

Student's Learning Outcomes (SLOs)

After studying this chapter, students will be able to:

- describe the pattern and direction of the magnetic field due to currents in straight wires and in solenoids.
- state the effect on the magnetic field of changing the magnitude and direction of the current.
- describe how the magnetic effect of a current is used in relays and loudspeakers (including giving examples of their application).
- describe an experiment to show that a force acts on a current-carrying conductor in a magnetic field (including the effect of reversing:
(a) the current (b) the direction of the field
- state and use the relative directions of force, magnetic field, and current.
- describe the magnetic field patterns between currents in parallel conductors and relate these to the forces on the conductors (excluding the Earth's field).
- state that a current-carrying coil in a magnetic field may experience a turning effect and that the turning effect is increased by increasing:
(a) the number of turns on the coil (b) the current
(c) the strength of the magnetic field
- describe the operation of an electric motor, including the action of a split-ring commutator and brushes.
- describe and explain the action of relays in switching circuits.
- state that it is theorized that the Earth's magnetic field is generated by the rotation of the Earth and its molten iron core that contains charged particles in motion.

Subjective Type Questions

Long Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

Introduction

Q.1: What is electromagnetism? Briefly explain.

Ans. Electromagnetism is the branch of physics that deals with the interactions between electric and magnetic fields. It explains how electric charges produce electric fields, and how moving charges, like an electric current, create magnetic fields. This connection helps us to understand how modern devices work. Electromagnetism is an essential part of everyday life, powering electric circuits, communication systems and generators. Even light is an electromagnetic wave, showing how important this force is in science and technology. Learning about electromagnetism gives us the knowledge to build useful machines and to understand the science behind today's technology.

Q.2: What are the magnetic effect of steady current? Also explain right hand rule.

Ans. Definition: When current passes through a conductor a magnetic field is produced in the space.

The magnetic effects of a steady current can be demonstrated through experiments involving a current-carrying conductor.

Magnetic Field B Due to Current in a Straight Wire:

Hans Christian Orsted stated that, a steady electric current in a conductor generates a magnetic field B around it.

Explanation:

This can be demonstrated by passing a current-carrying wire through a vertical cardboard sheet and connecting it to a battery. When current flows, magnetic field is produced around it whose direction can be determined using right hand grip rule. Concentric circles are formed by the magnetic field around the conductor. This can be observed by placing small compasses or sprinkling iron filings on the cardboard. The compass needles align themselves along the direction of the magnetic field, pointing tangentially to the circular lines of force (Fig. 17.1-a).

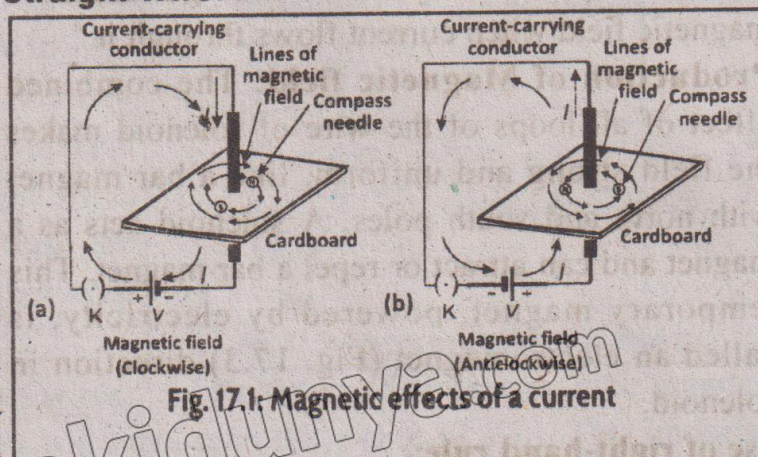


Fig. 17.1: Magnetic effects of a current

Direction of Current:

If the direction of the current is reversed by switching the battery terminals, the compass needles and iron filings also reverse their alignment, indicating that the magnetic field direction depends on the current flow (Fig. 17.1-b). In the dot and cross convention, a dot (.) represents current flowing out of the paper, while a cross (x) indicates into the paper. The magnetic field is strongest near the conductor and weakens with distance. This concept is essential in electrical engineering, particularly with alternating currents.

Direction of the Magnetic Field of a Current-Carrying Wire:

The direction of the magnetic field B around a current-carrying straight wire can be found using the right-hand grip rule, as shown in. Fig. 17.2

Right hand grip rule:

"If you hold the wire in your right hand with your thumb pointing in the direction of the current, then your fingers curl around the wire in the direction of the magnetic field."

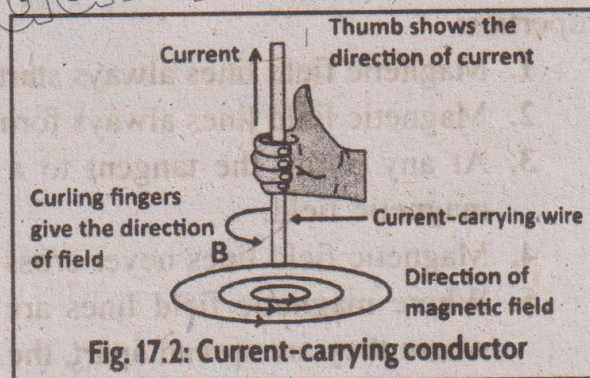


Fig. 17.2: Current-carrying conductor

This simple method helps us to quickly find the magnetic field direction around any straight current-carrying wire. The magnetic field forms circular loops around the wire, and its direction depends on the direction of the current. If the current changes direction, the direction of magnetic field also changes.

Q.3: What is solenoid? How can it be made electromagnet?

Ans.

Solenoid: "A solenoid is a coil of wire wound in the shape of a cylinder that generates a magnetic field when current flows through it."

Production of Magnetic field: The combined effect of all loops of the wire of solenoid makes the field strong and uniform, like a bar magnet with north and south poles. A solenoid acts as a magnet and can attract or repel a bar magnet. This temporary magnet, powered by electricity, is called an electromagnet (Fig. 17.3) direction in solenoid.

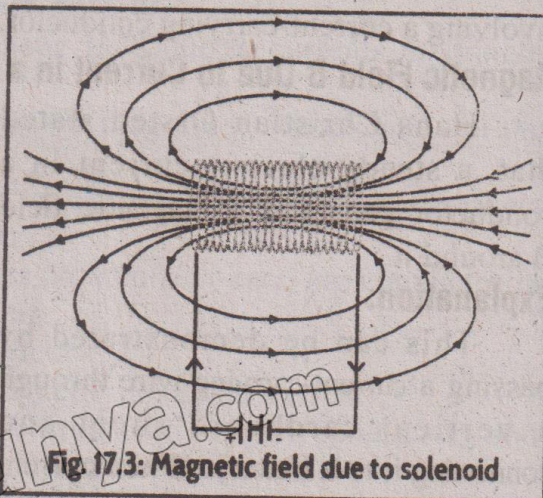
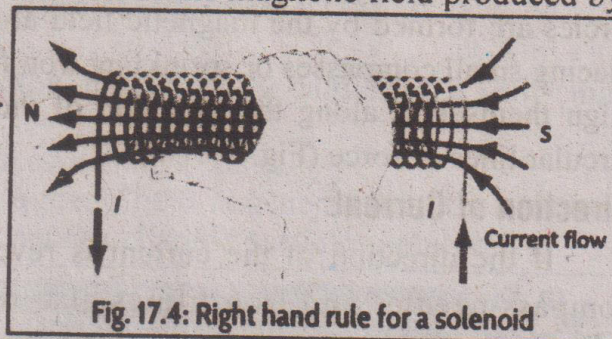


Fig. 17.3: Magnetic field due to solenoid

Use of right-hand rule:

The right-hand rule helps to find out the direction of the magnetic field produced by the solenoid. According to this rule, "if you grip the solenoid with your right hand such that the curled fingers point in the direction of the conventional current, then the thumb will point towards the north pole of the solenoid". (Fig. 17.4)



Use: Electromagnets are useful in motors,

relays, and magnetic locks because their magnetic strength can be controlled by adjusting the current.

Q.4: Write properties of magnetic field lines.

Ans. Properties of magnetic field lines:

Magnetic field lines, just like electric field lines, are imaginary. They do not physically exist but are a way to visualize the magnetic field. These lines have important properties:

1. Magnetic field lines always start from the north pole and end at the south pole.
2. Magnetic field lines always form closed loops.
3. At any point, the tangent to a magnetic field line shows the direction of the magnetic field.
4. Magnetic field lines never cross (intersect) each other.
5. Where magnetic field lines are closer together, the magnetic field is stronger; where they are spread apart, the magnetic field is weaker.

Importance:

Understanding these properties helps us to visualize how magnetic fields behave around magnets, current-carrying wires, and in devices like motors and generators. These ideas are very important in real-world technologies.

Q.5: Explain about forces on parallel current-carrying conductors.

Ans. Forces on parallel current-carrying conductors:

When two wires carry electric current in the same direction, they create magnetic fields around themselves. As shown in Fig. 17.5(a), the magnetic fields between the two wires interact in such a way that the opposite poles are near each other, and the two wires attract each other. This happens because the magnetic fields support each other between the wires and pull them together.

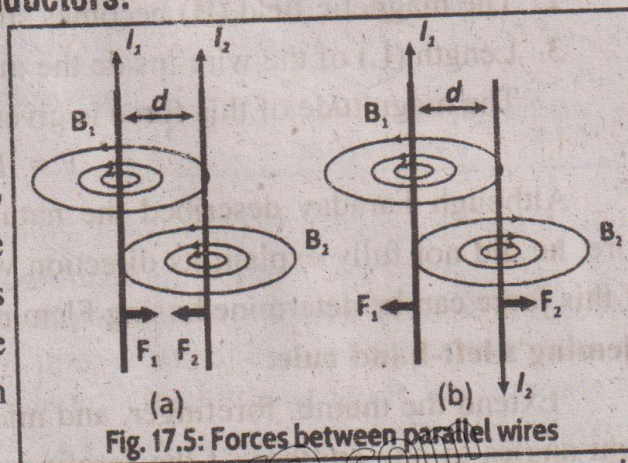


Fig. 17.5: Forces between parallel wires

However, if the current in the two wires flows in opposite directions, their magnetic fields oppose each other, and the wires will repel each other (Fig. 17.5-b). This important behaviour is the basic idea behind electromagnetic devices and technologies like electric motors and electromagnets.

17.2

Force on a Current-Carrying Conductor in a Magnetic Field

Q.6: Describe an experiment to show that when a straight current carrying conductor is placed in magnetic field, it experience a force. Also state rule by which this force can be determine.

Ans. It is known that an electric current generates a magnetic field, much like a permanent magnet does. Since a magnetic field exerts a force on a permanent magnet, it follows that a current-carrying conductor should also experience a force when placed in a magnetic field.

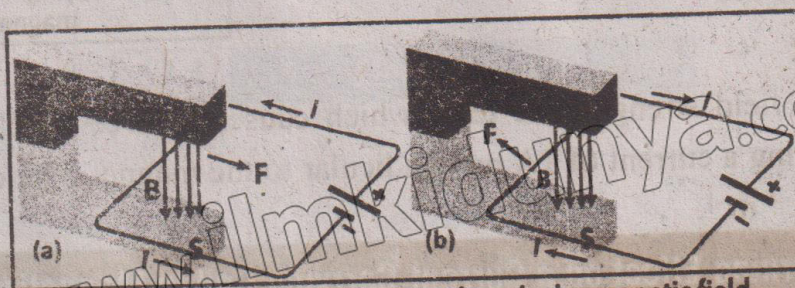


Fig. 17.6: Force on a current-carrying wire in magnetic field

Explanation:

The effect of a magnetic field on a wire carrying current can be illustrated using the setup in Fig. 17.6. A battery creates an electric current in the wire positioned inside the magnetic field of a permanent magnet. This wire then generates its own magnetic field, which interacts with the magnetic field of the magnet. As a result, a force acts on the

wire. Based on the direction of the current, the wire is either pushed to the right (Fig. 17.6-a) or pulled to the left (Fig. 17.6-b).

Increase the force:

The force is increased if:

1. The electric current (I) in the wire increases
2. The magnetic field (B) becomes stronger
3. Length (L) of the wire inside the magnetic field.

The magnitude of this force is given as:

$$F = ILB\sin\theta$$

Although Faraday described the nature of the force acting on a current-carrying wire, he did not fully explain its direction whether it is to the left or right. The direction of this force can be determined using Fleming's left-hand rule, which states.

Fleming's left-hand rule:

"Extend the thumb, forefinger, and middle finger of the left hand so that they are at right angles to one another. If the forefinger represents the magnetic field direction and the middle finger shows the current direction, then the thumb will point in the direction of the force acting on the conductor."

Diagrammatic representation of Fleming's left-hand rule:

As illustrated in Fig. 17.7, the force on the conductor is perpendicular to both the current and the magnetic field, in accordance with Fleming's left-hand rule.

SI unit:

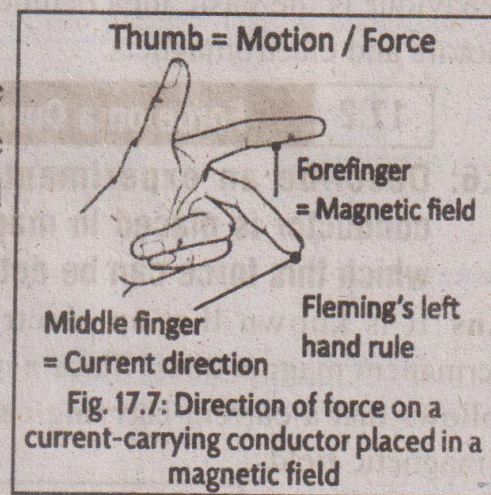
The SI unit of magnetic field (also called magnetic flux density) is the tesla (T).

1 tesla (T) is defined as:

Definition of Tesla:

The magnetic field strength one tesla which causes a force of 1N on a 1 metre length of wire carrying a current of 1A perpendicular to the magnetic field.

$$\text{i.e.; } 1\text{T} = 1\text{NA}^{-1}\text{m}^{-1}.$$



17.3

Turning Effect on a Current-Carrying Coil in Magnetic Field

Q.7: How current carrying coil rotate in a magnetic field?

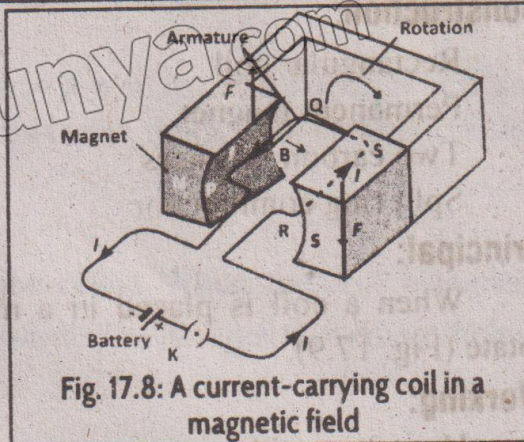
Or State that current carrying coil placed in magnetic field experiences a torque.

Ans.

When a current carrying rectangular coil is placed in magnetic field then it rotates about its axis.

Explanation:

Let us imagine a rectangular coil PQRS that is carrying a current and is placed in a magnetic field, as shown in Fig. 17.8. The coil is positioned in such a way that it is perpendicular to the magnetic field of a permanent magnet. Now, if we connect the ends of the coil to a battery, electric current starts flowing through the coil.



Direction of Force:

When this happens, we can apply Fleming's Left Hand Rule to understand what force acts on the different parts of the coil. According to the rule:

On the side PQ of the coil, the force acts outward. On the side RS, the force acts inward. This happens because the current flows in opposite directions on the two sides of the coil. As a result, two forces are produced that are equal in magnitude but opposite in direction. These opposite forces form a couple. A couple produces a rotational effect or torque, which causes the coil to start rotating.

Principal:

When a current-carrying coil is placed in a magnetic field, it experiences a couple of forces that makes the coil rotate, as shown in Fig. 17.8.

This is the working principle of electric motors, which are used everywhere around us from fans to cars.

Dependence of Torque:

The turning effect on the coil can be made stronger by

1. increasing the number of turns of the coil. More loops mean a stronger turning effect of force.
2. increasing the current flowing through the coil. More current creates a stronger torque.
3. increasing the strength of the magnetic field. A stronger magnet makes the coil to rotate with more torque. These factors help to make electric motors more powerful and efficient.

17.4

Electric Motor

Q.8: Write a note on D.C motor.

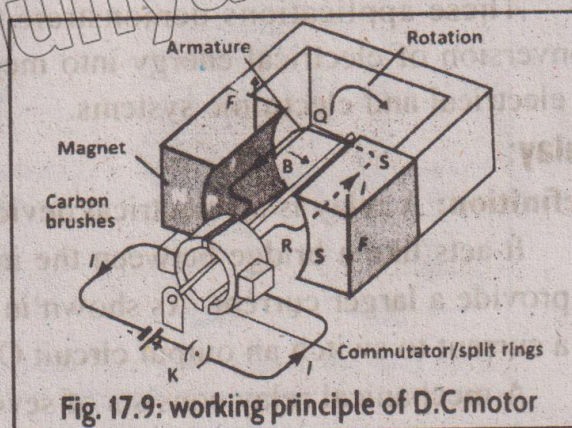
Ans. Definition:

An electric motor is a device that converts electrical energy into mechanical energy.

Types of Motors:

There are two types of electric motors, one is Alternating Current (A.C) motor and the other is Direct Current (D.C) motor.

A D.C motor operates using the interaction between a current-carrying coil (armature) and a magnetic field.



Construction:

- Rectangular coil
- Permanent magnet
- Two carbon brushes
- Split ring commutator

Principal:

When a coil is placed in a magnetic field, it experiences forces that cause it to rotate (Fig. 17.9).

Working:

However, without any external help, the coil would stop rotating after 90° , as the forces acting on its sides (such as PQ and RS) push it into a vertical position, making the coil perpendicular to the magnetic field. At this point, the net force becomes zero, preventing further rotation. To keep the coil rotating, the current direction must be reversed just as the coil reaches the vertical position. This is achieved using a split ring commutator, which is a metal ring divided into two halves, each connected to one end of the coil. Carbon brushes maintain contact with the commutator, allowing current to flow. As the coil rotates, the commutator also rotates, and when the coil reaches the vertical position, each half of the commutator switches brushes, reversing the current direction.

Result:

As a result, direction of the current changes the direction of the forces which allows continuous rotation of the coil. The speed of the motor can be adjusted by controlling the current flowing through it.

17.5**Use of Magnetic Effects of Current****Q.9: Write about use of magnetic effects of current.**

Ans. The magnetic effects of electric current are used in modern technology.

Principal:

The principle of creation of magnetic field due to current flow in a wire is utilized in relays and loudspeakers which rely on the interaction between electric currents and magnetic fields to perform their functions.

Application:

These applications demonstrate how the magnetic effects of current enable the conversion of electrical energy into mechanical energy or sound, making them essential in electrical and electronic systems.

Relay:

Definition: A relay is an electrical device that uses magnetism to control another circuit.

It acts like a bridge between the input and output circuits, allowing a small current to provide a larger current. As shown in figure 17.10 (a), a relay uses the magnetic effect of a current to switch an output circuit ON or OFF.

A mechanical relay consists of several important parts:

(a) Coil and Core:

The relay has a coil made of wire wound around a magnetic core. When an electrical current passes through the coil, it creates a magnetic field. This magnetic field is the key that makes the relay work.

(b) Armature:

The armature is a small movable piece inside the relay. When the coil becomes magnetised and demagnetised, it pulls the armature towards itself. This movement helps to open or close the switch connected to the relay.

(c) Return Spring:

The return spring is connected to the armature. It brings the armature back to its original position when the current stops. In simple words, it acts like a reset button that resets the relay when electricity is cut off.

(d) Moving Contact:

The moving contact is attached to the armature. When the armature moves due to magnetism, the moving contact also moves. This contact either joins or breaks the circuit, allowing or stopping the flow of current to the device (like a lamp). Similarly, it helps to open door lock, starting of motor car and heavy machines.

How a Relay Works?

A relay helps to turn ON and OFF a lamp easily:

When the switch is OFF:

No current flows through the coil. The armature stays in its normal position. As a result, the lamp's circuit remains open, and the lamp does not glow, as shown in Fig. 17.10 (b).

When the switch is ON:

Current starts flowing through the coil. The coil becomes magnetised and pulls the armature towards it. This action closes the lamp's circuit and the lamp glows, as shown in Fig. 17.10 (c).

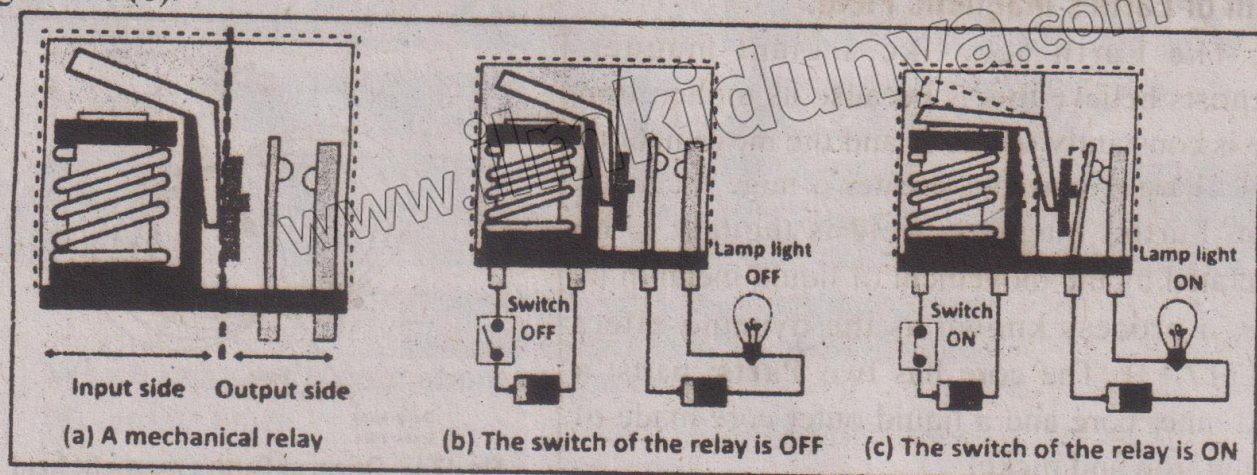


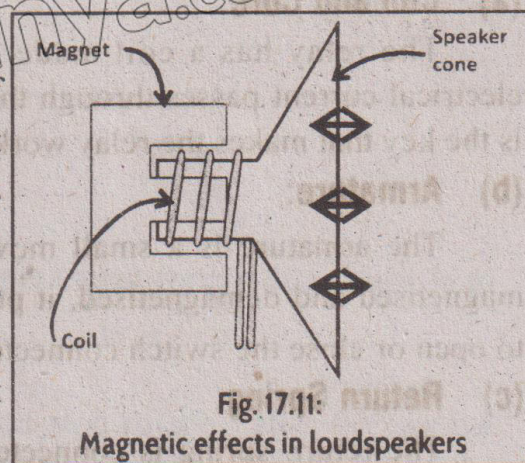
Fig. 17.10: Relay

Q.10: Write a note on loudspeaker.

Ans: Loudspeaker:

A loudspeaker also uses the magnetic effects of current to convert an electrical signals into sound. It consists of a coil (attached to a diaphragm) which is placed in a permanent magnetic field as shown in Fig. 17.11. When an alternating current (audio signal) flows through the coil, it generates a varying magnetic field that interacts with the permanent magnetic field.

This interaction generates a force on the coil, causing it to move back and forth. The movement of the coil vibrates the diaphragm, producing sound waves that correspond to the electrical signal. Loudspeakers are used in audio systems, public address systems, and televisions etc.

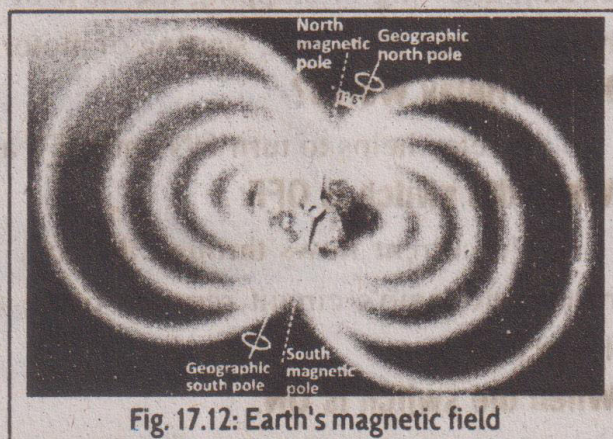


17.6

Earth's Magnetic Field

Q.11: Write about Earth's magnetic field?

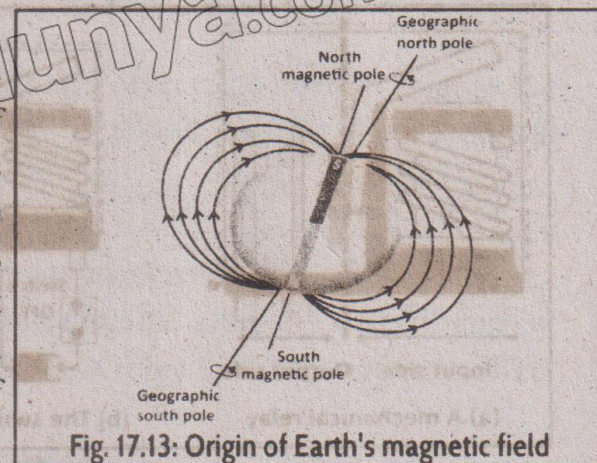
Ans. Earth's magnetic field acts like an invisible shield that surrounds the planet and stretches into space (Fig. 17.12). It is similar to the field of a bar magnet, with a north and south pole, but unlike a regular magnet, it constantly shifts and can even flip over time. This magnetic field is essential because it protects the Earth from dangerous solar winds and cosmic radiations by pushing away harmful charged particles and radiations.



It also helps with navigation, guiding both humans and animals like migratory birds and sea turtles by allowing them to sense Earth's magnetic direction.

Origin of Earth's Magnetic Field:

The Earth acts like a giant magnet. Scientists believe this is because its molten iron core is constantly spinning and the movement of these charged particles creates a huge magnetic field. Earth's magnetic field is thought to be generated by the movement of liquid metal in its core, a process known as the dynamo effect (Fig. 17.13). The core has two Parts: parts: a solid inner core and a liquid outer core made of molten iron and nickel.



Magnetohydrodynamics:

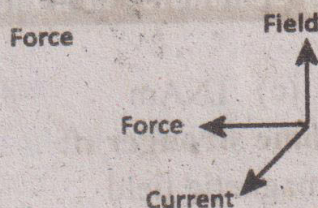
As the Earth spins, heat from the inner core causes the liquid metal to flow, creating electric currents. These currents produce magnetic fields, which combine and grow stronger due to the Earth's rotation. This process, called magnetohydrodynamics, keeps the magnetic field active and forms the magnetosphere, a protective barrier that shields Earth from harmful solar wind and space radiation.

DO YOU KNOW?

Force on current-carrying conductor in Magnetic field

Direction of force - Fleming's Left hand rule

Field
Current



Electric Motor

- Convert electrical energy into mechanical energy

- As current passes through the coil in a magnetic field, force acting on the coil turns the coil.



The solar wind and the Earth's magnetic field

At the centre of the Earth is the solid inner core. The inner iron nickel core is solid due to the extremely high pressure rather than a drop in temperature. The inner core is in fact hotter than the outer core.



Tidbits

What is the special role of a split-ring commutator in D.C motor?

Ans: The split ring commutator reverses the direction of the current in the armature coil every half rotation, ensuring continuous unidirectional torque and rotation of the DC motor.

Objective Type Questions

Additional MCQ's

Multiple Choice Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

17.1 Magnetic Effects of a Steady current

- Which segment is true about magnetic poles?
 - unlike poles
 - like poles attract
 - magnetic poles do not affect each other

- (d) a single magnetic pole does not exist
- The presence of magnetic field can be detected by:
 - magnetic compass
 - stationary +ve charge
 - small mass
 - stationary -ve charge
 - The lines will be in the form of concentric circles if conductor is:
 - solenoid
 - straight
 - circular
 - none of these
 - The end of solenoid from which line of force emerge out is called:
 - North pole
 - South pole
 - North and South pole
 - None
 - The magnetic field of solenoid resemble as:
 - Iron wire
 - U-shaped
 - Bar magnet
 - Point charge

17.2 Force on a Current Carrying Conductor in a Magnetic Field

- 1 Tesla is equal to:
 - $1\text{N}^{-2}\text{Am}$
 - $1\text{NA}^{-1}\text{m}^{-2}$
 - $1\text{NA}\text{m}$
 - $1\text{NA}^{-1}\text{m}^{-1}$
- According to Faraday's rule force become stronger if:
 - large portion of wire lies within the magnetic field
 - long portion of wire lies out of magnetic field
 - none of them
 - electric current in wire decreases
- Which statement is right?
 - Magnetic field lines always from closed loops
 - Magnetic field lines always from distanced loops
 - Magnetic field lines never come from a bar magnet
 - all are true
- Force on a current carrying conductor in a magnetic field is given by.
 - $F = ma$
 - $F = ILB\cos\theta$
 - $F = ILB\sin\theta$
 - $F = ILB$
- Magnetic field represented by:
 - I
 - B
 - L
 - M

17.3 Turning Effect on a Current-Carrying Coil in Magnetic Field

- The turning effect of a coil made stronger by:
 - increasing loops
 - decreasing loops
 - neither increase or decrease
 - none

17.4 Electric Motor

- D.C motor converts:
 - mechanical energy into chemical energy
 - electrical energy into mechanical energy
 - electrical energy into chemical energy
 - none
- Which part of D.C motor reverses the direction of current through it every half-cycle?
 - the armature
 - the commutator
 - the brushes
 - the slip ring

17.5 Use of Magnetic Effects of Current

14. Principal of loud speaker works at:

- (a) convert chemical signal into electrical
- (b) convert electrical signal into sound
- (c) convert electrical signal into mechanical
- (d) none of above

15. A relay is a device that uses:

- (a) magnetism to control other circuit
- (b) electricity to control other circuit
- (c) (a) and (b)
- (d) none

17.6

Earth Magnetic Field

16. Earth magnetic field act like:

- (a) invisible shield
- (b) force
- (c) invisible attraction
- (d) none

17. The earth act like a giant magnet because of:

- (a) invisible attraction
- (b) gravity
- (c) molten iron core
- (d) none

Answers

- | | | | | | | |
|---------|---------|---------|---------|---------|---------|---------|
| 1. (d) | 2. (a) | 3. (b) | 4. (a) | 5. (c) | 6. (d) | 7. (a) |
| 8. (a) | 9. (c) | 10. (b) | 11. (a) | 12. (b) | 13. (b) | 14. (b) |
| 15. (c) | 16. (a) | 17. (c) | | | | |

Additional Short Questions

Short Answer Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

17.1 Magnetic Effects of Steady Current

1. State the rule to find North and South poles of a current carrying solenoid.

Ans. Hold down the end of current carrying solenoid in front of you. If the direction of the flow of current to this end is anti-clockwise, it will be the north pole, otherwise it will be south pole.

2. State Fleming's left hand rule.

Ans. The direction of force on a current carrying conductor is given state that "extend the thumb, forefinger and middle finger of the left hand mutually at right angles to each other if forefinger point out the magnetic field the middle finger in the direction of current and thumb will indicate direction of force".

3. What is solenoid? What type of magnetic field it possess?

Ans. A solenoid is a closely wound cylindrical coil of insulated wire.

The magnetic field pattern of solenoid is just like the magnetic field resembling to the bar magnet.

17.2**Force on a Current Carrying Conductor in a Magnetic Field**

4. When the force on a current carrying conductor in a magnetic field maximum and when its minimum?

Ans. When current carrying conductor makes an angle of 90° with the magnetic field i.e. when it perpendicular to field, the force will be maximum if the conductor is placed along or parallel to the magnetic field no force act on the conductor.

5. What is meant by intensity of magnetic field?

Ans. The strength of magnetic field or intensity is defined as the number of magnetic lines of passing through any surface.

6. Define 1 Tesla?

Ans. The magnetic field strength that cause a force of 1N on a 1 meter length of wire carrying a current if 1A, perpendicular to the magnetic field.

$$1\text{T} = 1\text{NA}^{-1}\text{m}^{-1}$$

17.3**Turning Effect on a Current-Carrying Coil in Magnetic Field**

7. What is the working principle of electric motor?

Ans. When a current-carrying coil is placed in a magnetic field, it experience a couple of forces that makes the coil rotate. This is the working principle of electric motors.

8. How the turning effect on the coil can be made stronger?

Ans. The turning effect on the coil can be made stronger by.

- i) increasing the number of turn of the coil.
- ii) increasing the current flowing through the coil.
- iii) increasing the strength of the magnetic field.

17.4**Electric Motor**

9. What is armature?

Ans. In practical electric motor the coil called armature and it is made of many loops mounted on a shaft or axle.

10. What is the function of split ring in D.C motor?

Ans. Split ring connect the coil to the battery through carbon bushes. When coil rotate in between the pole pieces of a magnet split ring keep the current in coil and hence coil rotate in the field.

11. What is D.C motor? On which principal does it work?

Ans. D.C motor is a device which converts electrical energy in to mechanical energy. It work on principal when current passes through coil placed in magnetic it experiences a force due to which coil rotates in the field.

12. Write name of parts of D.C motor.

Ans. • Rectangular coil
• Permanent magnet
• Two carbon brushses
• Split ring commutator

13. What is the function of relay?

Ans. The relay is an electrical switch is used to control a large current with the help of small current it open and closes under the control of another electrical circuit.

Explanation: The 1st circuit supplies current to the electromagnet. The electromagnet is magnetized and attracts one end of iron armature. The armature then closes the contact (2nd switch) and allow current to flow second circuit. When 1st switch open again the current to electromagnet stop. Now electromagnet loses its magnetism and 2nd switch opens. Thus flow of current stop in 2nd circuit.

14. Can magnetic poles separated?

Ans. Magnetic poles never separated. Even when magnet is broken, every piece has two poles north and south.

15. On which principal loud speaker work and write about its uses?

Ans. Loud speaker uses the magnetic effects of current to convert electrical signal in to sound.

Uses: It is use in audio system, public address system and television.

16. What is magneto-hydrodynamics?

Ans. The earth spin, heat from inner core causes the liquid metal to flow, creating electric current. This current creating magnetic field which combine and grow stronger due to Earth's rotation. This process is known as magneto-hydrodynamics.

17. Earth act like giant magnet justify it.

Ans. Because its molten iron core is constantly spinning and movement of these charged particles create huge magnetic field.

Earth magnetic field thought to be generated by the movement of liquid metal in its core.

Exercise Questions (Solved)

A. Multiple Choice Questions

☆ Tick (✓) the correct answer.

17.1 Which statement is true about the magnetic poles?

- (a) Unlike poles repel
- (b) Like poles attract
- (c) Magnetic poles do not affect each other
- (d) A single magnetic pole does not exist

17.2 A D.C motor converts:

- (a) mechanical energy into electrical energy
- (b) mechanical energy into chemical energy
- (c) electrical energy into mechanical energy
- (d) electrical energy into chemical energy

- 17.3 The part of a D.C motor that reverses the direction of current through the coil every half-cycle:
 (a) the armature (b) the commutator (c) the brushes (d) the split rings
- 17.4 The two main layers of the Earth's core that contribute to the generation of the magnetic field are:
 (a) crust and mantle (b) inner core and outer core
 (c) lithosphere and asthenosphere (d) troposphere and stratosphere
- 17.5 What does a steady electric current in a conductor generate around it?
 (a) Electric field (b) Light (c) Magnetic field (d) Sound waves
- 17.6 What happens to the magnetic field direction when the direction of the current is reversed?
 (a) The magnetic field remains unchanged
 (b) The magnetic field also reverses direction
 (c) The magnetic field becomes stronger (d) The magnetic field disappears

Answers

17.1 (d) 17.2 (c) 17.3 (b) 17.4 (b) 17.5 (c) 17.6 (c)

B. Short Answer Questions

17.1 What is the direction of the magnetic field around a straight current carrying wire?

Ans. The magnetic field around a straight current-carrying wire forms concentric circles. The direction of the magnetic field is determined by the right-hand rule:
 "If we point our right thumb in the direction of the current, your fingers curl in the direction of the magnetic field."

17.2 What happens to the magnetic field if the magnitude of the current in a wire is increased?

Ans. When magnitude of current increased in a wire is increased the magnetic field around the wire become stronger.

This is because $B \propto I$

More current $\rightarrow$ stronger magnetic field

Less current $\rightarrow$ weak magnetic field

17.3 How can you identify the north and south poles of an unmarked magnetized steel bar?

Ans. Suspend the steel bar horizontally, allowing it to rotate freely. The end that points towards the Earth's geographic north is the north pole of the magnet, and the end that points towards the earth's geographic south is the south pole of the magnet.

17.4 What rule determines the direction of force on a current-carrying conductor placed in a magnetic field? Explain briefly.

Ans. The direction of force on a current carrying conductor placed in a magnetic field is determined by Fleming's left hand rule.

"Extend the thumb, forefinger, and middle finger of the left hand so that they are at

right angles to one another. If the forefinger represents the magnetic field direction and the middle finger shows the current direction, then the thumb will point in the direction of the force acting on the conductor."

17.5 What role does the commutator play in a D.C motor?

Ans. It reverses the direction of current in the armature of coil after every half rotation. This reversal ensures that the direction of force on the coil remains the same. So, the coil continues to rotate continuously.

Without commutator the coil would rotate only half a turn and then stop. In short, commutator helps in continuous rotation of D.C motor by maintaining unidirectional torque.

17.6 What is the source of the Earth's magnetic field according to the theory?

Ans. According to theory, the source of Earth's magnetic field is Geodynamo.

The Earth's magnetic field originates from electric current produced by the motion of molten iron in the Earth's outer core. This movement creates electric current, which in turn generates the magnetic field through a process called the geodynamo.

C. Constructed Response Questions

17.1 Why does a magnetic field form around a conductor when current flows through it, but not when the current is OFF? What does this reveal about the nature of electricity and magnetism?

Ans. When current flows through a conductor moving electric charges produce a magnetic field around conductor. When current is OFF, charges are not moving, so no magnetic field is produced.

This demonstrates that magnetism is a consequence of moving electric charges, revealing the interconnected nature of electricity and magnetism.

17.2 In a D.C motor, why does the coil stop turning after 90° if the direction of the current is not reversed? What mechanical feature solves this issue?

Ans. If the current is not reversed, the force acting on the coil reverses after 90° causing the coil to stop rotating. The problem is solved by split ring commutator. Which reverses the direction of current every half rotation, allowing continuous rotation of coil.

17.3 How does placing a wire at different angles to a magnetic field affect the magnetic force it experiences, and why is this important in designing motors?

Ans. The magnetic force on a current-carrying wire in a magnetic field is given by the formula; $F = BIL \sin\theta$,

Where B is the magnetic field strength, I is the current, L is the length of the wire, and θ is the angle between the wire and the magnetic field.

When the wire is parallel to the magnetic field ($\theta = 0^\circ$), $\sin 0^\circ = 0$, and the magnetic force is zero.

When the wire is perpendicular to the magnetic field ($\theta = 90^\circ$), $\sin 90^\circ = 1$ and the magnetic force is maximum ($F = BIL$).

At other angles, the force is proportional to $\sin\theta$, so, it varies between zero and maximum value.

This is crucial in motor design to maximize torque and ensure continuous rotation.

D. Comprehensive Questions

17.1 How is a magnetic field created around a current-carrying wire, and what factors affect its strength?

Ans. See Answer Q. 2 & 4

17.2 Explain the concept of the right-hand grip rule and how it helps determine the direction of the magnetic field around a current-carrying conductor.

Ans. See Answer Q. 2.

17.3 Describe an experiment that demonstrates the magnetic field produced by a current-carrying conductor using a compass or iron filings.

Ans. Case-I:

Experiment to demonstrate the magnetic field using a compass:

- Set up a straight wire connected to a power supply to create a current
- Place a compass near the wire when there is no current. The compass needle will align with the Earth's magnetic field.
- Turn on the power supply to create a current in the wire.
- Observe the compass needle deflecting from its original position. The deflection indicates the presence of a magnetic field produced by the current carrying wire.
- Vary the current and observe the change in deflection angle.

Case-II

Experiment to demonstrate the magnetic field using iron filings:

- Pass a straight wire vertically through a horizontal piece of cardboard.
- Sprinkle iron filings evenly on the cardboard around the wire.
- Pass a current through the wire.
- Observe the iron filings aligning themselves in concentric circles around the wire, visualizing the magnetic field lines.
- Tap the cardboard gently to help the filings align more clearly.

Conclusion:

A compass deflects near a current-carrying wire, showing a magnetic field. Iron filings align in concentric circles around the wire, visualizing the field lines.

17.4 Discuss the theory behind the Earth's magnetic field and the role of the Earth's molten core in generating it.

Ans. See Answer Q.11.

