference between live and neutral wire in India is 220 V.
- Pole → Main supply → Fuse → Electricity meter → Distribution box → To separate circuits



Earth Wire : Protects us from electric shock in case of leakage of current especially in metallic body appliances. It provides a low resistance path for current in case of leakage of current.

Short Circuit : When live wire comes in direct contact with neutral wire accidently.

- Resistance of circuit becomes low.
- Can result in overloading.

Overloading : When current drawn is more than current carrying capacity of a conductor, it results in overloading.

Causes of overloading :

(i) Accidental hike in voltage supply.

(ii) Use of more than one appliance in a single socket.

Safety devices :

(i) Electric fuse

(ii) Earth wire

(iii)MCB (Miniature Circuit Breaker)

QUESTIONS

VERY SHORT ANSWER TYPE QUESTIONS (1 Mark)

1. Define magnetic field lines.
2. What is the frequency of a.c. in India ?
3. Who discovered the electromagnetic induction ?
4. What is short circuit ?
5. Why does two magnetic field lines not intersect ?

6. What should be the core of an electromagnet?
   a) Soft iron b) Hard iron
   c) Rusted iron d) None of above
7. Who has stated the Right hand Thumb Rule?
   a) Oersted b) Fleming
   c) Einstein d) Maxwell
8. In all the electrical appliances, the switches are put in the
   a) Live wire b) Earth wire
   c) Neutral wire d) All of above
9. What is the condition of an electromagnetic induction?
   a) There must be a relative motion between the coil of wire and galvanometer
   b) There must be a relative motion between the galvanometer and a magnet
   c) There must be a relative motion between the galvanometer and generator
   d) There must be a relative motion between the coil of wire and a magnet
10. No force acts on a current carrying conductor when it placed—
   a) Perpendicular to the magnetic field b) Parallel to the magnetic field
   c) Far away from the magnetic field d) Inside a magnetic field
11. What is that instrument which can detect the presence of electric current in a circuit?
   a) Galvanometer b) Motor
   c) Generator d) None of above
12. Which device produces the electric current?
   a) Generator b) Galvanometer
   c) Ammeter d) Motor
13. What is electromagnetic induction?
   a) The process of charging a body
   b) The process of rotating a coil of an electric motor.
   c) Producing induced current in a coil due to relative motion between a magnet and the coil.
   d) The process of generating magnetic field due to a current passing through a coil.
14. What happens to the current in short circuit?
   a) Reduces substantially b) Does not change
   c) increase heavily d) Vary continuously

15. An alpha particle is diverted towards west is deflected towards north by a field. The field is magnetic. What will be the direction of field?

a) Towards south b) Towards east

c) Downward d) Upward

Answer: 6. (a) 7. (d) 8. (c) 9. (d) 10. (b) 11. (a) 12. (a) 13. (b) 14. (c) 15. (c)

16. Very Short Answer Type Questions:

1. What is a magnet?
2. What is a permanent magnet?
3. What is a temporary magnet?
4. What is an electromagnet?
5. What is the direction of magnetic field lines?
6. What is the shape of magnetic field lines due to a straight current-carrying conductor?

17. Fill in the blanks:

1. A microphone works on ..... effect of electric current.
2. There are ..... poles in a magnet.
3. A freely suspended bar magnet always points to ..... direction when it is in rest.
4. ..... poles of two magnets repel each other.
5. ..... poles of two magnets attract each other.

18. Write True/False for the following:

1. Natural magnets are permanent magnets.
2. All current-carrying conductors may not produce the magnetic effect.
3. All electromagnets are solenoids.
4. Electromagnetism is responsible for working with speakers.
5. A solenoid creates the uniform magnetic field.
6. Magnetic strength decreases with increase in current in a coil of solenoid.
7. Magnetic strength increases with increase in a number of turns in the coil in the solenoid.

Answer: 1. → T, 2. → F, 3. → T, 4. → T, 5. → T, 6. → T, 7. → T

19. Assertion (A): Every magnet has two poles–North and South.

Reason (R): Like poles repel each other.

(a) (A) is incorrect and (R) is correct.

(b) (A) is correct and (R) is incorrect.

(c) Both (A) and (R) are correct but (R) is not the correct explanation of (A).

(d) Both (A) and (R) are correct but (R) is the correct explanation of (A).

20. Assertion (A): Magnetic field lines never intersect each other.

Reason (R): There must not be two north directions at a point.

(a) (A) is incorrect and (R) is correct.

(b) (A) is correct and (R) is incorrect.

(c) Both (A) and (R) are correct but (R) is not the correct explanation of (A).

(d) Both (A) and (R) are correct but (R) is the correct explanation of (A).

21. Assertion (A): As the speed of the coil in the motor increases, there is reduction in the current flowing through it.

Reason (R): During rotation in electric motor, some induced current is produced.

(a) (A) is incorrect and (R) is correct.

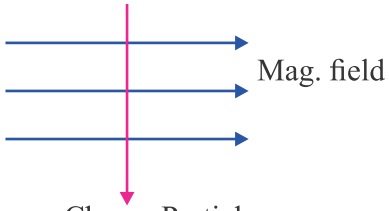
(b) (A) is correct and (R) is incorrect.

(c) Both (A) and (R) are correct but (R) is not the correct explanation of (A).

(d) Both (A) and (R) are correct but (R) is the correct explanation of (A).

SHORT ANSWER TYPE QUESTIONS (3 Marks)

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



Use Fleming's Left Hand Rule

2. When does short circuit occur ?
3. Write the three ways to produce magnetic field.
4. What is overloading ?
5. Write the use of safety device used in electric circuit.
6. What is solenoid ? Where the magnetic field is uniform in solenoid ?
7. Draw the pattern of magnetic field lines due to current carrying straight conductor.
8. What is earth wire ? How it works in our domestic circuit ?

LONG ANSWER TYPE QUESTIONS (5 Marks)

1. What is electromagnetic induction ? Explain with an activity. Write its one application.
2. Draw the schematic diagram of domestic circuit. Write the colour and nature of neutral wire, live wire and earth wire.
3. What is an electromagnet ? What material are used to make electromagnet ? Can we use steel to make electromagnet ?

4. (a) State Fleming's left hand rule.
   (b) Write the principle of working of an electric motor.
   (c) Explain the function
   (i) Armature (ii) Brushes (iii) Split ring. (CBSE 2018)

Hints to Long Answer Type Questions

1. The process by which a changing magnetic field in a conductor induces a current in another conductor is called electromagnetic induction.

   See Fig. 15.17 NCERT

2. Refer to given diagram

3. A strong magnetic field produced inside a solenoid can be used to magnetise a piece of magnetic material, like soft iron, when placed inside the coil. The magnet so formed is called an electromagnet.

   Yes, steel can be used to make electromagnet.