Chapter 17

ELECTROMAGNETISM

Physics – Class 10 (Unit 17 Notes, Unique Publications)

The branch of physics which deals with electric and magnetic fields is called electromagnetism.

• An electric field is the force field around charged particles.

• A magnetic field is the region around a magnet or current-carrying wire where magnetic force acts.

Key Concepts

- Magnetic effects of steady current
- Force on a current-carrying conductor in a magnetic field
- Turning effect on a current-carrying coil in a magnetic field
- Electric motor
- Use of magnetic effects of current
- Earth's magnetic field

Q.1 Magnetic field produced by a current in a straight wire — experiment, and the right-hand rule.

Magnetic Effects of Steady Current

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

1. Magnetic Field B due to Current in a Straight Wire

- Ampere stated that a steady electric current in a conductor generates a magnetic field B around it. This can be demonstrated by passing a current-carrying wire through a vertical cardboard sheet and connecting it to a battery.
- When current flows, a magnetic field is produced around it whose direction can be determined using the right-hand grip rule.

Fig 17.1: Magnetic Effects of Current

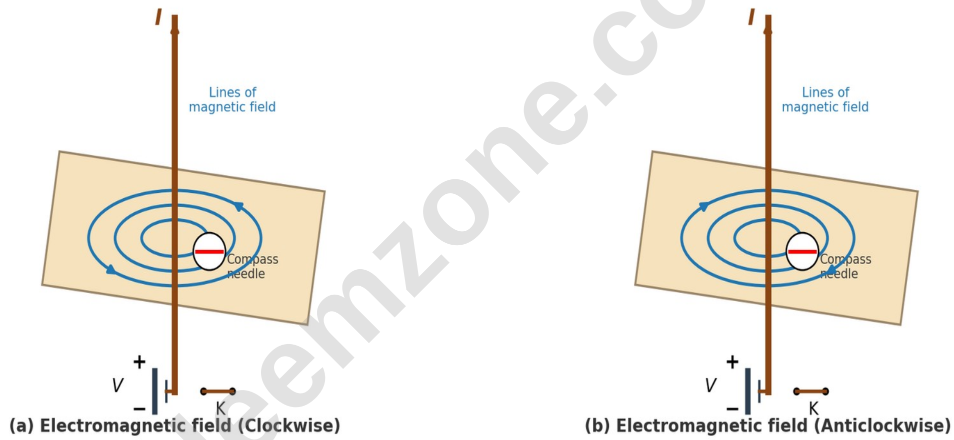

Fig 17.1: Magnetic effects of current

- 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.
- If the direction of the current is reversed by switching the battery terminals, the compass needles and iron filings also reverse their alignment, showing that the magnetic field direction depends on the current flow.
- In the dot-and-cross convention, a dot (•) represents current flowing toward the observer, while a cross (×) indicates it moving away.
- The magnetic field is strongest near the conductor and weakens with distance.
- This concept is essential in electrical engineering, particularly with alternating currents.

2. 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 rule.

3. Right-Hand Grip Rule

Statement: *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.*

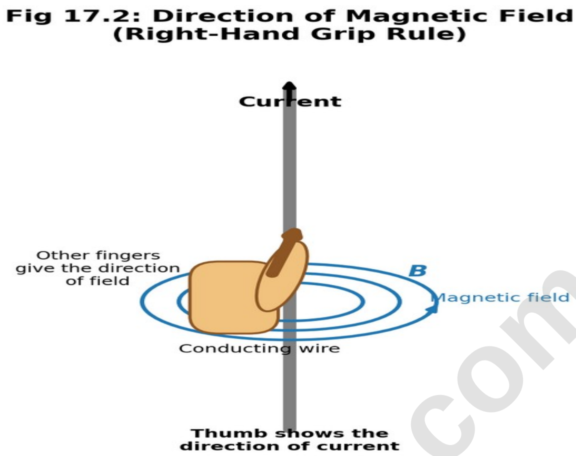

Fig 17.2: Direction of magnetic field — current-carrying conductor

- 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 the magnetic field also changes.

Q.2 What is a solenoid? Explain the magnetic field due to a solenoid.

1. Magnetic Field Due to Current in a Solenoid

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

Explanation

- The combined effect of all loops of the wire of the 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.

Fig 17.3: Magnetic Field Due to a Solenoid

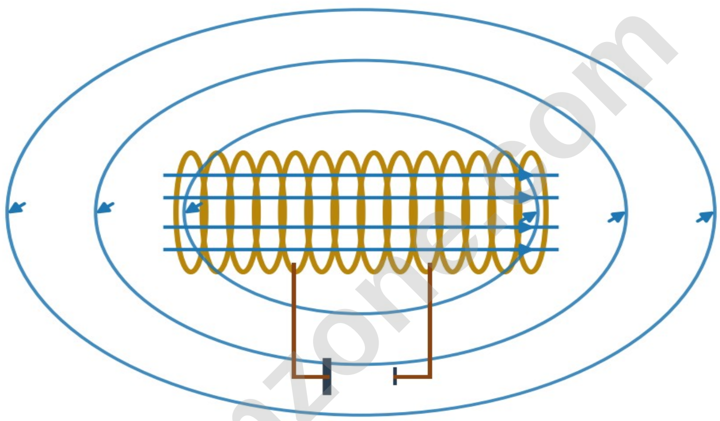

Fig 17.3: Magnetic field due to solenoid

Electromagnet

- The temporary magnet, powered by electricity, is called an electromagnet.
- The right-hand rule helps to find out the direction of the magnetic field produced by the solenoid.

2. Right-Hand Grip Rule (for a 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.

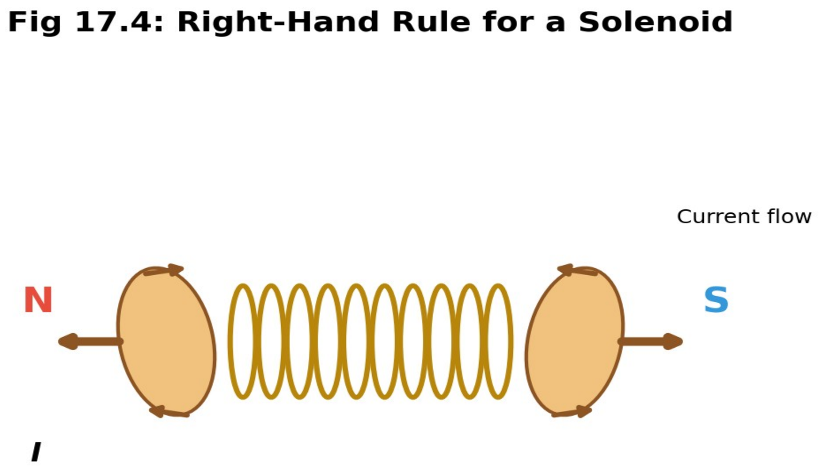

Fig 17.4: Right-hand rule for a solenoid

Uses

Electromagnets are useful in motors, relays, and magnetic locks because their magnetic strength can be controlled by adjusting the current.

Q.3 Describe properties of magnetic field lines.

Properties of Magnetic Field Lines

Definition: *Magnetic field lines, just like electric field lines, are imaginary. They do not physically exist but are a way to visualize the magnetic field.*

1. Properties

These lines have important properties:

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

2. Applications

Understanding these properties helps us 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.4 Forces acting on parallel current-carrying conductors.

Forces on Parallel Current-Carrying Conductors

- When two wires carry electric current in the same direction, they create magnetic fields around themselves.
- The magnetic fields between the two wires interact in such a way that 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.
- 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.

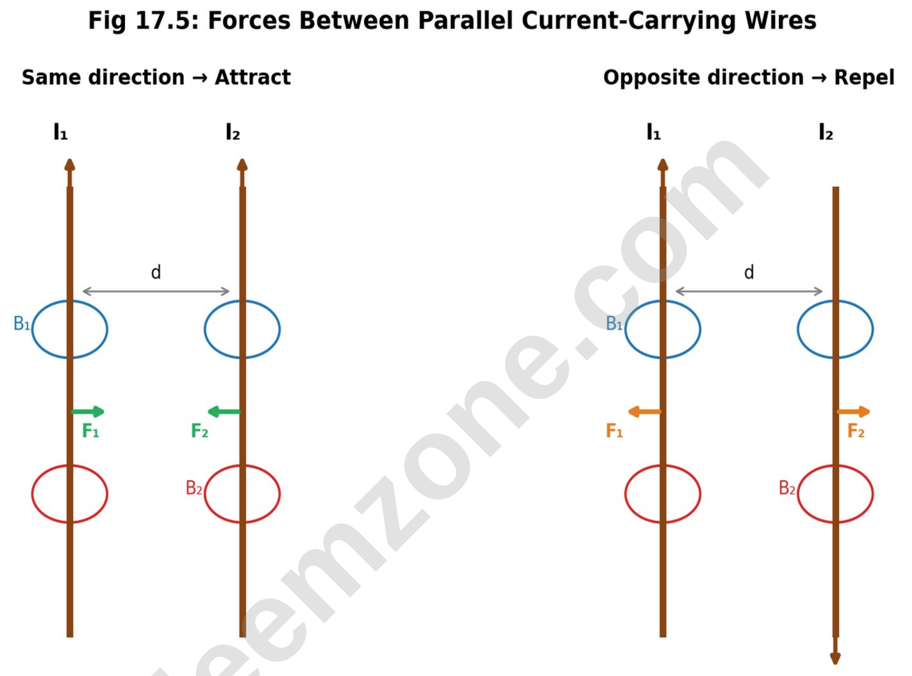

Fig 17.5: Forces between parallel wires

This important behaviour is the basic idea behind electromagnetic devices and technologies like electric motors and electromagnets.

Q.5 Force on a current-carrying conductor in a magnetic field, and Fleming's left-hand rule.

Force on a Current-Carrying Conductor in a Magnetic Field

- 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 a Magnetic Field

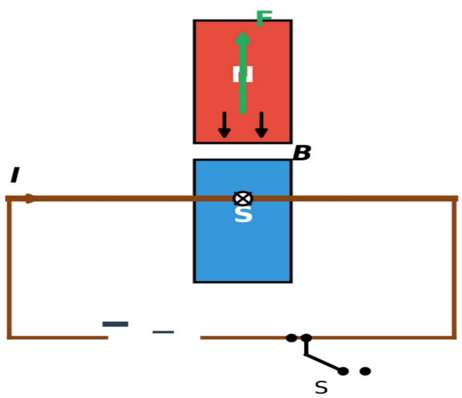

Fig 17.6: Force on a current-carrying wire in a magnetic field

- The effect of a magnetic field on a wire carrying current can be illustrated: 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 field of the magnet. As a result, a force acts on the wire — the wire is either pushed to the right or pulled to the left, depending on the direction of the current.

$$F = ILB \sin \theta$$

Michael Faraday found that this force is always at right angles to both the direction of the magnetic field and the direction of the current. The force becomes stronger if:

  - (i) The electric current (I) in the wire increases
  - (ii) The magnetic field (B) becomes stronger
  - (iii) The length (L) of the wire lies within the magnetic field

- 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.

Fleming's Left-Hand Rule

The direction of this force can be determined using Fleming's left-hand rule, which states:

Statement: *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.*

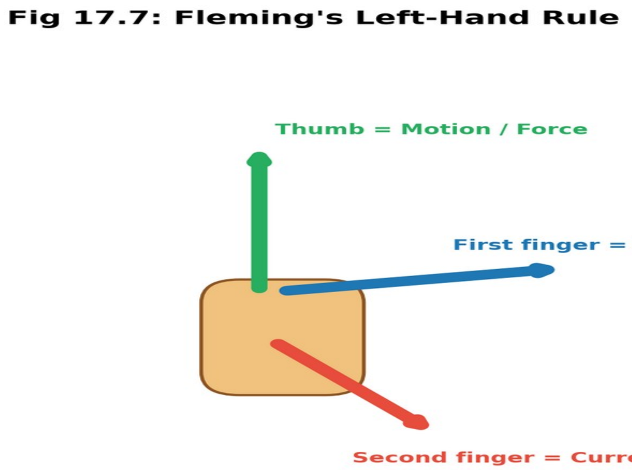

Fig 17.7: Direction of force on a current-carrying conductor placed in a magnetic field

- As illustrated, the force on the conductor is perpendicular to both the current and the magnetic field, in accordance with Fleming's left-hand rule.
- The SI unit of magnetic field (also called magnetic flux density B) is the tesla (T).

Tesla — Unit of Magnetic Field

Definition: *1 tesla (T) is the magnetic field strength that causes a force of 1 N on a 1 metre length of wire carrying a current of 1 A perpendicular to the magnetic field.*

$$1\,T = 1\,N\,A^{-1}\,m^{-1}$$

Q.6 Turning effect (torque) on a current-carrying coil in a magnetic field, and factors affecting torque.

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

- Let us imagine a rectangular coil PQRS that is carrying a current and is placed in a magnetic field.
- The coil is positioned such 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.
- When this happens, we can apply Fleming's left-hand rule to understand what force acts on the different parts of the coil.

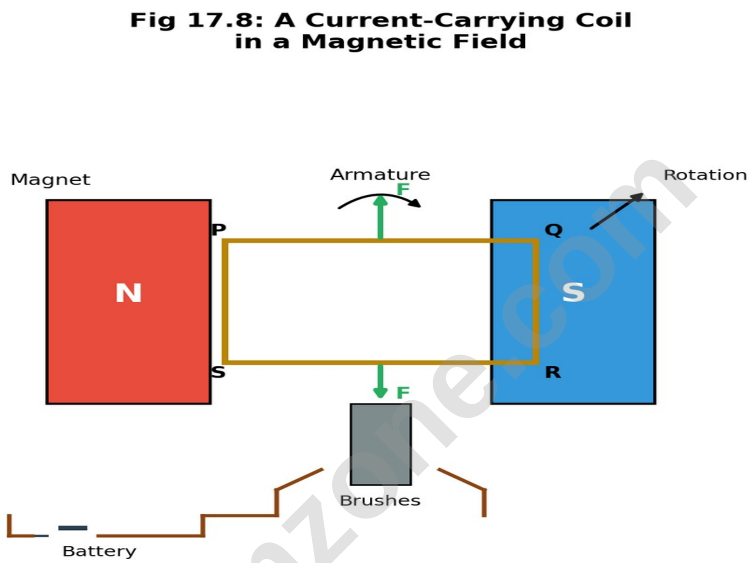

Fig 17.8: A current-carrying coil in a magnetic field

According to the rule: *On the side PQ of the coil, the force acts upward. On the side RS, the force acts downward.*

- 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.

Thus, we can say that: *When a current-carrying coil is placed in a magnetic field, it experiences a couple of forces that makes the coil rotate.*

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

The turning effect on the coil can be made stronger by:

  - (i) increasing the number of turns of the coil — more loops mean a stronger turning force.
  - (ii) increasing the current flowing through the coil — more current creates a stronger force.
  - (iii) increasing the strength of the magnetic field — a stronger magnet makes the coil rotate with more force.

These factors help to make electric motors more powerful and efficient.

Do You Know? — Earth's Magnetic Field and the Solar Wind

Q. How do the solar wind and the Earth's magnetic field interact?

Ans. The Earth's magnetic field acts as an invisible shield, forming a protective region called the magnetosphere. The solar wind, a stream of charged particles from the Sun, interacts with this field. The field pushes away most of these harmful charged particles and radiation, protecting the Earth's surface and atmosphere from their damaging effects.

Q.7 What is an electric motor? Draw its labelled diagram and explain its components and working.

Electric Motor

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

Types

There are two types of electric motors: Alternating Current (A.C) motor and Direct Current (D.C) motor.

Operation

A D.C motor operates using the interaction between a current-carrying coil (armature) and a magnetic field. When a coil is placed in a magnetic field, it experiences forces that cause it to rotate.

Fig 17.9: Working Principle of a D.C Motor

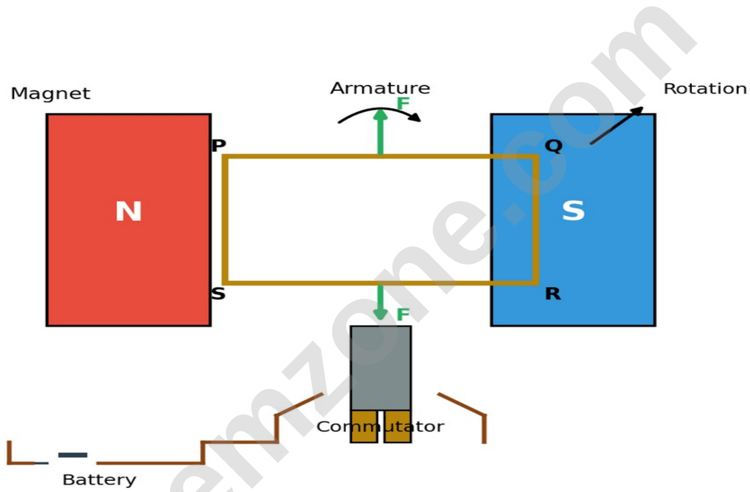

Fig 17.9: Working principle of D.C motor

- 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.
- Graphite 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.
- As a result, the 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.

Tidbit

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

Ans. The split-ring commutator is a metal ring divided into two halves, each connected to one end of the coil. As the coil rotates and reaches the vertical position (90°), the commutator also rotates and switches brushes, reversing the current direction. This reversal changes the direction of the forces on the coil sides, preventing it from stopping and allowing continuous rotation. Without the commutator, the coil would stop after half a turn.

Q.8 Applications of the magnetic effect of current in devices like relays and loudspeakers.

Magnetic Effect of Current — Use of Magnetic Effects of Current

- The magnetic effects of electric current are used in modern technology. The principle of creation of a 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.
- These applications demonstrate how the magnetic effects of current enable the conversion of electrical energy into mechanical motion or sound, making them essential in electrical and electronic systems.

1. 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 control a larger current.
- 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 — 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, opening or closing 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 — 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, joining or breaking the circuit and allowing or stopping the flow of current to the device (like a lamp).

How a Relay Works

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

(i) 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.

(ii) 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.

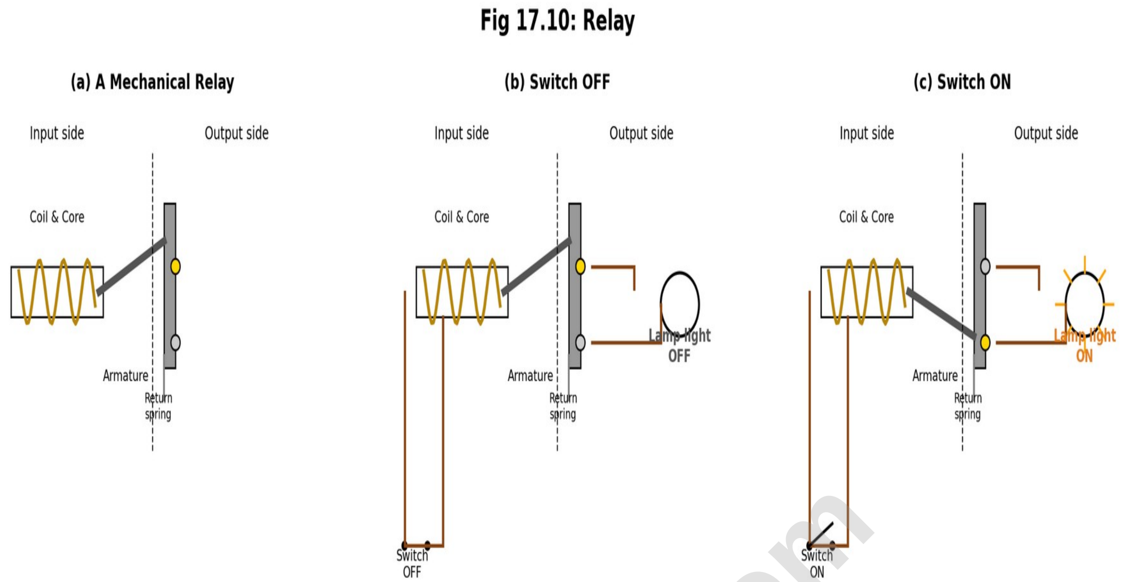

Fig 17.10: Relay — (a) A mechanical relay (b) Switch OFF (c) Switch ON

2. Loudspeaker

Definition: *A loudspeaker also uses the magnetic effects of current to convert an electrical signal into sound.*

Construction

- It consists of a coil (attached to a diaphragm) which is placed in a permanent magnetic field.
- 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.

Fig 17.11: Magnetic Effects in Loudspeakers

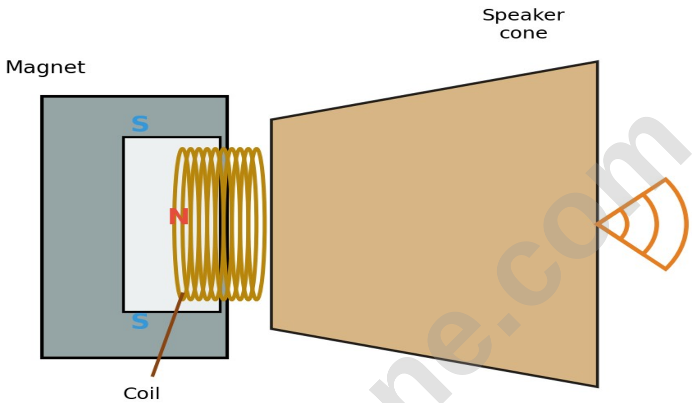

Fig 17.11: Magnetic effects in loudspeakers

Uses

Loudspeakers are used in audio systems, public address systems, and televisions, etc.

Q.9 What is Earth's magnetic field? Explain the origin of Earth's magnetic field.

Earth's Magnetic Field

- Earth's magnetic field acts like an invisible shield that surrounds the planet and stretches into space.
- 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 radiation by pushing away harmful charged particles and radiation.

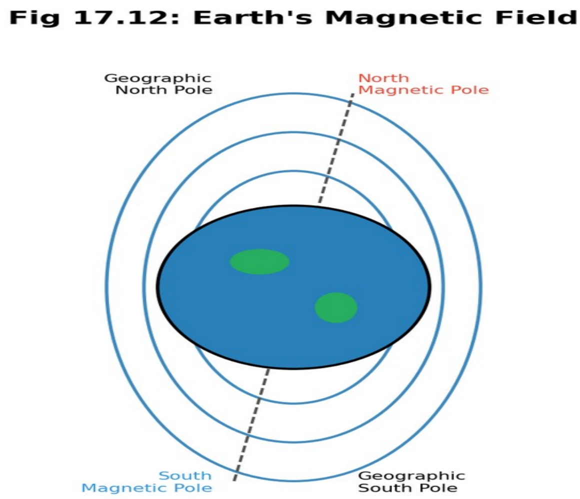

Fig 17.12: Earth's magnetic field

- 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.

The core has two parts: *a solid inner core and a liquid outer core made of molten iron and nickel.*

- 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 magneto-hydrodynamics, keeps the magnetic field active and forms the magnetosphere, a protective barrier that shields Earth from harmful solar wind and space radiation.

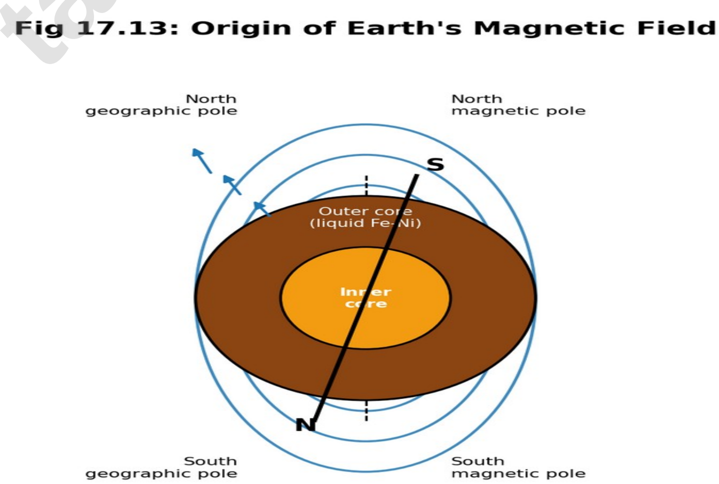

Fig 17.13: Origin of Earth's magnetic field

Do You Know? — Force on a Current-Carrying Conductor and the Electric Motor

Q. What are the key principles behind the force on a current-carrying conductor in a magnetic field, and how is this applied in an electric motor?

Ans. A current-carrying conductor placed in a magnetic field experiences a force. The direction of this force can be determined using Fleming's left-hand rule. This principle is the foundation of electric motors, which convert electrical energy into mechanical energy. In a motor, a current-carrying coil in a magnetic field experiences forces that create a turning effect, causing the coil to rotate.

Note: At the very 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.

Formula Sheet

Sr. #	Formula	Description
1	$F = ILB \sin \theta$	Magnetic force acting on a current-carrying conductor placed in a magnetic field
2	$1\ T = 1\ N\ A^{-1}\ m^{-1}$	Definition of tesla — SI unit of magnetic field (flux density)

Multiple Choice Questions — Exercise

1. Which statement is true about 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

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

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 slip rings

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

5. What does a steady electric current in a conductor generate around it?

(a) Electric field (b) Light (c) Magnetic field (d) Sound waves

6. What happens to the magnetic field direction when the direction of the current is reversed?

(a) remains unchanged (b) also reverses direction (c) becomes stronger (d) disappears

Answer Key

1-d 2-c 3-b 4-b 5-c 6-b

SLO Based Additional MCQs + Past Papers MCQs of Punjab Boards

Magnetic Field Due to Current in a Straight Wire & Solenoid

1. According to the right-hand grip rule for a straight current-carrying wire, the thumb points in the direction of the:

(a) Magnetic field (b) Electric current (c) Force on the wire (d) Compass needle

2. The magnetic field produced by a solenoid resembles that of a:

(a) Straight wire (b) Bar magnet (c) Horseshoe magnet (d) Circular loop

3. To find the north pole of a solenoid using the right-hand rule, the thumb points in the direction of the:

(a) Magnetic field lines (b) Conventional current flow (c) South pole (d) North pole

4. Magnetic field lines around a straight current-carrying wire form:

(a) Straight lines (b) Concentric circles (c) Elliptical loops (d) Parallel lines

Properties of Magnetic Field Lines & Forces Between Conductors

5. Which of the following is NOT a property of magnetic field lines?

(a) They start from the north pole and end at the south pole (b) They form closed loops (c) They can intersect each other (d) They are closer where the field is stronger

6. When two parallel wires carry current in the same direction, they:

(a) Attract each other (b) Repel each other (c) Have no effect on each other (d) Cancel each other's magnetic fields

7. If the current in one of two parallel wires is reversed, the wires will:

(a) Attract each other (b) Repel each other (c) Remain stationary (d) Generate more heat

Force on a Current-Carrying Conductor

8. The force on a current-carrying conductor in a magnetic field is greatest when the conductor is:

(a) Parallel to the field (b) Perpendicular to the field (c) At a 45° angle to the field (d) Outside the field

9. Which factor does NOT increase the force on a current-carrying wire in a magnetic field?

(a) Increasing the current (b) Increasing the wire's length in the field (c) Increasing the wire's temperature (d) Increasing the magnetic field strength

10. According to Fleming's left-hand rule, the forefinger represents the direction of the:

(a) Current (b) Magnetic field (c) Force (d) Motion

Turning Effect & Electric Motors

11. In a current-carrying coil placed in a magnetic field, the turning effect is increased by:

(a) Decreasing the magnetic field strength (b) Decreasing the current (c) Increasing the magnetic field strength (d) Reducing the coil size

12. The purpose of a split-ring commutator in a D.C motor is to:

(a) Increase the magnetic field (b) Reverse the current direction in the coil every half-turn (c) Reduce friction (d) Generate alternating current

13. Without a commutator, the coil in a D.C motor would stop rotating after:

(a) 45° (b) 90° (c) 180° (d) 360°

Relays & Loudspeakers

14. In a relay, the part that moves to open or close the switch is called the:

(a) Coil (b) Core (c) Armature (d) Return spring

15. The return spring in a relay functions to:

(a) Amplify the current (b) Reset the armature when current stops (c) Increase the magnetic field (d) Generate sound

16. A loudspeaker converts electrical signals into sound by using:

(a) A stationary coil and moving magnet (b) A moving coil in a permanent magnetic field (c) A rotating commutator (d) An electromagnetic relay

Earth's Magnetic Field

17. The Earth's magnetic field is believed to be generated primarily by the:

(a) Movement of charged particles in the molten outer core (b) Earth's solid crust (c) Atmospheric currents (d) Sun's radiation

18. The protective region around Earth formed by its magnetic field is called the:

(a) Atmosphere (b) Hydrosphere (c) Magnetosphere (d) Ionosphere

Answer Key

1-b 2-b 3-d 4-b 5-c 6-a 7-b 8-b 9-c 10-b 11-c 12-b 13-b 14-c 15-b 16-b 17-a 18-c

Exercise Short 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 around the conductor.

The direction of the magnetic field can be determined using the 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. If the current changes direction, the direction of the magnetic field also changes.

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

Ans. The magnetic field becomes stronger when the magnitude of the current in a wire is increased.

Explanation: The strength of the magnetic field around a current-carrying wire is directly proportional to the magnitude of the current flowing through it. When the current increases, the magnetic field lines become denser (closer together), indicating a stronger magnetic field.

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

Ans. A magnetic compass can be used to identify the north and south poles of an unmarked magnetized steel bar.

Explanation: When the north pole of a compass is brought near one end of the steel bar and it is repelled, that end is the north pole of the bar. When the north pole of the compass is attracted to the other end, that end is the south pole of the bar. This works because like poles repel and unlike poles attract. The compass needle aligns itself with the magnetic field of the bar magnet.

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

Ans. Fleming's left-hand rule determines the direction of force on a current-carrying conductor placed in a magnetic field.

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. The commutator reverses the direction of current through the coil every half-cycle in a D.C motor.

Explanation: The split-ring commutator is a metal ring divided into two halves, each connected to one end of the coil. As the coil rotates and reaches the vertical position (90°), the commutator also rotates and switches brushes, reversing the current direction. This reversal changes the direction of the forces on the coil sides, preventing it from stopping and allowing continuous rotation. Without the commutator, the coil would stop after half a turn.

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

Ans. The Earth's magnetic field is generated by the rotation of the Earth and its molten iron core that contains charged particles in motion.

Explanation: The Earth has a molten iron-nickel core with a solid inner core and liquid outer core. The movement of liquid metal in the outer core, caused by Earth's rotation and heat from the inner core, creates electric currents through the dynamo effect. These currents produce magnetic fields that combine to form Earth's overall magnetic field, acting like a giant bar magnet with north and south magnetic poles.

SLO Based Additional Short Questions + Past Papers Short Questions of Punjab Boards

Electromagnetism — Basic Concepts

Q.1 What is electromagnetism and how are electricity and magnetism related in it?

Ans. Electromagnetism is the branch of physics that deals with the interaction between electricity and magnetism. It explains how electric charges produce electric fields. It also shows that moving charges, such as electric current, create magnetic fields. Thus, electricity and magnetism are closely connected phenomena.

Magnetic Effects of Steady Current

Q.2 What is meant by magnetic field due to a steady current in a straight conductor?

Ans. A steady electric current in a conductor generates a magnetic field around it. This can be demonstrated by passing a current-carrying wire through a vertical cardboard sheet connected to a battery. When current flows, magnetic field lines form concentric circles around the conductor. The compass needles or iron filings on the cardboard align tangentially to these circular field lines, showing the magnetic effect of the current.

Q.3 What is the dot-and-cross convention used for current direction in magnetic field diagrams?

Ans. In magnetic field diagrams, a dot (•) represents current flowing toward the observer (coming out of the page), while a cross (×) indicates current flowing away from the observer (going into the page). This convention helps visualize the three-dimensional direction of current in two-dimensional diagrams of magnetic field patterns around conductors.

Magnetic Field Patterns

Q.4 What is a solenoid and how does it produce a magnetic field?

Ans. A solenoid is a coil of wire wound in the shape of a cylinder. When current flows through it, a magnetic field is produced. The combined effect of all loops makes the field strong and uniform. The solenoid behaves like a bar magnet.

Q.5 What are the characteristics of the magnetic field produced by a solenoid?

Ans. A solenoid produces a uniform magnetic field inside, like a bar magnet with distinct north and south poles. The field strength is maximum inside and resembles a bar magnet externally. The solenoid acts as an electromagnet whose strength can be controlled by current, making it useful in motors, relays, and magnetic locks.

Q.6 How does the right-hand rule help identify the poles of a solenoid?

Ans. Grip the solenoid with the right hand such that curled fingers point in the direction of conventional current flow through the turns. The thumb points toward the north pole of the solenoid. This rule works because the combined effect of all current loops creates a magnetic field similar to a bar magnet with definite polarity.

Properties of Magnetic Field Lines

Q.7 State any four properties of magnetic field lines with their significance.

Ans. (i) Magnetic field lines form closed loops.

(ii) Magnetic field lines never intersect each other.

(iii) The direction of the magnetic field is given by the tangent to the field line.

(iv) Closer magnetic field lines indicate a stronger magnetic field.

Q.8 Why do magnetic field lines never intersect each other?

Ans. Each magnetic field line has a definite direction at every point. If two lines intersected, there would be two directions at one point. This is not possible for a magnetic field. Therefore, magnetic field lines never cross.

Force on Current-Carrying Conductors

Q.9 What factors affect the magnitude of force on a current-carrying conductor in a magnetic field?

Ans. The force $F = ILB \sin \theta$.

• The magnetic force increases when the electric current through the conductor increases.

• The force also increases if the magnetic field becomes stronger.

• A longer length of conductor in the magnetic field produces a greater force.

• The force is maximum when the conductor is perpendicular to the magnetic field ($\theta = 90°$).

Q.10 Explain Fleming's left-hand rule with its practical application.

Ans. Extend the thumb, forefinger, and middle finger of the left hand at right angles. The forefinger shows the magnetic field, the middle finger shows the current direction, and the thumb shows the force direction. This rule determines the force direction on current-carrying conductors in motors and explains why the force is always perpendicular to both the field and the current.

Turning Effect

Q.11 How can the turning effect on a coil be increased in a motor?

Ans. The turning effect increases by increasing the number of turns in the coil. It also increases by increasing the current through the coil. A stronger magnetic field also increases the turning effect. These factors make motors more powerful.

Applications of Magnetic Effects

Q.12 Describe the basic principle of a relay's operation.

Ans. A relay uses the magnetic effect of current in a coil to control another circuit. When the switch is ON, current through the coil creates a magnetic field attracting the armature, closing the lamp circuit. When the switch is OFF, the return spring resets the armature, opening the lamp circuit. Thus, a small current controls a larger current.

Q.13 How does a loudspeaker convert electrical signals into sound using magnetic effects?

Ans. Alternating audio current in the coil creates a varying magnetic field interacting with the permanent magnetic field. This produces a back-and-forth force on the coil, vibrating the attached diaphragm. Diaphragm vibrations create sound waves matching the electrical signal, used in audio systems and televisions.

Earth's Magnetic Field

Q.14 How is the Earth's magnetic field helpful for life and navigation?

Ans. Earth's magnetic field protects the planet from harmful solar winds. It deflects charged particles and cosmic radiation. It helps humans and animals in navigation. Migratory birds and sea animals use it to find direction.

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. A magnetic field forms around a conductor only when current flows through it because moving charges (current) produce magnetic fields.

Reason: A steady electric current in a conductor generates a magnetic field around it. When current is OFF, there are no moving charges, so no magnetic field is produced. This reveals that electricity (moving charges) and magnetism are interconnected — electric current creates magnetic fields, demonstrating that electromagnetism is a single phenomenon where moving electric charges produce magnetic effects.

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. The coil stops turning after 90° because the forces on its sides become zero when perpendicular to the magnetic field.

Reason: When current flows through the rectangular coil perpendicular to the magnetic field, sides PQ and RS experience equal and opposite forces forming a couple that rotates the coil. After 90° rotation, the coil becomes parallel to the field lines, so the net turning effect drops to zero at that instant. The split-ring commutator solves this by reversing the current direction every half-cycle through rotating brushes, changing force directions and maintaining continuous rotation.

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 is maximum when perpendicular to the magnetic field and zero when parallel.

Reason: The force $F = ILB \sin\theta$, where θ is the angle between current I and magnetic field B. When $\theta = 90°$ (perpendicular), $\sin\theta = 1$, so the force is maximum. When $\theta = 0°$ or $180°$ (parallel), $\sin\theta = 0$, so the force is zero. This is important in motor design because maximum torque occurs when coils are perpendicular to the field. The commutator ensures the coil experiences maximum force by reversing current at optimal angles, maximizing rotation efficiency and power output.

Comprehensive Questions

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

Ans. See Q.1 of theory.

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

Ans. See Q.2 of theory.

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

Ans. See Q.1 of theory.

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 Q.9 of theory.

Important Questions of Board Examination

(i) Describe with the help of an experiment that a magnetic field is produced around a straight current-carrying conductor. Also state the rule by which the direction of lines of force of the magnetic field around such a conductor can be determined.

(ii) Explain force acting on a (a) straight current-carrying conductor placed in a magnetic field — how do we increase the force? (b) State the rule by which the direction of force on current-carrying conductor placed in a magnetic field can be found out. (OR state Fleming's left-hand rule.)

(iii) Explain that a current-carrying coil placed in a magnetic field experiences a torque.

(iv) What is an electric motor? Describe the construction and working of a D.C motor.

(v) Define electromagnetic induction and explain it with the help of a simple activity (experiment) as an example.

(vi) State Faraday's law of electromagnetic induction. Write its mathematical form.

(vii) What is an electric generator? Draw a labelled diagram to illustrate the structure and working of an A.C generator.

Important Short Questions of Board Examination

(i) What is function of split ring commutator and brushes in an electric motor?

(ii) State right hand rule.

(iii) State two properties of magnetic field lines.

(iv) State Fleming's left hand rule.

(v) Upon what factors force acting on current carrying conductor placed in a magnetic fields depends?

(vi) Define Tesla.

(vii) What is function of split ring in D.C motor?

(viii) When the force on current carrying conductor in a magnetic field is: (i) Max (ii) Min

Note: Board-exam questions (v)–(vii) on electromagnetic induction and the A.C generator are drawn from the following chapter and are listed here as printed in the original notes.