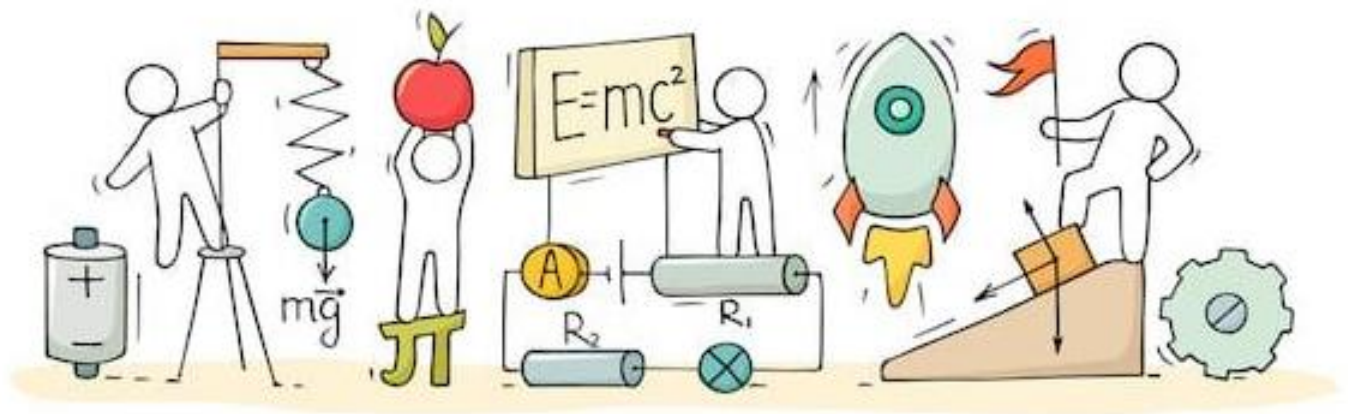


SCIENCE

(Physics)

Chapter 12: Magnetic Effects of Electric Current



Magnetic Effects of Electric Current

Magnet



A magnet is a material that produces a field that attracts or repels other such materials of magnetic nature.

Lodestone (Fe_3O_4) is a naturally occurring magnet. It attracts materials like Iron, Nickel, Cobalt, etc.

A magnet is always bipolar with poles named north and south **poles**. These two poles always exist together and cannot be separated. North pole of a magnet is the side which points to Earth's geographic north when it is freely suspended.

Bar magnet: A bar magnet is a rectangular object, composed of iron, steel or any form of a ferromagnetic substance, that shows permanent magnetic properties. It has two different poles, a north and a south pole such that when suspended freely, the north pole aligns itself towards the geographic north pole of the Earth.

Magnetic Field and Field Lines

- The space around a magnet in which the force of attraction and repulsion caused by the magnet can be detected is called the **magnetic field**.
- The curved paths along which iron filings arrange themselves due to the force acting on them in the magnetic field of a bar magnet are called **magnetic field lines**.



Iron filings near the bar magnet align themselves along the field lines

- The direction of the magnetic field at any point is obtained by drawing a tangent to the field line at that point.

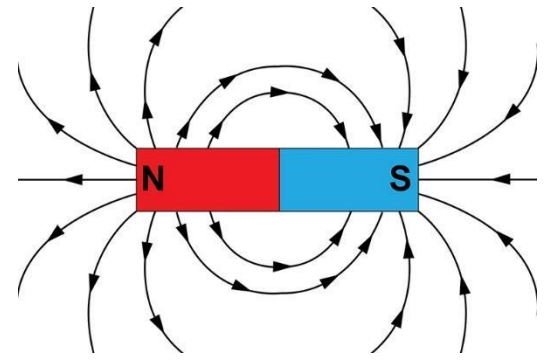
Properties of Magnetic Field Lines

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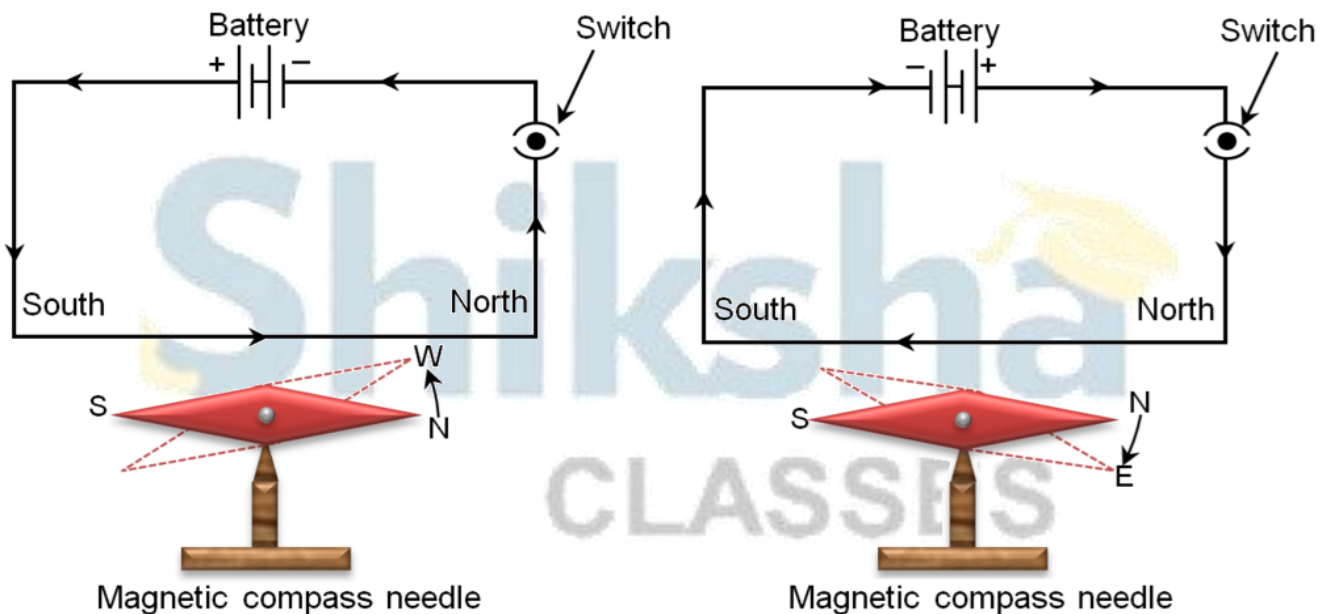
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- A magnetic field line is directed from the North Pole to the South Pole outside the magnet.
- A magnetic field line is a closed and continuous curve.
- The magnetic field lines are closer where the magnetic field is strong and farther apart where the magnetic field is weak.
- The magnetic field lines never intersect each other.
- Parallel and equidistant field lines represent a uniform magnetic field.

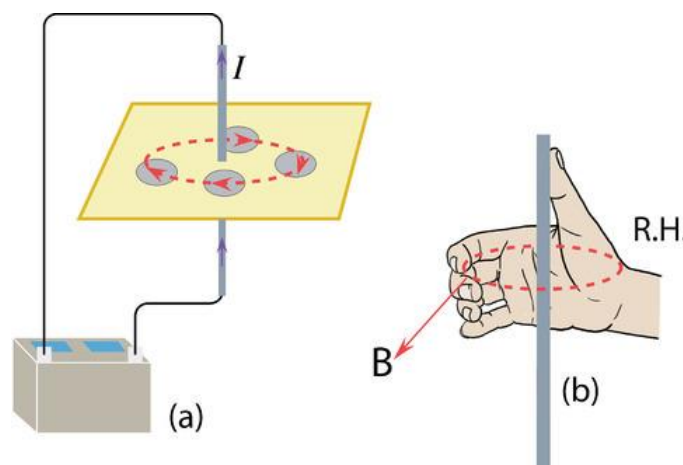


Magnetic Field Due to a Current Carrying Conductor

Oersted's experiment: When electric current flows through a current carrying conductor, it produces a magnetic field around it. This can be seen with the help of a magnetic needle which shows deflection. The more the current, the higher the deflection. If the direction of current is reversed, the direction of deflection is also reversed.

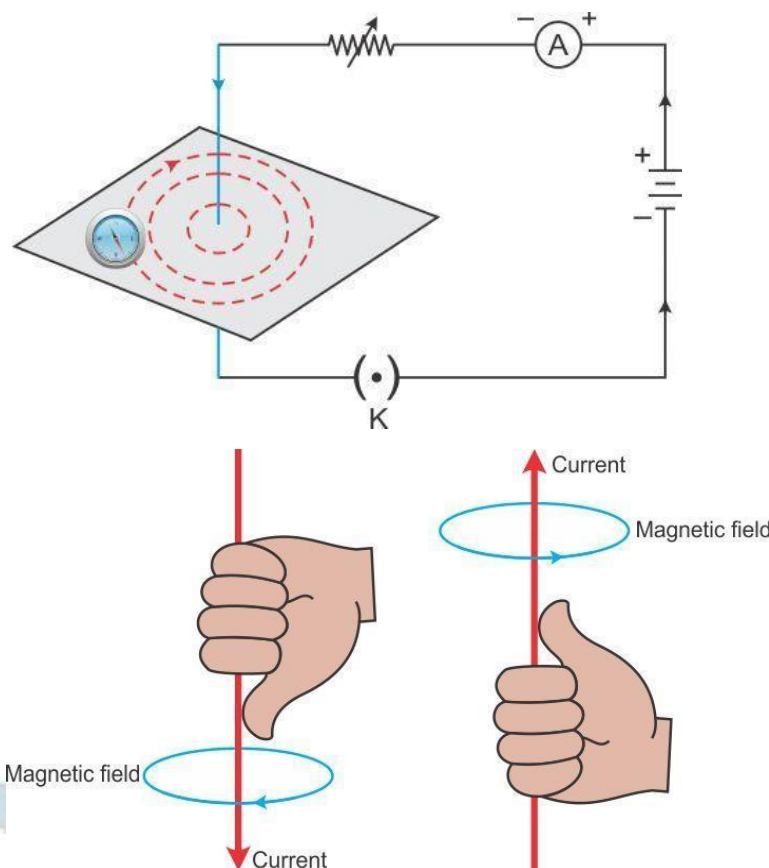


Magnetic Field due to a Straight Current-carrying Conductor



- The magnetic field lines around a straight conductor carrying a current are concentric

circles.



- The direction of a magnetic field is given by the **Right-Hand Thumb Rule**.

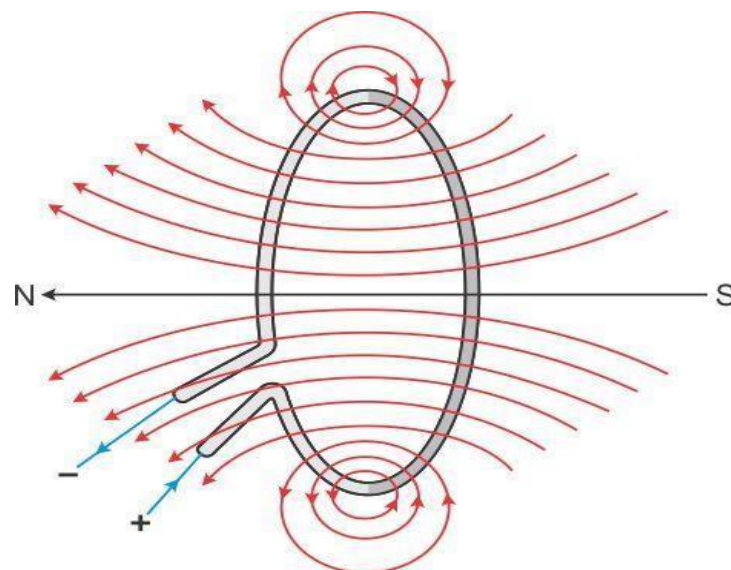
Right-Hand Thumb Rule:

Imagine that you are holding a straight current-carrying conductor in your right hand such that the thumb points towards the direction of the current. Then, your curved fingers wrapped around the conductor point in the direction of the field lines of the magnetic field.

The **magnitude of the magnetic field** due to a straight current-carrying conductor at a given point is

- Directly proportional to the current flowing through the conductor
- Inversely proportional to the distance of that point from the conductor

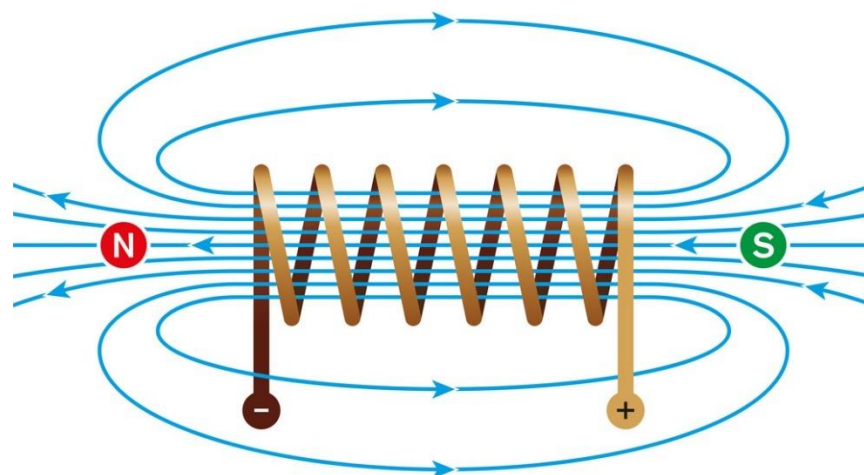
Magnetic Field due to a Current-carrying Circular Coil



- The magnetic field lines near the coil are nearly circular or concentric.
- The magnetic field at the centre of the coil is maximum and almost uniform.
- Looking at the face of a coil, if the current around it is in the clockwise direction, then it faces the South Pole. If the current around it is in the anticlockwise direction, then it faces the North Pole. This is called the **Clock rule**.
- The **magnitude of a magnetic field** at the centre of the coil is
 - Directly proportional to the current flowing through it
 - Inversely proportional to the radius of the coil
 - Directly proportional to the number of turns of the coil

Magnetic Field due to a Current-carrying Solenoid

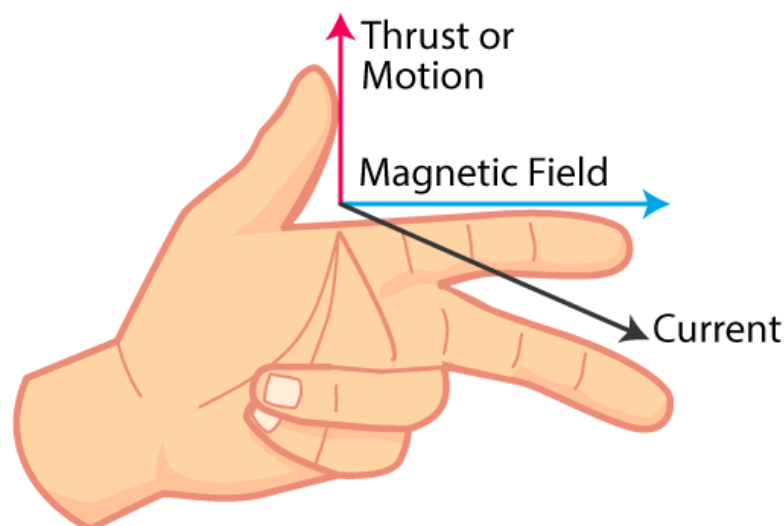
- The pattern of the magnetic field lines around a current-carrying solenoid is similar to that produced by a bar magnet as shown in the figure below.
- The magnetic field inside a solenoid is uniform.



- In accordance with the **Clock rule**, the end of the solenoid at which the current flows in the anticlockwise direction behaves as a North Pole, while the end at which the current flows in the clockwise direction behaves as a South Pole.
- The **magnitude of the magnetic field** inside the solenoid is directly proportional to the
 - Current flowing through it
 - Number of turns per unit length of the solenoid

Force on a Current-carrying Conductor in a Magnetic Field

- A current-carrying conductor when placed in a magnetic field experiences a force.
- The direction of the force gets reversed when the direction of the current is reversed or when the direction of the magnetic field is reversed.
- The force acting on a conductor is found to be maximum when the current and magnetic field are at right angles to each other.
- When the conductor is placed parallel to the magnetic field, no force acts on it.
- **Fleming's Left-Hand Rule** gives the direction of the magnetic force acting on the conductor.



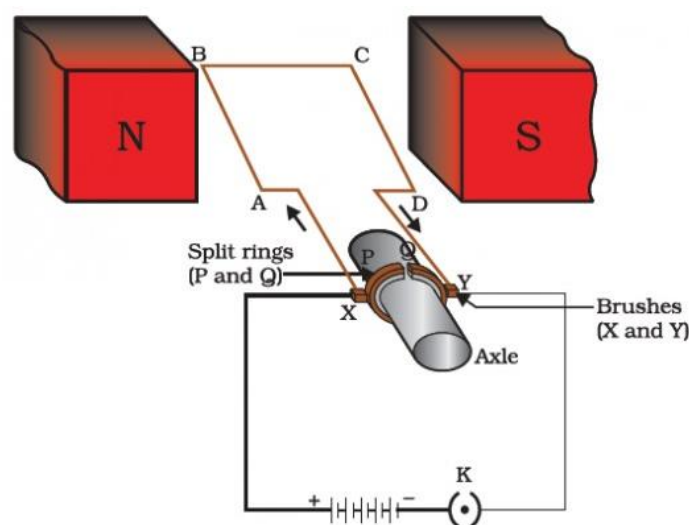
Fleming's Left-Hand Rule:

Stretch the thumb, forefinger and middle finger of the left hand such that they are mutually perpendicular to each other. If the forefinger points in the direction of the field, and the middle finger in the direction of the current, then the thumb gives the direction of motion or the force acting on the conductor.

- The force experienced by a current-carrying conductor in a magnetic field is the underlying principle of an **electric motor** where electric energy is converted into mechanical energy. Such motors are used to run many electrical appliances, including fans, toys etc.

Electric motor

- An electric motor is a rotating device that converts electrical energy to mechanical energy.
- An electric motor consists of a rectangular coil ABCD of insulated copper wire. The coil is placed between the two poles of a magnetic field such that the arm AB and CD are perpendicular to the direction of the magnetic field.



- The ends of the coil are connected to the two halves P and Q of a split ring. The inner sides of these halves are insulated and attached to an axle.

- The external conducting edges of P and Q touch two conducting stationary brushes X and Y, respectively.
- Current in the coil ABCD enters from the source battery through conducting brush X and flows back to the battery through brush Y.
- The force acting on arm AB pushes it downwards while the force acting on arm CD pushes it upwards.
- Thus the coil and the axle O, mounted free to turn about an axis, rotate anti-clockwise.
- 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.
- The split ring acts as a commutator which reverse the direction of current and also reverses the direction of force acting on the two arms AB and CD.
- Thus 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.
- 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.

Commutator: A device that reverses the direction of flow of current through a circuit is called a commutator.

Armature: The soft iron core, on which the coil is wound including the coils is called armature. It enhances the power of the motor.

Electromagnetic Induction (EMI)

- The phenomenon of generating an electric current in a circuit (coil) by changing the magnetic flux linked with it is called **electromagnetic induction**.
- The change in magnetic flux in a coil may be due to the
 - Relative motion between the coil and the magnet placed near it.
 - Relative motion between the coil and a current-carrying conductor placed near it
 - Change of current in the conductor placed near the coil
- This either happens when a conductor is set in a moving magnetic field (when utilizing AC power source) or when a conductor is always moving in a stationary magnetic field.

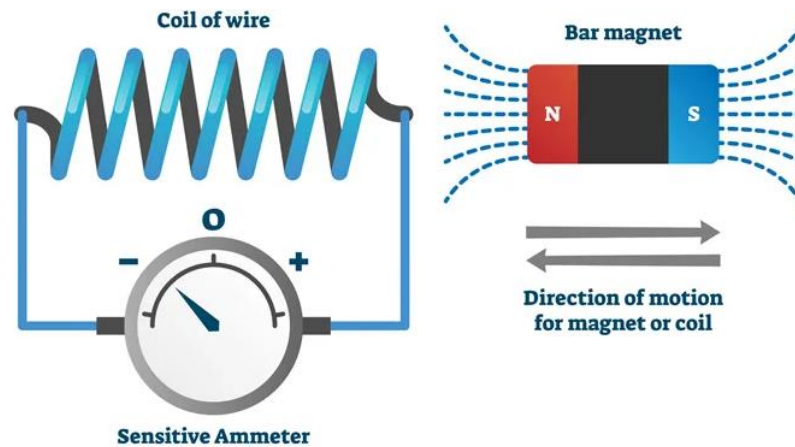
This law of electromagnetic induction was found by **Michael Faraday**. He organized a leading wire according to the setup given underneath, connected to a gadget to gauge the voltage over the circuit. So when a bar magnet passes through the snaking, the voltage is measured in the circuit. The importance of this is a way of producing electrical energy in a circuit by using magnetic fields and not just batteries anymore. The machines like generators, transformers also the motors work on the principle of electromagnetic induction.

Faraday's law of Electromagnetic Induction

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- **First law:** Whenever a conductor is placed in a varying magnetic field, EMF induces and this emf is called an induced emf and if the conductor is a closed circuit than the induced current flows through it.
- **Second law:** The magnitude of the induced EMF is equal to the rate of change of flux linkages.

Based on his experiments we now have Faraday's law of electromagnetic induction according to which the amount of voltage induced in a coil is proportional to the number of turns and the changing magnetic field of the coil.

So now, the induced voltage is as follows:

$$e = N \times d\Phi dt$$

where,

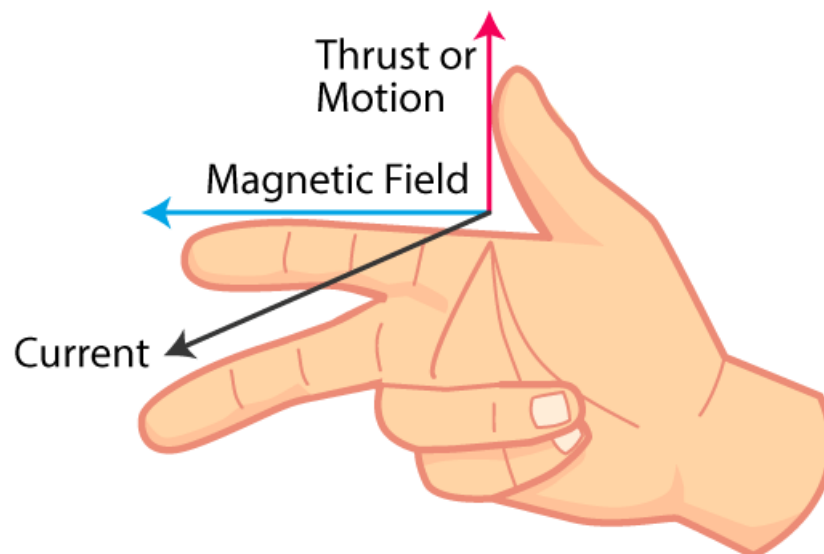
e is the induced voltage

N is the number of turns in the coil

Φ is the magnetic flux

t is the time

Fleming's Right-Hand Rule is used to find the direction of induced current.

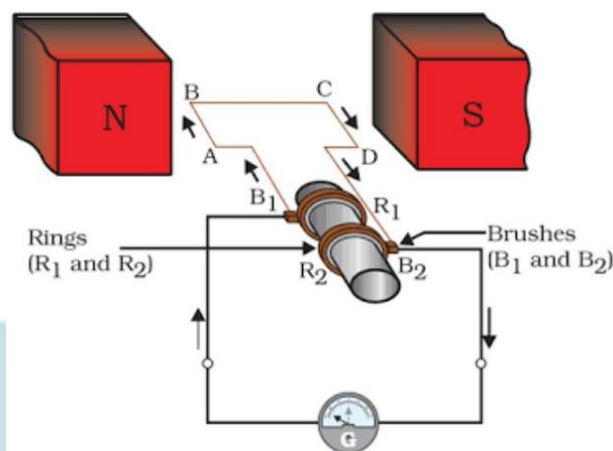


Fleming's Right-Hand Rule:

Stretch the thumb, forefinger and middle finger of the right hand such that they are mutually perpendicular to each other. If the forefinger points in the direction of the field and the thumb in the direction of the motion of the conductor, then the middle finger gives the direction of the induced current in the conductor.

Electric Generator

- An electric generator, mechanical energy is used to rotate a conductor in a magnetic field to produce electricity.
- An electric generator consists of a rotating rectangular coil ABCD placed between the two poles of a permanent magnet.



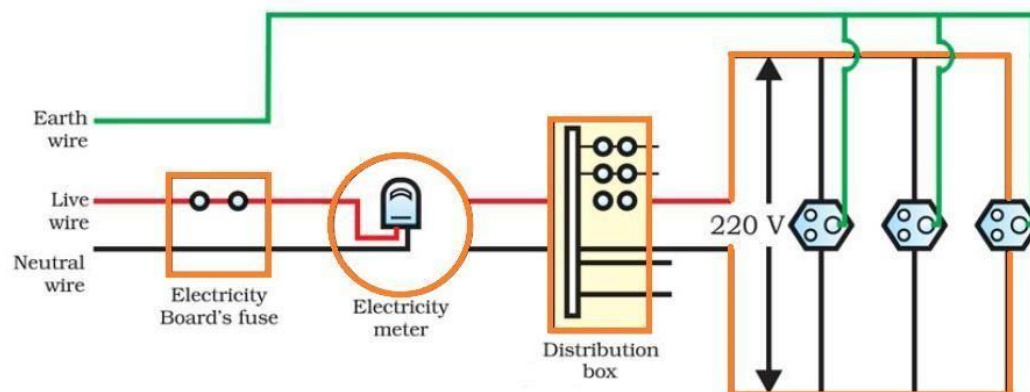
- The two ends of this coil are connected to the two rings R1 and R2. The inner side of these rings are made insulated.
- The inner side of these rings are made insulated. The two conducting stationary brushes B1 and B2 are kept pressed separately on the rings R1 and R2, respectively.
- The two rings R1 and R2 are internally attached to an axle. The axle may be mechanically rotated from outside to rotate the coil inside the magnetic field.
- Outer ends of the two brushes are connected to the galvanometer to show the flow of current in the given external circuit.
- 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.
- 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 B1 to B2. Thus after every half rotation the polarity of the current in the respective arms changes.

To get a direct current (DC), a split-ring type commutator must be used. 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.

The direct current always flows in one direction, whereas the alternating current reverses its direction periodically.

Domestic Electric Circuits

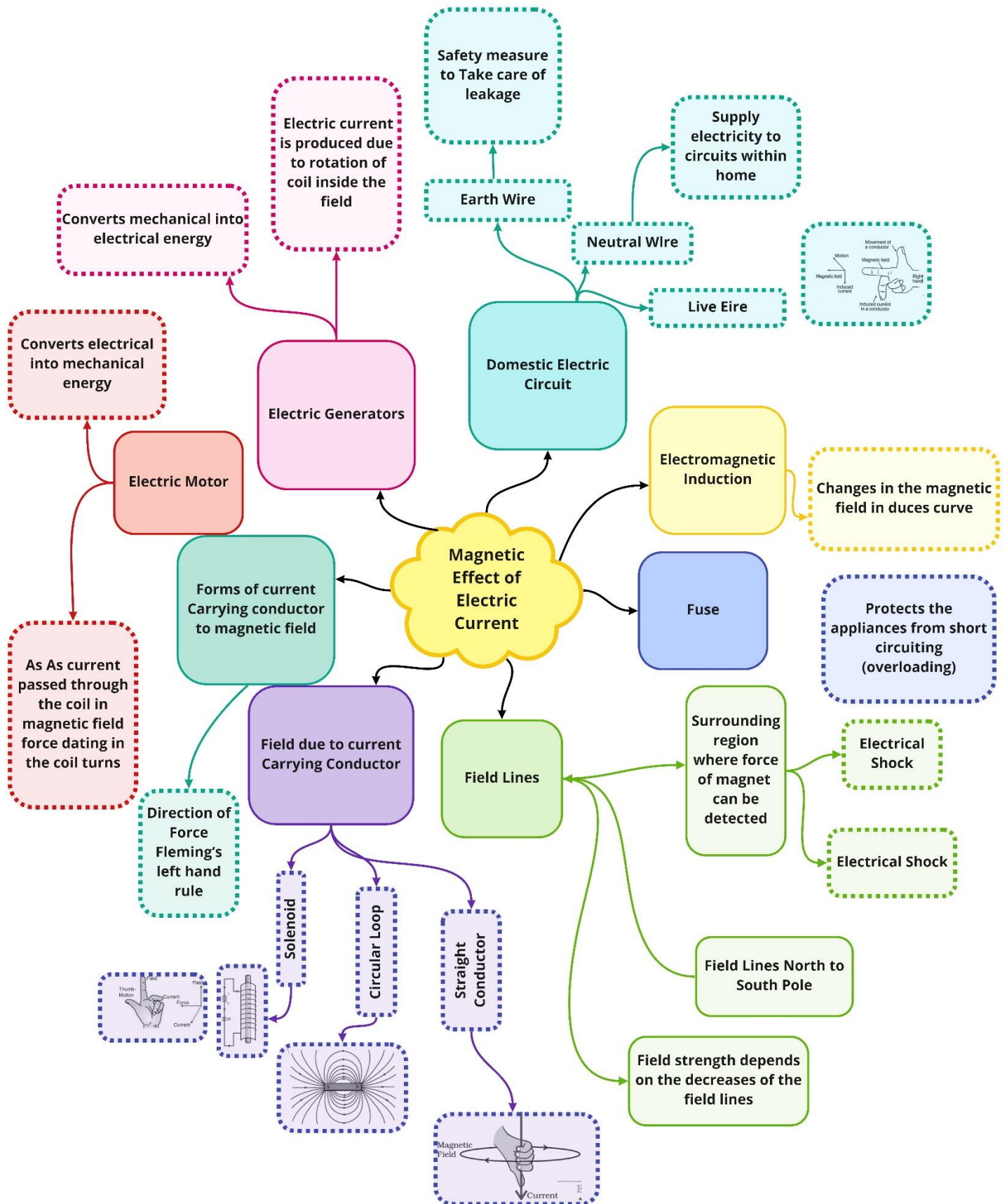
- In our homes, we receive electric power through a main supply called the **mains**. We receive an AC electric power of 220 V with a frequency of 50 Hz.
- One of the wires in the electricity wiring of houses has a red insulation and is called the **live wire**. The other, of black insulation is called the **neutral wire**. The third is the **earth wire** which has green insulation and is connected to a metallic plate deep inside the Earth.



The earth wire in wiring is used as a safety measure to ensure that any leakage of current in the metallic body does not give the user a severe shock.

A **fuse** is an important safety device used to protect circuits and appliances from **short-circuiting** (which occurs when a live wire and a neutral wire come in contact) or **overloading** (which occurs when an electric circuit draws more current than the permitted value).

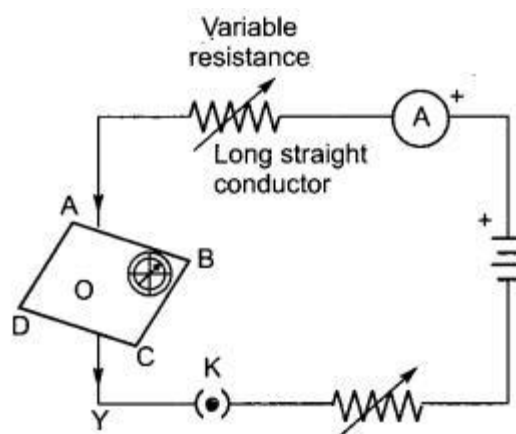
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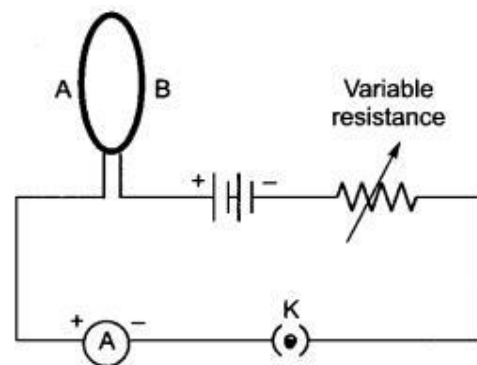
Important Questions

➤ Multiple Choice Questions:

- Choose the incorrect statements from the following regarding magnetic lines of field.
 - the direction of magnetic field at a point is taken to be the direction in which the north pole of a magnetic compass needle points
 - magnetic field lines are closed curves
 - if magnetic field lines are parallel and equidistant, they represent zero field strength
 - relative strength of magnetic field is shown by the degree of closeness of the field lines.
- If the key in the arrangement figure given below is taken out (the circuit is made open) and magnetic field lines are drawn over the horizontal plane ABCD, the lines are



- concentric circles
 - elliptical in shape
 - straight lines parallel to each other (Due to earth's magnetic field)
 - concentric circles near the point O but of elliptical shapes as we go away from it.
- A circular loop placed in a plane perpendicular to the plane of paper carries a current when the key is ON. The current as seen from points A and B (in the plane of paper and on the axis of the coil) is anticlockwise and clockwise respectively. The magnetic field lines point from B to A. The N-pole of the resultant magnet is on the faces close to.

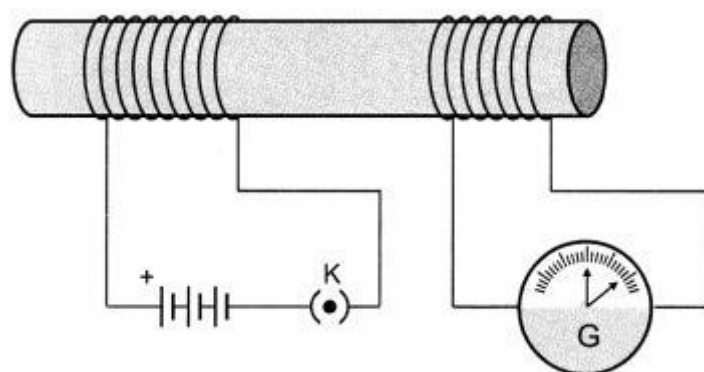


- (a) A
 (b) B
 (c) A if the current is small, and B if the current is large
 (d) B if the current is small and A if the current is large.

4. For a current in a long straight solenoid, N- and S-poles are created at the two ends. Among the following statements, the incorrect statement is

- (a) the field lines inside the solenoid are in the form of straight lines which indicates that the magnetic field is the same at all points inside the solenoid
 (b) the strong magnetic field produced inside the solenoid can be used to magnetize a piece of magnetic material like soft iron, when placed inside the coil
 (c) the pattern of the magnetic field associated with the solenoid is different from the pattern of the magnetic field around a bar magnet
 (d) the N- and S-poles exchange position when the direction of current through the solenoid is reversed.

5. In the arrangement shown in the figure there are two coils wound on a non-conducting cylindrical rod. Initially the key is not inserted. Then the key is inserted and later removed. Then

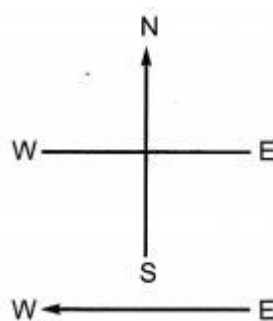


- (a) the deflection in the galvanometer remains zero throughout.
 (b) there is a momentary deflection in the galvanometer, but it dies out shortly and there is no effect when the keys is removed.
 (c) there are momentary galvanometer deflections that die out shortly; the deflections are in the same direction.
 (d) there are momentary galvanometer deflections that die out shortly; the deflection are in opposite directions.

6. Choose the incorrect statement

- (a) Fleming's right-hand rule is a simple rule to know the direction of induced current.
- (b) The right-hand thumb rule is used to find the direction of magnetic fields due to current carrying conductors.
- (c) The difference between the direct and alternating currents is that the current always flows in one direction, whereas the alternating current reverses its direction periodically.
- (d) In India, the AC changes direction after every 150 second.

7. A constant current flows in a horizontal wire in the plane of the paper from east to west as shown in the figure. The direction of magnetic field at a point will be North to South.



- (a) directly above the wire
- (b) directly below the wire
- (c) at a point located in the plane of the paper, on the north side of the wire
- (d) at a point located in the plane of the paper, on the south side of the wire.

8. The strength of magnetic field inside a long current carrying straight solenoid is

- (a) more at the ends than at the center
- (b) minimum in the middle
- (c) same at all points
- (d) found to increase from one end to the other

9. The most important safety method used for protecting home appliances from short circuiting or overloading is by

- (a) earthing
- (b) use of fuse
- (c) use of stabilizers
- (d) use of electric meter.

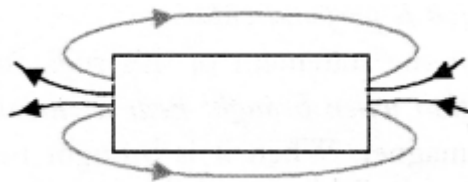
10. Select the incorrect statement

- (a) Magnetic field lines are closed curves
- (b) No two field lines can cross each other
- (c) Field lines can cross each other
- (d) The relative strength of the magnetic field is shown by degree of closeness of the

field lines.

➤ Very Short Question:

1. Identify the poles of a magnet in the figure.



2. What is the direction of magnetic field lines outside a bar magnet?
3. What does crowding of magnetic field lines indicate?

Or

What does the degree of closeness of magnetic field lines near the poles signify?

4. At what place of the magnet are the magnetic field lines denser ?
5. What is meant by magnetic field?
6. How is the direction of magnetic field at a point determined?
7. What is SI unit of magnetic field?
8. What is the direction of magnetic field lines inside a bar magnet?
9. Define a magnetic field line?

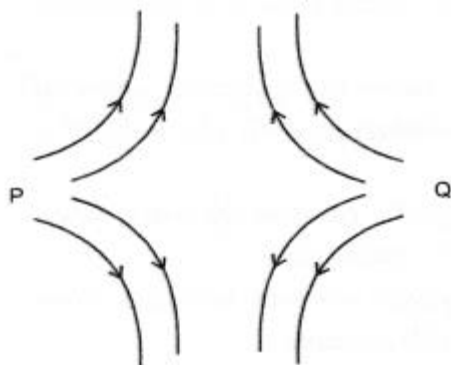
Or

What are magnetic field lines?

10. Give two uses of a magnetic compass.

➤ Short Questions:

1. In the figure below, identify the poles marked P and Q as North Pole or South pole. Give reason for your answer.



2. State the factors on which the strength of magnetic field at a point due to a current carrying conductor depends. State the rule which gives the direction of magnetic field.

3. Describe an activity to show that magnetic field is generated around straight current carrying wire.

Or

With the help of a labelled circuit diagram describe an activity to illustrate the pattern of the magnetic field lines around a straight current carrying long conducting wire.

4. A horizontal power line carries current in east to west direction. What is the direction of the magnetic field due to the current in the power line at a point above and at a point below the power line?

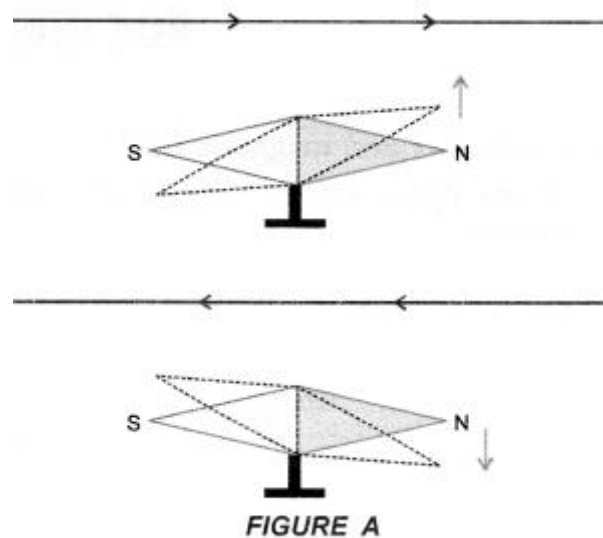
5. A magnetic compass is placed near a current carrying wire. What will you observe?

- When current in the wire is increased,
- When the magnetic compass is displaced away from the wire?

Or

A magnetic compass shows a deflection near a current carrying wire. How will the deflection of the compass get affected if current in the wire is increased? Support your answer with reason.

6. Draw a diagram to show how a magnetic needle deflects when it is placed above and below a straight conductor carrying current depending on the direction of the current in the conductor.



7. A student performs an experiment to study the magnetic effect of current around a current carrying conductor with the help of a magnetic compass. He reports that:

- The degree of deflection of the magnetic compass increases when the compass is moved away from the conductor.
- The degree of deflection of the magnetic compass increases when the current through the conductor is increased

Which of the above observations of the student appears to be wrong and why?

8. With the help of a diagram describe an activity to show that an electric current can affect a magnet.

➤ Long Questions:

1. Explain, the construction and working of an electric motor using a well labelled diagram.
2. Describe the construction and working of A.C. generator with the help of a labelled diagram. How can you convert AC generator to DC generator?

➤ Assertion Reason Questions:

1. For two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:
 - a. Both A and R are true, and R is correct explanation of the assertion.
 - b. Both A and R are true, but R is not the correct explanation of the assertion.
 - c. A is true, but R is false.
 - d. A is false, but R is true.

Assertion: In a conductor, free electrons keep on moving but no magnetic force acts on a conductor in a magnetic field.

Reason: Force on free electron due to magnetic field always acts perpendicular to its direction of motion.

2. For two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:
 - a. Both A and R are true, and R is correct explanation of the assertion.
 - b. Both A and R are true, but R is not the correct explanation of the assertion.
 - c. A is true, but R is false.
 - d. A is false, but R is true.

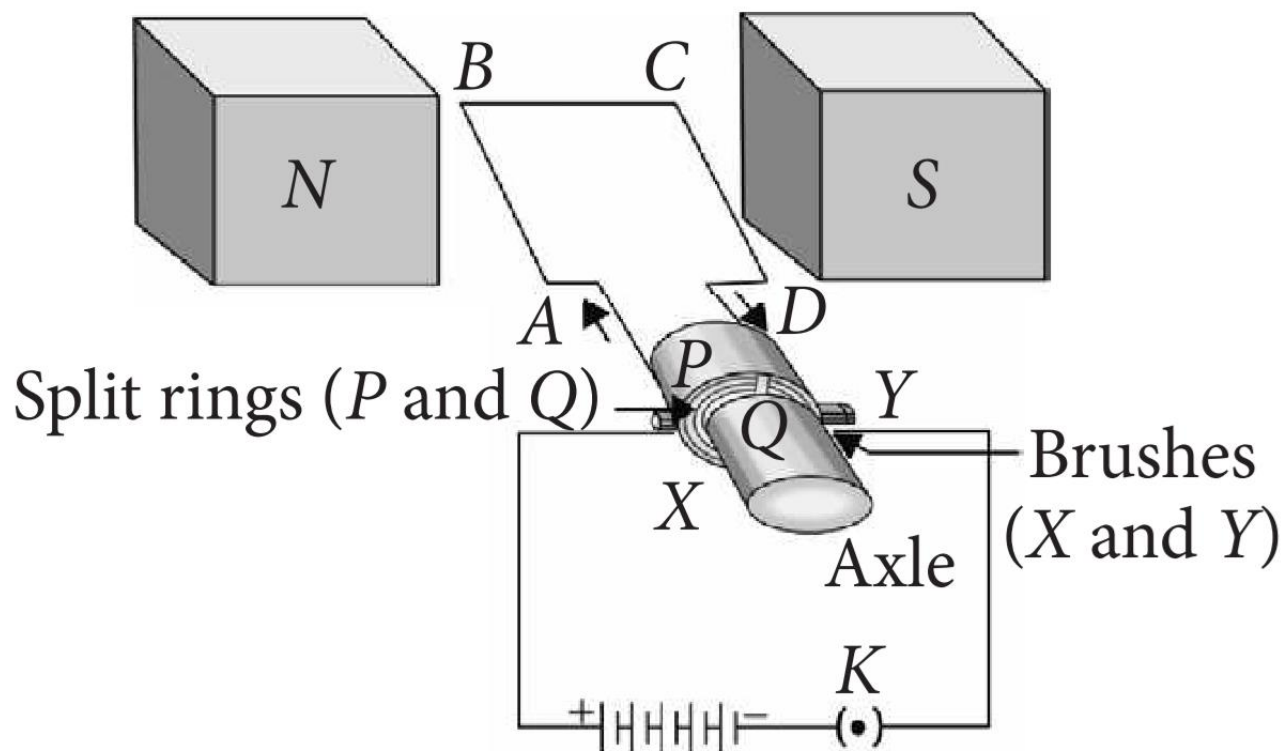
Assertion: No net force acts on a rectangular coil carrying a steady current when suspended freely in a uniform magnetic field.

Reason: Forces acting on each pair of the opposite sides of the coil are equal and opposite.

➤ Case Study Questions:

1. Read the following and answer any four questions from (i) to (v).

An electric motor is a rotating device that converts electrical energy into mechanical energy. Electric motor is used as an important component in electric fans, refrigerators, mixers, washing machines, computers, MP3 players, etc.



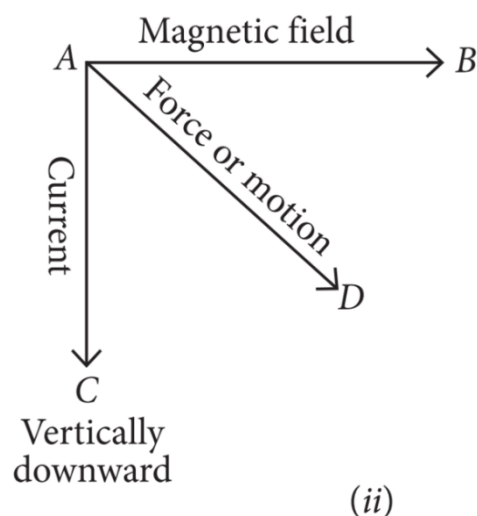
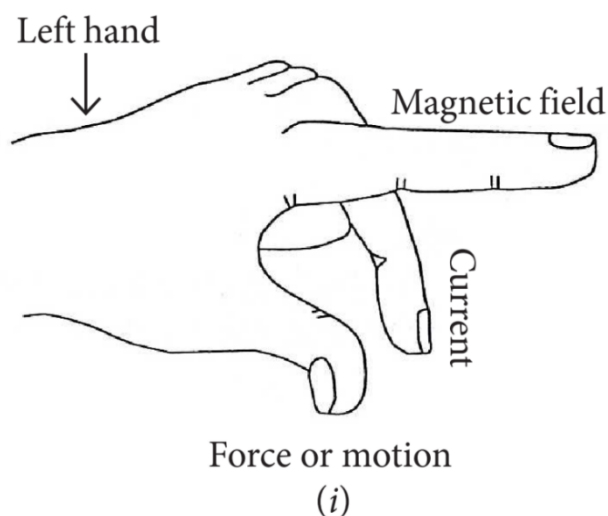
An electric motor consists of a rectangular coil ABCD of insulated copper wire. The coil is placed between the two poles of a magnetic field such that the arm AB and CD are perpendicular to the direction of the magnetic field. The ends of the coil are connected to the two halves P and Q of a split ring. The inner sides of these halves are insulated and attached to an axle. The external conducting edges of P and Q touch two conducting stationary bushes X and Y, respectively, as shown in the figure. Commercial motors use an electromagnet in place of a permanent magnet, a large number of turns of conducting wire in the current carrying coil and a soft iron core on which the coil is wound.

- i. Choose incorrect statement from the following regarding split rings.
 - a. Split rings are used to reverse the direction of current in coil.
 - b. Split rings are also known as commutator.
 - c. Split ring is a discontinuous or a broken ring.
 - d. Both (a) and (b).
- ii. Which of the following has no effect on the size of the turning effect on the coil of an electric motor?
 - a. The amount of the current in the coil.
 - b. The direction of the current in the coil.
 - c. The number of turns in the coil.
 - d. The strength of the magnetic field.
- iii. When current is switched ON, an electric fan converts?
 - a. Mechanical energy to chemical energy.

- b. Electrical energy to mechanical energy.
 - c. Chemical energy to mechanical energy.
 - d. Mechanical energy to electrical energy.
- iv. In an electric motor, device that makes contact with the rotating rings and through them to supply current to coil is:
- a. Axle.
 - b. Brushes.
 - c. Coil.
 - d. Split rings.
- v. In an electric motor, the direction of current in the coil changes once in each:
- a. Two rotations.
 - b. One rotation.
 - c. Half rotation.
 - d. One-fourth rotation.

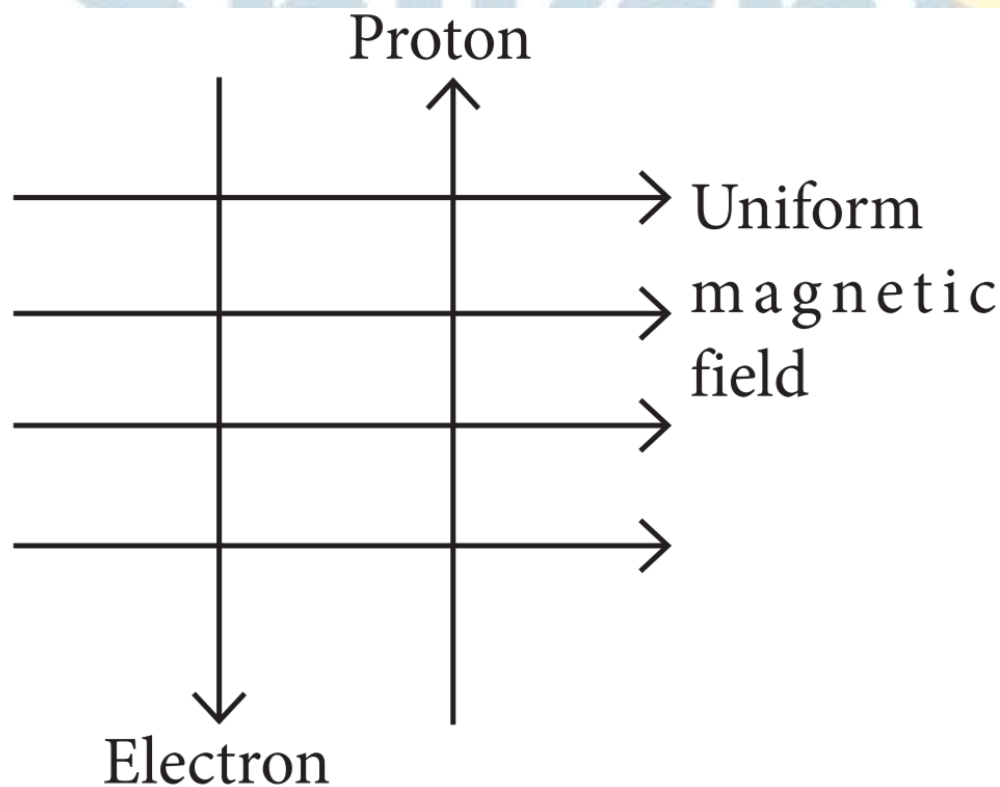
2. Read the following and answer any four questions from (i) to (v).

Andre Marie Ampere suggested that a magnet must exert an equal and opposite force on a current carrying conductor, which was experimentally found to be true. But we know that current is due to charges in motion. Thus, it is clear that a charge moving in a magnetic field experience a force, except when it is moving in a direction parallel to it. If the direction of motion is perpendicular to the direction of magnetic field, the magnitude of force experienced depends on the charge, velocity (v), strength of magnetic field (B), and sine of the angle between v and B . Direction of magnetic force is given by Fleming's left-hand rule.



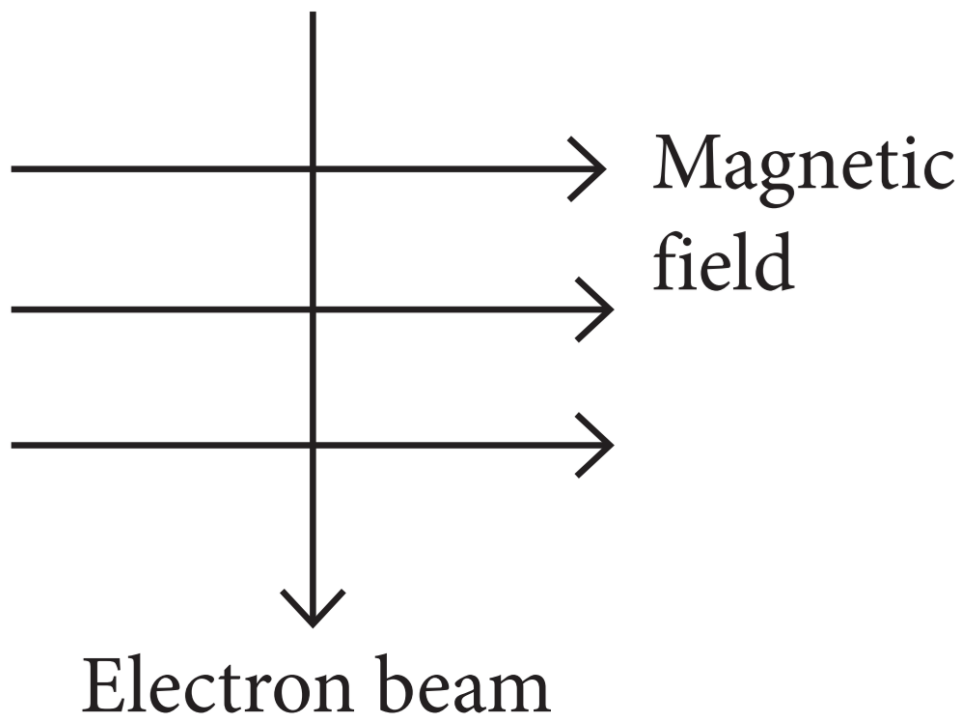
- i. If an electron is travelling horizontally towards east. A magnetic field in vertically downward direction exerts a force on the electron along:
- a. East.

- b. West.
 - c. North.
 - d. South.
- ii. If a charged particle is moving along a magnetic field line. The magnetic force on the particle is:
- a. Along its velocity.
 - b. Opposite to its velocity.
 - c. Perpendicular to its velocity.
 - d. Zero.
- iii. A magnetic field exerts no force on:
- a. A stationary electric charge.
 - b. A magnet.
 - c. An electric charge moving perpendicular to its direction.
 - d. An unmagnetised iron bar.
- iv. A uniform magnetic field exists in the plane of paper pointing from left to right, as shown in figure. In the field, an electron and a proton move as shown. The electron and the proton experience:



- a. Forces both pointing into the plane of paper.
- b. Forces both pointing out of the plane of paper.

- c. Forces pointing into the plane of paper and out of the plane of paper, respectively.
- d. Force pointing opposite and along the direction of the uniform magnetic field respectively.
- v. An electron beam enters a magnetic field at right angles to it as shown in the figure. The direction of force acting on the electron beam will be:



- a. To the left.
- b. To the right.
- c. Into the page.
- d. Out of the page.

✓ Answer Key-

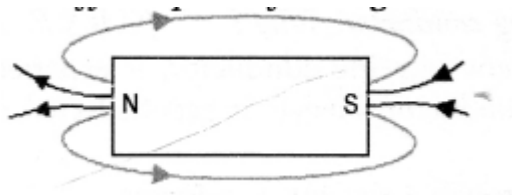
➤ Multiple Choice Answers:

- (c) if magnetic field lines are parallel and equidistant, they represent zero field strength
- (c) straight lines parallel to each other (Due to earth's magnetic field)
- (a) A
- (c) the pattern of the magnetic field associated with the solenoid is different from the pattern of the magnetic field around a bar magnet
- (d) there are momentary galvanometer deflections that die out shortly; the deflection are in opposite directions.
- (d) In India, the AC changes direction after every 150 second.

7. (b) directly below the wire
8. (c) same at all points
9. (b) use of fuse
10. (c) Field lines can cross each other

➤ Very Short Answers:

1. Answer:



2. Answer: From North pole to South pole.
3. Answer: Crowding of magnetic field lines indicates that magnetic field in that region is strong.
4. Answer: Near the poles of the magnet.
5. Answer: The space around a magnet or current carrying conductor within which its influence can be felt by a magnetic substance like iron is called magnetic field.
6. Answer: Direction of magnetic field is determined by a compass needle. The direction of magnetic field is towards the north pole of the compass needle at a point.
7. Answer: tesla (T).
8. Answer: From South pole to the North pole.
9. Answer: It is a curve around a magnet or a current carrying straight conductor such that the tangent at any point on the curve gives the direction of magnetic field at that point.
10. Answer:
 - It is used to determine the direction of north and south of earth.
 - It is used to draw the magnetic field lines around a bar magnet.

➤ Short Answers:

1. Answer: Both P and Q are North poles. Magnetic field lines emerge from North pole.

2. Answer:

The strength of magnetic field at a point due to current carrying conductor depends on

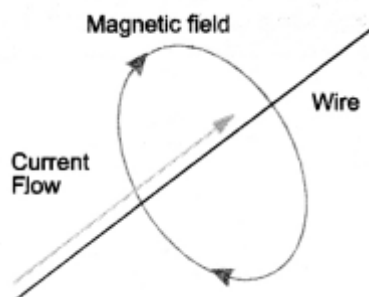
- strength of electric current flowing in the conductor.

- the distance of the point from the conductor.

Right hand thumb rule: If a current carrying conductor is imagined to be held in the right hand such that the thumb points in the direction of the current, then the curled fingers of the hand indicate the direction of magnetic field (Figure 14).

3. Answer:

Describe an activity to plot the magnetic field around a straight conductor carrying current.



- Take the thick piece of wire consisting of ten turns of insulated copper wire and a cardboard.
- Pass this thick wire through a hole in the cardboard placed horizontally as shown in Fig 13.a

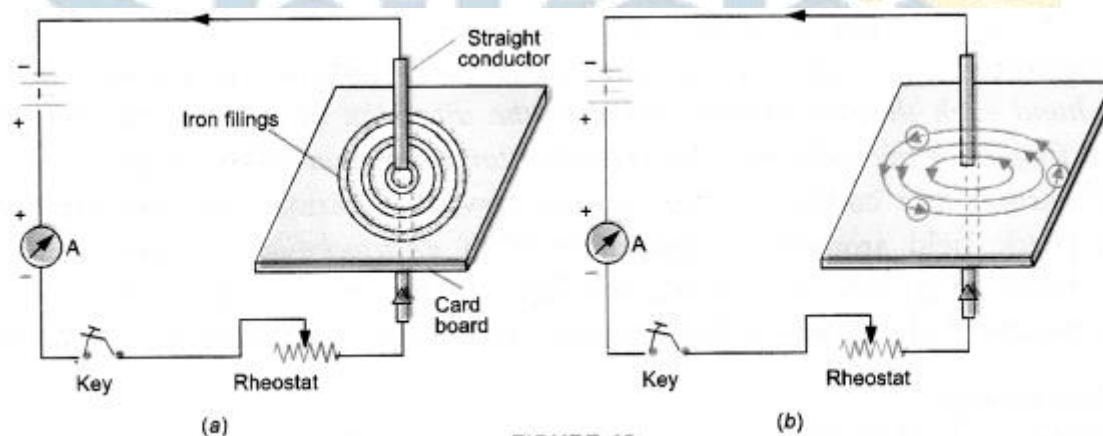


FIGURE 13

- Now pass electric current (about 4 A) through the wire by pressing the key and sprinkle some iron filings on the cardboard around the wire.
- Tap the cardboard gently.

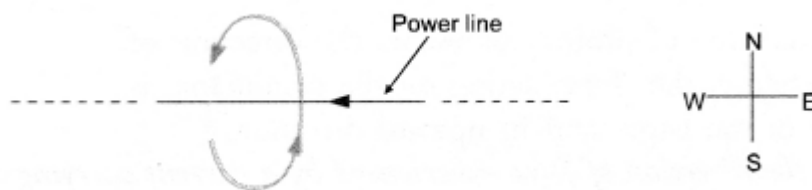
Observation: We find that the iron filings are arranged in concentric circles around the wire as shown in figure 13(a). If magnetic compass is placed near the current carrying wire and at different positions, we get concentric circles around the wire as shown in figure 13(b). These concentric circles around the wire carrying current represent the magnetic field around the wire.

4. Answer: According to right-hand thumb rule:

- the direction of magnetic field at a point above the power line is from south

to north,

- the direction of magnetic field at a point below the power line is from north to south.



5. Answer:

- We observe that the deflection of the needle of the magnetic compass increases. This is because the magnetic field strength due to a current carrying wire increases, when current in the wire is increased.
- We observe that the deflection of the needle of the magnetic compass decreases. This is because the magnetic field strength due to a current carrying wire decreases with the increase of the distance from the wire.

6. Answer: Direction of deflection of magnetic needle due to the current passing through a conductor can be found using Ampere's swimming rule as shown in figure A.

7. Answer:

Observation:

- is incorrect. Degree of deflection of magnetic compass depends on the strength of the magnetic field produced by the current carrying conductor. Magnetic field increases with the increase in the current through the conductor and hence degree of deflection of the magnetic compass increases.
- Magnetic field decreases with the increase in the distance from the conductor and hence degree of deflection of the magnetic compass decreases when the compass is moved away from the conductor.

8. Answer: When a straight conductor carries electric current (dc), a magnetic field is set up around the conductor. This magnetic field causes the deflection in the needle of the magnetic compass.

Describe an activity to plot the magnetic field around a straight conductor carrying current.

- Take the thick piece of wire consisting of ten turns of insulated copper wire and a cardboard.
- Pass this thick wire through a hole in the cardboard placed horizontally as shown in Fig 13.a.

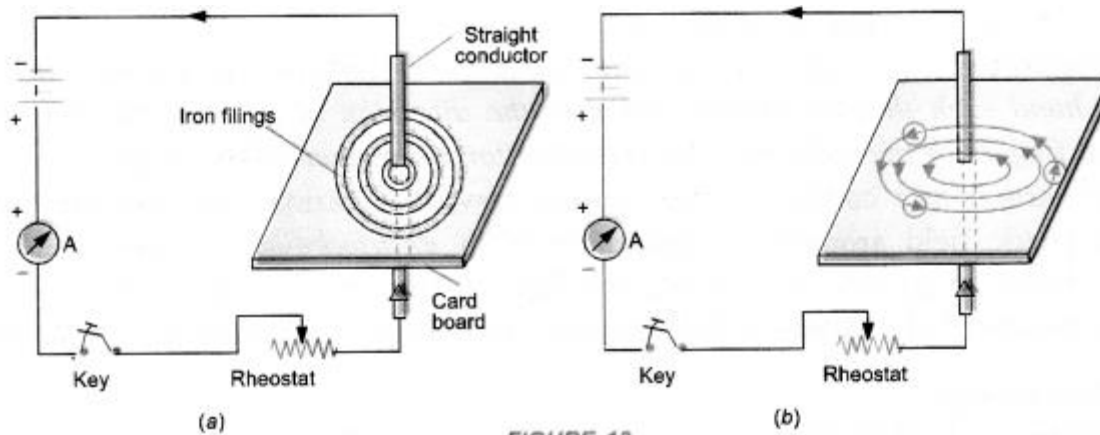


FIGURE 13

- Now pass electric current (about 4 A) through the wire by pressing the key and sprinkle some iron filings on the cardboard around the wire.
- Tap the cardboard gently.

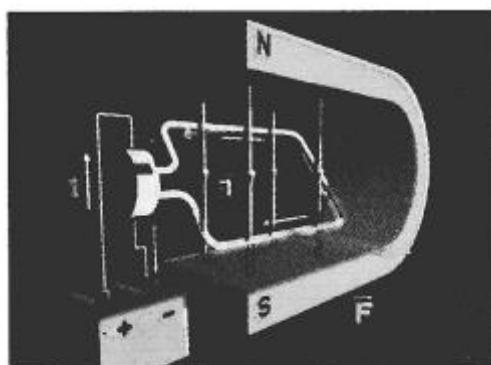
Observation: We find that the iron filings are arranged in concentric circles around the wire as shown in figure 13(a). If magnetic compass is placed near the current carrying wire and at different positions, we get concentric circles around the wire as shown in figure 13(b). These concentric circles around the wire carrying current represent the magnetic field around the wire.

➤ Long Answers:

1. Answer:

Electric motor converts electrical energy into mechanical energy.

Principle: Electric Motor is based on the fact that a current carrying conductor placed perpendicular to the magnetic field experiences a force.



Electric Motor

- Armature coil: It consists of a single loop of an insulated copper wire in the form of a rectangle. Rectangle ABCD shown in figure 25 is an armature coil.

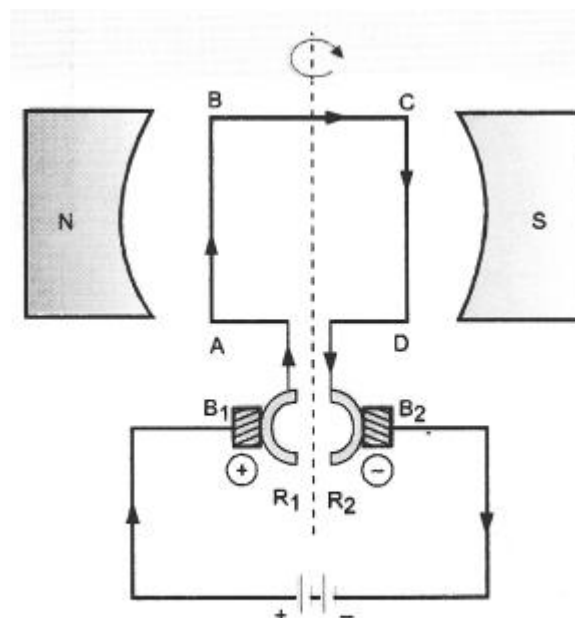


FIGURE 25

- Strong field magnet: Armature coil is placed between two pole pieces (N and S poles) of a strong magnet. This magnet provides a strong magnetic field.
- Split-ring type Commutator. It consists of two halves (R1 and R2) of a metallic ring. The two ends of the armature coil are connected to these two halves of the ring. Commutator reverses the direction of current in the armature coil.
- Two carbon brushes B1 and B2 press against the commutator. These brushes act as the contacts between the commutator and the terminals of the battery.
- A battery is connected across the carbon brushes. This battery supplies the current to the armature coil.

2. Answer:

An electric device used to convert mechanical energy (kinetic energy) into electrical energy (electricity) is called an electric generator.

Principle: Electric generator works on the principle of electromagnetic induction. When the coil of electric generator rotates in a magnetic field, induced current flows in the circuit connected with the coil.

types of electric generator

- AC generator
- DC generator

AC generator: AC generator converts mechanical energy into electrical energy in the form of alternating current or AC.

DC generator: DC generator converts mechanical energy into electrical energy in the form of direct current or DC.

AC Generator Construction: The main components of AC generator are

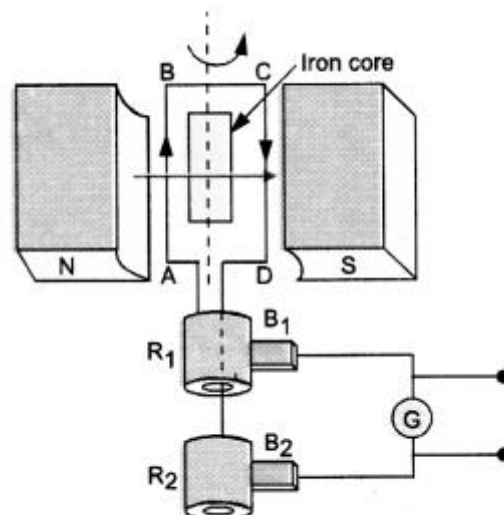


FIGURE 33

- **Armature:** Armature coil (ABCD) consists of large number of turns of insulated copper wire wound over a soft iron core.
- **Strong field magnet:** A strong permanent magnet or an electromagnet whose poles (N and S) are cylindrical in shape is a field magnet. The armature coil rotates between the pole pieces of the field magnet. The uniform magnetic field provided by the field magnet is perpendicular to the axis of rotation of the coil.
- **Slip Rings:** The two ends of the armature coil are connected to two brass slip rings R₁ and R₂. These rings rotate along with the armature coil. Rings R₁ and R₂ are at different heights.
- **Brushes:** Two carbon brushes (B₁ and B₂), are pressed against the slip rings. The brushes are fixed while slip rings rotate along with the armature. These brushes are connected to the external circuit across which the output is obtained.

Working: When the armature coil ABCD rotates in the magnetic field provided by the strong field magnet, it cuts the magnetic field lines. Thus, the changing magnetic field produces induced current in the coil. The direction of the induced current in the coil is determined by the Fleming's right-hand rule.

The current flows out through the brush B₁ in one direction in the first half of the revolution and through the brush B₂ in the next half revolution in the reverse direction. This process is repeated. Therefore, induced current produced is of alternating nature. Such a current is called alternating current.

DC generator or Dynamo Construction:

- **Armature coil.** It consists of large number of turns of insulated copper wire wound on iron core in the form of a rectangle coil. Rectangle coil ABCD shown in figure 34 is an armature coil.

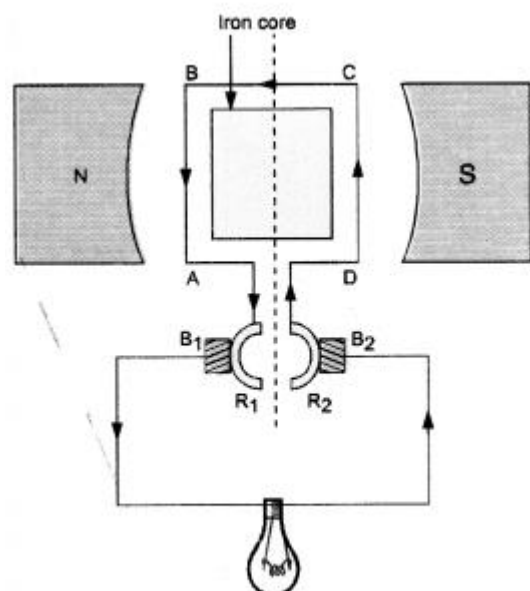


FIGURE 34

- Strong field magnet. Armature coil is placed between two pole pieces (N and S poles) of a strong magnet. This magnet provides a strong magnetic field.
- Split-ring Type Commutator. It consists of two halves (R1 and R2) of a metallic ring. The two ends of the armature coil are connected to these two halves of the ring.
- Two carbon brushes B1 and B2 press against the commutator.
- The output is shown by the glowing bulb connected across the carbon brushes.

Working of d.c. generator: When the coil of d.c. generator rotates in the magnetic field, induced potential difference is produced in the coil. This induced potential difference gives rise to the flow of current through the bulb and hence the bulb glows.

In d.c. generator, the flow of current in the circuit is in the same direction as long as the coil rotates in the magnetic field. This is because one brush is always in contact with the arm of the armature moving up and the other brush is in contact with the arm of the armature moving downward in the magnetic field.

Note: AC generator can be converted into DC generator by replacing slip rings used in AC generator by a split ring type commutator.

➤ Assertion Reason Answer:

1. (c) A is true, but R is false.

Explanation:

In a conductor, the average velocity of electrons is zero. Hence, no current flows through the conductor. Hence, no force acts on this conductor.

2. (a) Both A and R are true, and R is correct explanation of the assertion.

Explanation:

In a rectangular coil carrying a steady current, the direction of current in opposite sides of coil is opposite to each other, therefore, forces acting on each pair of the opposite sides of the coil are equal and opposite, i.e., net force on the coil is equal to zero.

➤ Case Study Answer:

1. i (d) Both (a) and (b).

ii. (b) The direction of the current in the coil.

Explanation:

The direction of the current has no effect on the size of the turning effect on the coil.

iii. (b) Electrical energy to mechanical energy.

Explanation:

Electric fan works on the principle of electric motor. It converts electrical energy to mechanical energy.

iv. (b) Brushes.

v. (c) Half rotation.

2. i (d) South.

Explanation:

Fleming's left-hand rule is used to determine the direction of force on electron i.e., in south direction.

ii. (d) Zero.

Explanation:

The angle between velocity and magnetic field is zero. Therefore, magnetic force on the particle is zero.

iii. (a) A stationary electric charge.

iv. (a) Forces both pointing into the plane of paper.

Explanation:

As the direction of current is taken opposite to the direction of motion of electrons, therefore, current from the motion of electron and proton is in the same direction, i.e., from bottom to top. Now, according to Fleming's left-hand rule, the electron and the proton experience forces both pointing into the plane of paper.

v. (c) Into the page.