MAGNETIC EFFECTS OF ELECTRIC CURRENT

TOPIC 1

MAGNETIC FIELD AND FIELD LINES

Danish physicist, H. C. Oersted observed during the course of a lecture that there is a connection between current and magnetism. In this Chapter we will study magnetic fields and also about electromagnets and electric motors which involve the magnetic effect of electric current, and electric generators which involve the electric effect of moving magnets.

A compass needle is a small bar magnet whose ends point approximately towards north and south directions. The end pointing towards north is called north seeking or north pole. The other end that points towards south is called south seeking or south pole.

Magnetic Field

It is defined as the region around a magnet in which the force of attraction and repulsion can be detected.

Magnetic Field Lines

These are imaginary lines drawn around a magnet which describe the magnetic field around a magnet and indicate the direction in which a hypothetical North pole would move if placed at that point.

Characteristics of Magnetic Lines of Force

(1) The magnetic lines of force indicate the direction in which a N-pole would move if placed at that point.

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

(3) No two lines of force intersect each other, for if they did, it would mean that there would be two directions of magnetic field at the point of inter-section.

(4) The direction of magnetic field at any point is found by drawing a tangent at that point.

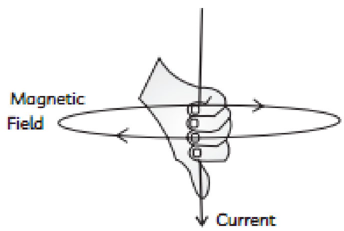
TOPIC 2

MAGNETIC FIELD DUE TO A CURRENT CARRYING STRAIGHT CONDUCTOR

A current carrying conductor has a magnetic field associated with it, which was first demonstrated by H. C. Oersted. Let us understand what determines the pattern of the magnetic field generated by a current through a conductor.

Right Hand Thumb Rule

Imagine that you are holding a current carrying wire in your right hand such that the thumb is stretched along the direction of the current, then, the direction in which the fingers wrap around the conductor will give the direction of the field lines of the magnetic field.

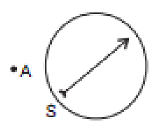


MOST LIKELY Questions

Short Answer Type-I Questions (SA-I)

[2 marks]

1. A magnetic compass needle is placed in the plane of paper near point A, as shown in the figure. In which plane should a straight current carrying conductor be placed so that it passes through A and there is no change in the deflection of the compass? Under what condition is the deflection maximum and why?



Ans. The straight current carrying conductor should be placed in the same plane as that of paper. According to the Right hand thumb rule, the direction of the magnetic field is perpendicular to the direction of the current and if a magnetic compass is brought closer to the current carrying conductor, the deflection is maximum. But, when the needle is placed near the point A on the plane as that of the paper as given in the figure, there is no deflection.

2. A current through a horizontal power line flows in west to east direction.

What is the direction of the magnetic field at a point directly above it and at a point directly below it?

Ans. The current is in the east-west direction. Applying the right-hand thumb rule, we get that the direction of magnetic field at a point above the wire is from south to north or anticlockwise direction. The direction of magnetic field at a point directly below the wire is north to south or clockwise direction.

3. Name the rule used to determine:

(A) The direction of force when a current carrying wire is placed in a strong magnetic field.

(B) Magnetic field in a current carrying conductor.

Ans. (A) According to Fleming's left-hand rule, hold the forefinger, the centre finger and the thumb of your left hand at right angles to one another.

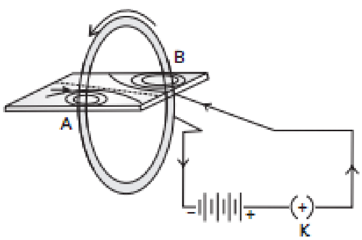
Adjust your hand in such a way that the forefinger points in the direction of the magnetic field and the centre finger points in the direction of current, then the direction in which the thumb points, gives the direction of the force acting on the conductor.

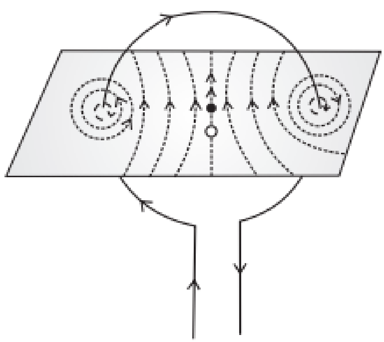
(B) According to Maxwell's right hand thumb rule: Imagine that you are holding the current-carrying wire in your right hand so that your thumb points in the direction of current, then the direction in which your fingers encircle the wire will give the direction of the magnetic field lines around the wire.

TOPIC 3

MAGNETIC FIELD DUE TO A CURRENT CARRYING CIRCULAR WIRE

The magnetic field due to a current carrying circular wire is shown in the figure below. Every section of the wire contributes to the magnetic field lines in the same direction within the loop.





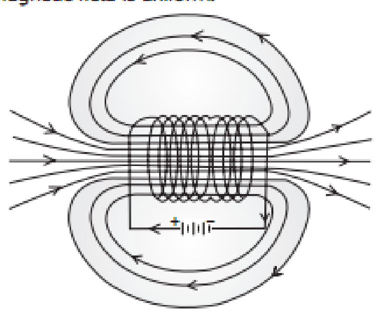
The field produced at the centre of a circular wire depends on the following factors:

It is directly proportional to the strength of the current passing through it.

It is inversely proportional to the radius of the loop.

Solenoid

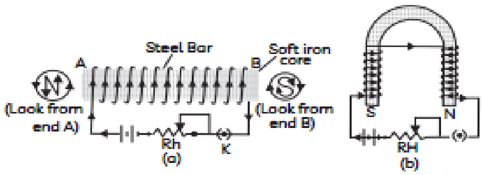
A coil of many circular turns of wire wrapped in the shape of a cylinder, as shown in the Fig below is called a solenoid. The magnetic field, thus produced, is very much similar to that of a bar magnet. The field lines inside the solenoid are in the form of parallel straight lines. The magnetic field is the same at all points inside the solenoid. That is, inside the solenoid, the magnetic field is uniform.



Magnetic Field of a Current Carrying Solenoid	Magnetic Field of a Bar Magnet
(1) Solenoid is an electro-magnet, i.e., the magnetic field will remain as long as current is passed through it.	(1) Bar magnet is a permanent magnet, i.e., there is no effect of current on its magnetic field.
(2) The strength of the magnetic field of a solenoid depends on the number of turns of the coil and magnitude of electric current passed through it.	(2) The strength of the magnetic field of a bar magnet cannot be changed.
(3) The poles of the solenoid or the direction of magnetic field lines can be reversed by reversing the direction of current.	(3) A bar magnet has fixed north and south poles which cannot be changed.

Electromagnets: When a material is placed inside a coil carrying current, it will get magnetised. A bunch of nails or an iron rod placed along the axis of the coil can be magnetized by the current passing through the coil. Once the current is switched-off the magnetic field will also be lost. Such magnets are called electro magnets.

The strength of an electromagnet depends upon the number of turns per unit length of the solenoid and the current through the solenoid.



MOST LIKELY Questions

Short Answer Type-I Questions (SA-I)

[2 marks]

4. Give reasons for the following:

(A) There is either a convergence or a divergence of magnetic field lines near the ends of a current carrying straight solenoid.

(B) The current carrying solenoid when suspended freely rests along a particular direction.

Ans. (A) There is a divergence of magnetic field lines near the ends of a current carrying straight solenoid as at the ends, the magnetic field is small and appears to diverge.

(B) The current carrying solenoid when suspended freely rests along a particular direction because a current carrying solenoid behaves like a bar magnet with fixed polarities at its ends. The magnetic field lines are exactly identical to those of a bar magnet with one end of solenoid acting as a south-pole and its other end as north-pole.

Short Answer Type-II Questions (SA-II)

[3 marks]

5. Can a freely suspended current carrying solenoid stay in any direction? Justify your answer. What will happen when the direction of current in the solenoid is reversed? Explain.

Ans. Solenoid is a closely bound cylindrical coil of insulated metallic wire. A current carrying freely suspended solenoid behaves like a magnet and when suspended freely, it rests in north-south direction.

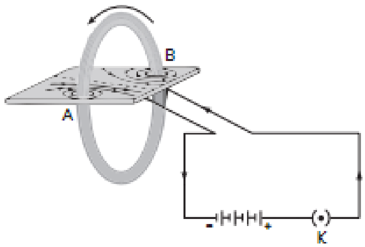
A current carrying solenoid behaves like a bar magnet with fixed polarities at its ends. The end of the current carrying solenoid at which the current flows anticlockwise behaves as a north pole while that end at which the direction of current is clockwise behaves as a south pole. The direction of magnetic field is always perpendicular to the direction of current flow and the magnitude of the magnetic field inside a solenoid is directly proportional to the current flowing through the solenoid.

Thus, when the current through the solenoid is reversed, the direction of magnetic field is reversed.

6. (A) Draw the pattern of magnetic field lines due to a magnetic field through and around a current carrying circular loop.

(B) Name and state the rule to find out the direction of magnetic field inside and around the loop.

Ans. (A)



(B) The magnetic field lines are concentric circles at every point of a current carrying circular loop. The direction of magnetic field of every section of the circular loop can be found be using the right hand thumb rule.

(1) The magnetic field lines are near circular at the points where the current enters or leaves the coil.

(2) Within the coil, the field lines are in the same direction.

(3) Near the centre of the coil, the magnetic field lines are almost parallel to each other.

(4) At the centre of the coil, the plane of magnetic field lines is at right angle to the plane of the circular coil.

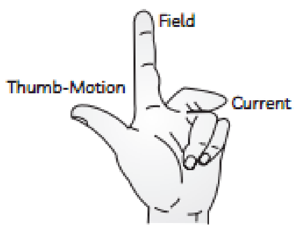
TOPIC 4

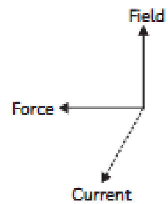
FORCE ON A CURRENT CARRYING CONDUCTOR IN A MAGNETIC FIELD

French scientist Andre Marie Ampere (1775–1836) suggested that the magnet must also exert an equal and opposite force on the current-carrying conductor. The force due to a magnetic field acting on a current-carrying conductor can be demonstrated through the following activity.

Fleming's Left Hand Rule

When a current carrying conductor is placed in a magnetic field, it experiences a force, whose direction is given by Fleming's Left Hand Rule, which states that " Stretch the forefinger, the central finger and the thumb of your left hand mutually perpendicular to each other. If the forefinger shows the direction of the field and the central finger that of the current, then the thumb will point towards the direction of motion of the conductor, i.e., force."





MOST LIKELY Questions

Short Answer Type-II Questions (SA-II)

[3 marks]

7. State the rule to determine the direction of a (A) magnetic field produced around a straight conductor-carrying current, (B) force experienced by a current-carrying straight conductor placed in a magnetic field which is perpendicular to it, and (C) current induced in a coil due to its rotation in a magnetic field.

Ans. Rule to determine the direction:

(A) Right hand thumb rule which states that that if one holds a straight current carrying conductor with right hand such that the thumb points towards the direction of current, then fingers will wrap around the conductor in the direction of field lines of the magnetic field.

This rule determines the magnetic field produced around a straight conductor carrying current.

(B) Fleming's Left Hand Rule, which states that if the first finger points in the direction of magnetic field and second finger in the direction of current, then the thumb will point in the direction of motion or the force acting on the conductor.

This determines force experienced by a current-carrying straight conductor placed in a magnetic field which is perpendicular to it.

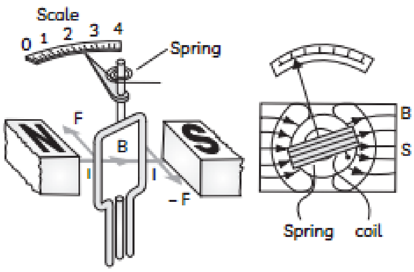
(C) Fleming's Right Hand Rule, which states that if the forefinger indicates the direction of the magnetic field and thumb shows the direction of motion of conductor, then the middle finger will show the direction of induced current.

This rule determines the current induced in a coil due to its rotation in a magnetic field.

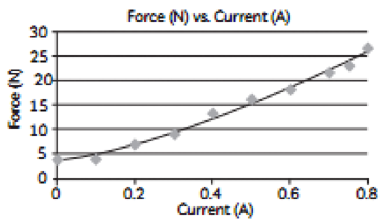
Case Based Questions

[4 marks]

8. *Meters, such as those in analog fuel gauges on a car, are common application of magnetic torque on a current-carrying loop. Figure below shows that a meter is very similar in construction to a motor. The torque is proportional to current I. A linear spring exerts a counter-torque that balances the current-produced torque. This makes the needle deflection proportional to I. If an exact proportionality cannot be achieved, the gauge reading can be calibrated.*



The graph below gives the variation of force experienced by a current carrying conductor placed in a magnetic field and the magnitude of current.



(A) What is the relation between the force experienced by a current carrying conductor in a magnetic field and current

(B) Name the rule used to find the direction of force experienced by the current carrying loop in the meter shown in figure?

(C) (i) What is the angle between the direction of current and the direction of magnetic field when the magnitude of force is hightest?

(ii) What is the relation between direction of current and the direction of force acting on a current carrying conductor when it is placed in a magnetic field?

Ans. (A) We observe that the graph between force and current is a straight line which shows that the force experienced by a current carrying conductor placed in a magnetic field increases linearly with the magnitude of current.

(B) The direction of force experienced by the current carrying loop in the above meter is given by Fleming's left hand rule.

(C) (i) The magnitude of the force is the highest when the direction of current is at right angles to the direction of the magnetic field.

(ii) The direction of force acting on a current carrying conductor, direction of current in the conductor and direction of magnetic field are mutually perpendicular to each other.

TOPIC 5

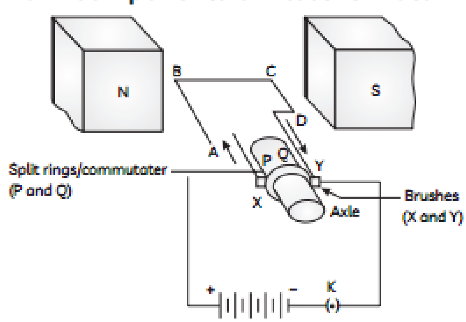
ELECTRIC MOTOR

Electric motor is a device that converts electric energy to mechanical energy and is used as an important component in electric fans, washing machines etc.

Principle of Working of an Electric Motor

Electric motor works on the principle of force experienced by a current carrying conductor in the form of coil of wire when placed between the two poles of the magnetic field. The direction of force is given by Fleming's Left Hand Rule.

Main Components of Electric Motor



Coil of wire: A coil of wire is wrapped around an axle and placed in the magnetic field.

Sliding contacts: These are meant to maintain contact between the split ring commutator and the coil.

Split ring commutator: Its function is to reverse the direction of current in the loop after every half a rotation so that the coil rotates continuously in the same direction.

Working of an Electric Motor

Current in the coil ABCD enters from the source battery through conducting brush X and flows back to the battery through brush Y. The current in arm AB of the coil flows from A to B and from C to D in arm CD. 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 forceacting on arm AB pushes it downwards while the force acting on arm CD pushes it upwards. At half rotation, Q makes contact with the brush X and P with brush Y. Therefore the current in the coil gets reversed and flows along the path DCBA.

Commercial motors: The commercial motors use:

(1) an electromagnet in place of permanent magnet;

(2) large number of turns of the conducting wire in the current carrying coil

(3) A soft iron core on which the coil is wound.

The soft iron core, on which the coil is wound, plus the coils, is called an armature. This enhances the power of the motor.

Uses of Electric Motor

(1) These are used in electric fans.

(2) Used for pumping water.

(3) Big DC motors are used for running tram cars.

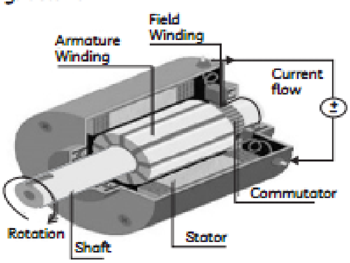
(4) Small DC motors are used in various toys.

MOST LIKELY Questions

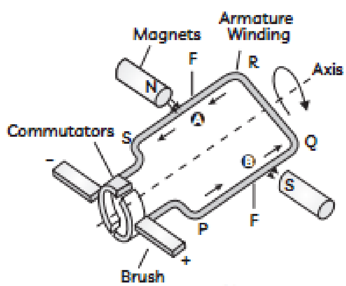
Case Based Questions

[4 marks]

9. *DC Motor is a motor which converts DC power into rotary movement and so is the name Direct Current (DC) Motor. Electrical energy to Mechanical energy. Application of Voltage produces Torque which results in Motion. Internal view of this type of Motor is shown in the Fig. below.*



(a)



(b)

It consists of four main components. They are: Stator, Rotor, Winding and Commutator

(A) Refer to the figure (b) and identify the directions of the force acting on arms PQ and RS.

(B) Which rule is used to determine the direction of rotation of D.C motor?

(C) (i) What is the role of commutator in DC motors.

(ii) What can be used in place of an electromagnet in commutator?

Ans. (A) Current is flowing in the coil in the direction PQRS and magnetic field is from North pole of the magnet to the South pole (Left to right).

Applying Fleming's left hand rule first on arm PQ (current flowing from P to Q) and then on RS (current flowing from R to S), we find that the force acting on PQ is downwards and it is upwards on RS.

(B) DC Motor works on the principle that a current carrying conductor when placed in a magnetic field, the conductor experiences magnetic field. This direction of force is given by Fleming's left hand rule, that when electric current pases throught a coil in a magnetic fielf, it experiences a force which produces a torque which is used to drive this type of Motor.

(C) (i) Commutator is a device thatreverses the direction of flow of current through a circuit and in electric motors, the split ring acts as a commutator. The reversing of the current is repeated at each halfrotation, giving rise to a continuous rotation of the coil and to the axle.

(ii) The commercial motors use an electro-magnet in place of permanent magnet. Moreover, the soft iron core, on which the coil is wound, plus the coils, is called an armature. This enhances the power of the motor.

TOPIC 6

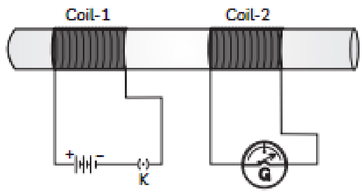
ELECTROMAGNETIC INDUCTION

In 1831, Faraday made an important break through by discovering how a moving magnet can be used to generate electric currents. The phenomenon of inducing current in a coil by a changing magnetic field is called electromagnetic induction. The magnetic field can be changed when there is a relative motion between the coil and the magnet.

Galvanometer: It is an instrument that can detect the presence of current in a circuit. The pointer remains at zero (centre of the scale) if no current flows through it and deflects to either the left or right of the zero mark depending on the direction of current.

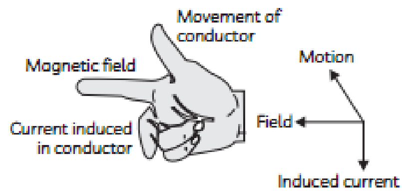
Explanation of Electromagnetic Induction

A current is induced in the secondary coil whenever the current in the primary coil is changing because the magnetic field associated with the primary coil changes. 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.



Fleming's Right Hand Rule

The direction of Induced current is given by Fleming's Right Hand Rule. Hold the forefinger, the central finger and the thumb of the right hand perpendicular to each other so that the forefinger indicates the direction of the field, and the thumb is in the direction of motion of the conductor. Then, the central finger shows the direction of current induced in the conductor.

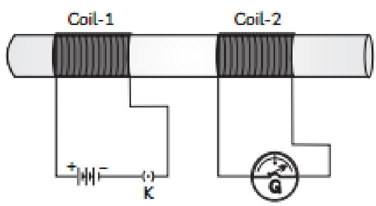


MOST LIKELY Questions

Short Answer Type-I Questions (SA-I)
[2 marks]

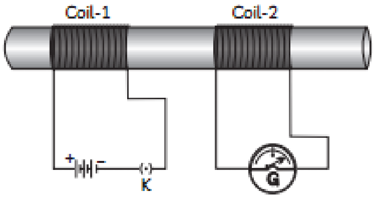
10. Two circular coils 'X' and 'Y' are placed close to each other. If the current in the coil 'X' is changed, will some current be induced in the coil 'Y'? Give reason.

Ans. Yes, if current is changed in coil *X*, a current will be induced in the coil *Y*. When current in coil *X* changes, the magnetic field associated with it also changes, thereby changing the magnetic field lines associated with the coil *Y*. This induces a current in coil *Y* by the process of electromagnetic induction.



Short Answer Type-II Questions (SA-II)
[3 marks]

11. Two coils of insulated copper wire are wound over a non-conducting cylinder as shown. Coil 1 has comparative large number of turns. State your observations, when:



(A) Key K is closed.

(B) Key K is opened.

Give reason for each of your observations.

Ans. (A) Key K is closed.

When key K is closed, (means the current is flowing through coil), we will observe that the needle of the galvanometer instantly jumps to one side and just as quickly returns to zero. This indicates that there is a momentary current in coil-2.

(B) Key K is opened.

When Key K is opened (means the current is not flowing through the coil), we 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.

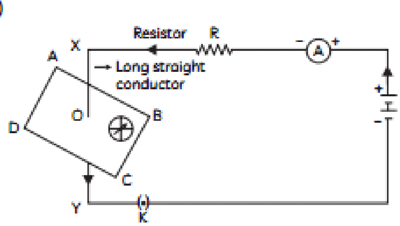
Reason: When the electric current through the coil–1 is changing (key K is closed or key K is open), potential difference is induced in coil–2. As the current in the first coil changes, the magnetic field associated with it will also change. The process, by which a changing magnetic field in a conductor induces a current in another conductor is called electromagnetic induction.

12. **(A) Draw a labelled diagram to show how an electromagnet is made.**

(B) State the purpose of soft iron core used in making an electromagnet.

(C) List two ways of increasing the strength of an electromagnet if the material of the electromagnet is fixed. [CBSE 2020]

Ans. (A)



(B) Soft iron increases the strength of the electromagnet.

(C) Ways of increasing the strength of an electromagnet:

(1) If we increase the number of turns in the coil, the strength of electromagnet increases.

(2) If the current in the coil is increased, the strength of electromagnet increases.

Related Theory

➥ *Solenoid containing soft iron core in it acts as a magnet only as long as the current is flowing in the solenoid. The core of an electromagnet must be soft iron because soft iron loses all of its magnetism when the current is switched off.*

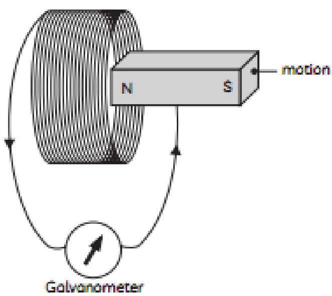
But if we use steel for making the core of electromagnet the steel does not loose all of its magnetism even after switching off electric current and it becomes a permanent magnet. Electromagnets all better than permanent magnets because it can produce very strong magnetic fields and its strength can be controlled by varying the number of turns in its coil.

Case Based Questions

[4 marks]

13. *The space surrounding a magnet in which magnetic force is exerted, is called a magnetic field. The direction of magnetic field lines at a place can be determined by using a compass needle. A compass needle placed near a magnet gets deflected due to the magnetic force exerted by the magnet.*

The north end of the needle of the compass indicates the direction of magnetic field at the point where it is placed. When the magnet shown in the diagram below is moving towards the coil, the galvanometer gives a reading to the right.



(A) What is the name of the effect being produced by the moving magnet?

(B) State what happens to the needle shown on the galvanometer when the magnet is moving away from the coil.

(C) (i) If the magnet is moved towards the coil at a great speed, state two

changes that you would notice in the galvanometer.

(ii) List three sources of magnetic fields.

Ans. (A) Electromagnetic induction

The phenomenon of production of an electric current in a circut from nagnetic effects is called electromagnetic induction.

$$\text{Mechanical Energy} \xrightarrow[\text{Field}]{\text{Magnetic}} \text{Electrical Energy}$$

(B) When the magnet is moving away from the coil the galvanometer gives a deflection to the left.

(C) (i) If the magnet is moved towards the coil at a great speed, large deflection occurs to the right and that too very quickly.

(ii) Three sources of magnetic fields are electromagnet, permanent magnet, current carrying wire.

14. *Vaibhav performed an activity to observe an important breakthrough made by the English Physicist faraday. He took a coil of wire AB having a large number of turns and connected the ends of the coil to a galvanometer. He observed a momentary deflection in the needle of the galvanometer, say to the right, when the North pole of a strong magnet was moved towards the end B of the coil.*

(A) Name the phenomenon discovered by Faraday.

(B) Why does Vaibhav observe momentary deflection in the galvanometer?

(C) (i) What happens to the deflection in the galvanometer when the motion of the magnet stops?

(ii) What will be observed when the north pole of the magnet is withdrawn away from the coil?

Ans. (A) The phenomenon was Electromagnetic induction.

(B) This is due to induced current in the coil as a result of changing magnetic field associated with the coil.

(C) (i) The deflection of the galvanometer becomes zero the moment the motion of the magnet stops.

(ii) We observe that the galvanometer is deflected toward the left, showing that the current is now set up in the direction opposite to the first.