# UNIQUE STUDY POINT

## By Sumeet Sahu

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| **Class:** X | **Subject:** Science | **Session:** 2025-26 |
| **Chapter:** 12 - Magnetic Effects of Electric Current | **Time:** 1½ Hours | **Max. Marks:** 40 |

### General Instructions:

1. All questions are compulsory.
2. This question paper contains 20 questions divided into five sections A, B, C, D and E.
3. Section A contains 10 MCQs of 1 mark each.
4. Section B contains 4 questions of 2 marks each.
5. Section C contains 3 questions of 3 marks each.
6. Section D contains 1 question of 5 marks.
7. Section E contains 2 Case Study Based questions of 4 marks each.

## SECTION A - Multiple Choice Questions (1 mark each)

**1.** The north pole of Earth's magnet is located near its:

(a) Geographic North Pole

(b) Geographic South Pole

(c) Equator

(d) Changes with time

**2.** A current-carrying conductor placed perpendicular to a magnetic field experiences:

(a) No force

(b) Minimum force

(c) Maximum force

(d) Force parallel to the field

**3.** The commercial unit of electrical energy is:

(a) Watt

(b) Watt-hour

(c) Kilowatt-hour

(d) Joule

**4.** A proton beam is moving along the direction of a magnetic field. The force on the proton is:

(a) Along the direction of field

(b) Opposite to the direction of field

(c) Perpendicular to the direction of field

(d) Zero

**5.** The device that detects the presence and direction of electric current is:

(a) Ammeter

(b) Voltmeter

(c) Galvanometer
(d) Ohmmeter

**6.** The frequency of AC (Alternating Current) in India is:
(a) 50 Hz
(b) 60 Hz
(c) 100 Hz
(d) 220 Hz

**7.** Which of the following is not attracted by a magnet?
(a) Iron
(b) Nickel
(c) Cobalt
(d) Copper

**8.** The magnetic field lines inside a current-carrying solenoid are in the form of:
(a) Concentric circles
(b) Parallel straight lines
(c) Curved lines
(d) Elliptical lines

**9.** An electric iron draws 5A current when connected to 220V mains. The power consumed is:
(a) 44 W
(b) 440 W
(c) 1100 W
(d) 2200 W

**10.** Magnetic field lines always emerge from:
(a) South pole
(b) North pole
(c) Both poles equally
(d) No specific pole

## SECTION B - Short Answer Questions (2 marks each)

**11.** Explain why a current-carrying conductor kept in a magnetic field experiences a force. What is the direction of this force?

**12.** Why is pure iron not used for making permanent magnets? Name two materials commonly used for making permanent magnets.

**13.** A household uses the following electric appliances: Two tube lights of 40 W each for 6 hours daily, one electric iron of 1000 W for 2 hours daily. Calculate the electricity bill for the month of January at the rate of ₹5 per unit.

**14.** What do you understand by the terms 'magnetic field' and 'magnetic field lines'? How is the direction of magnetic field at a point determined?

## SECTION C - Short Answer Questions (3 marks each)

**15.** Draw a circuit diagram to show how a battery of three cells, a resistor, an ammeter, a voltmeter, and a plug key can be connected to measure the current through the resistor and potential difference across it.

**16.** (a) What is the difference between DC (Direct Current) and AC (Alternating Current)?
(b) Which type of current is supplied to our homes and why?
(c) State one advantage of AC over DC.

**17.** Consider a circular loop of wire lying in the plane of the table. Let the current pass through the loop clockwise. Using right-hand thumb rule, find the direction of magnetic field:

(a) Inside the loop
(b) Outside the loop
(c) At the center of the loop

## SECTION D - Long Answer Question (5 marks)

**18.** (a) With the help of a labeled diagram, describe an activity to demonstrate that a current-carrying conductor experiences a force when placed in a magnetic field.
(b) State the rule used to find the direction of this force.
(c) On what factors does the magnitude of force depend? Write the expression for force when current is perpendicular to the magnetic field.

## SECTION E - Case Study Based Questions (4 marks each)

**19. Case Study 1: Electric Generator (Dynamo)**

Meera's bicycle has a dynamo attached to it that lights up the front and rear lamps when she rides. The dynamo works on the principle of electromagnetic induction - when a coil rotates in a magnetic field, an electric current is induced in it. As the bicycle wheel rotates, it turns the dynamo's coil in the magnetic field, generating electricity. The dynamo produces AC (Alternating Current) which changes direction periodically. The faster Meera rides, the faster the coil rotates, and brighter the lamps glow. When she stops, the rotation stops and the lamps go off as no current is generated.

Based on the above case study, answer the following questions:

(i) What is the principle on which a dynamo (generator) works? (1 mark)
(ii) Why do the lamps glow brighter when the bicycle is ridden faster? (1 mark)
(iii) How is a generator (dynamo) different from an electric motor? Explain the energy conversion in each. (2 marks)

**20. Case Study 2: Safety Measures in Laboratory**

In the school science laboratory, the teacher demonstrated various experiments on electricity and magnetism. She explained that the lab has special safety features: MCBs (Miniature Circuit Breakers) instead of traditional fuses, ELCB (Earth Leakage Circuit Breaker) for protection against electrocution, proper earthing for all equipment, and separate circuits for high-voltage experiments. She emphasized that students should never touch electrical connections with wet hands, should not overload sockets, and must ensure that the earth wire (green) is properly connected before using any equipment with metal body. The teacher also showed how MCBs can be reset after tripping, unlike fuses which need replacement.

Based on the above case study, answer the following questions:

(i) What is the advantage of MCB over traditional fuse? (1 mark)
(ii) Why should we not touch electrical connections with wet hands? (1 mark)
(iii) What is ELCB and how does it protect against electrocution? Explain its working mechanism. (2 marks)

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## DETAILED ANSWER KEY - PAPER 04

## SECTION A - Answers to MCQs

### 1. (b) Geographic South Pole

The north pole of Earth's magnet is located near the geographic South Pole. This is why the north pole of a compass needle (which is attracted to the south pole of a magnet) points towards the geographic North Pole. Earth's magnetic poles and geographic poles are not at the same location.

### 2. (c) Maximum force

When a current-carrying conductor is placed perpendicular to a magnetic field ($\theta = 90°$), it experiences maximum force. This is because $F = BIL \sin \theta$, and $\sin 90° = 1$ (maximum). When parallel, $\theta = 0°$ and $\sin 0° = 0$, so force is zero (minimum).

### 3. (c) Kilowatt-hour

The commercial unit of electrical energy is kilowatt-hour (kWh), also called 'unit'. One kilowatt-hour is the energy consumed when an appliance of 1 kW power is used for 1 hour. 1 kWh = 1000 Wh = $3.6 \times 10^6$ J.

### 4. (d) Zero

When a charged particle (proton) moves parallel to the magnetic field, the angle $\theta = 0°$. The force $F = qvB \sin \theta = qvB \sin 0° = 0$. Therefore, no force acts on the proton. Force is maximum when the particle moves perpendicular to the field.

### 5. (c) Galvanometer

A galvanometer is a device used to detect the presence and direction of electric current in a circuit. It has a magnetic needle that deflects when current passes through it. An ammeter measures current magnitude, while a voltmeter measures potential difference.

### 6. (a) 50 Hz

The frequency of AC (Alternating Current) supplied to homes in India is 50 Hz (cycles per second). This means the current changes its direction 100 times per second. In some countries like USA, the frequency is 60 Hz.

### 7. (d) Copper

Copper is not attracted by a magnet. Iron, Nickel, and Cobalt are ferromagnetic materials that are strongly attracted by magnets. Copper is a diamagnetic material with very weak magnetic properties and is generally considered non-magnetic.

### 8. (b) Parallel straight lines

Inside a current-carrying solenoid, the magnetic field lines are in the form of parallel straight lines. This indicates that the magnetic field inside the solenoid is uniform (same at all points). Outside the solenoid, the field pattern is similar to a bar magnet.

### 9. (c) 1100 W

Power = Voltage × Current
$P = V \times I$
$P = 220V \times 5A$
$P = 1100$ W

Therefore, the electric iron consumes 1100 watts or 1.1 kilowatts of power.

### 10. (b) North pole

By convention, magnetic field lines always emerge from the north pole of a magnet and merge at the south pole outside the magnet. Inside the magnet, they go from south to north, forming closed continuous loops.

## SECTION B - Answers to Short Answer Questions

### 11.

**Why force is experienced:**
A current-carrying conductor produces its own magnetic field around it. When this conductor is placed in an external magnetic field, the two magnetic fields interact with each other. This interaction of magnetic fields produces a force on the conductor. This phenomenon was first suggested by Andre Marie Ampere.

**Direction of force:**
The direction of force is given by Fleming's Left-Hand Rule. According to this rule:
- The force is always perpendicular to both the direction of current and the direction of magnetic field
- If the forefinger points in the direction of magnetic field and middle finger in the direction of current, then the thumb points in the direction of force
- The force is maximum when current and field are perpendicular to each other

### 12.

**Why pure iron is not used for permanent magnets:**
Pure iron is a magnetically soft material. It gets easily magnetized when placed in a magnetic field but also loses its magnetism very quickly when the magnetizing field is removed. For a permanent magnet, we need a material that retains its magnetism for a long time. Therefore, pure iron is not suitable for making permanent magnets.

**Materials used for permanent magnets:**
(i) **Steel:** Steel is an alloy of iron and carbon. It is magnetically hard and retains magnetism for a long time, making it suitable for permanent magnets.
(ii) **Alnico:** This is an alloy of Aluminium, Nickel, and Cobalt. It makes very strong permanent magnets and is widely used in various applications.

### 13.

**Given data:**
- Two tube lights: 40 W each, used for 6 hours daily
- One electric iron: 1000 W, used for 2 hours daily
- Rate: ₹5 per unit
- Month: January (31 days)

**Energy consumed by tube lights:**
Power of two tube lights = 2 × 40 W = 80 W = 0.08 kW
Time used daily = 6 hours
Energy per day = 0.08 kW × 6 h = 0.48 kWh
Energy in January = 0.48 kWh × 31 days = 14.88 kWh

**Energy consumed by electric iron:**
Power = 1000 W = 1 kW

Time used daily = 2 hours
Energy per day = 1 kW × 2 h = 2 kWh
Energy in January = 2 kWh × 31 days = 62 kWh

**Total energy consumed:**
Total energy = 14.88 + 62 = 76.88 kWh ≈ 77 units

**Electricity bill:**
Cost = Total units × Rate per unit
Cost = 77 × ₹5
Cost = ₹385

Therefore, the electricity bill for January is **₹385**.

**14.**

**Magnetic Field:**
Magnetic field is the region around a magnet where its magnetic force can be detected or experienced. Any magnetic material (like iron) or a moving charged particle placed in this region will experience a magnetic force. The strength of magnetic field varies from point to point and is maximum near the poles of the magnet.

**Magnetic Field Lines:**
Magnetic field lines are imaginary lines drawn to represent the magnetic field visually. These are the paths along which a hypothetical free north pole would move if placed in the magnetic field. The density of field lines indicates the strength of the field - where lines are crowded, the field is strong.

**Direction of magnetic field at a point:**
The direction of magnetic field at any point is determined by placing a small compass needle at that point. The direction in which the north pole of the compass needle points gives the direction of the magnetic field at that point. Alternatively, it is given by the tangent to the magnetic field line at that point.

## SECTION C - Answers to Short Answer Questions

**15.**

**Circuit Diagram:**

[The diagram would show:]

**Components arrangement:**
1. Three cells connected in series (positive of one to negative of next)
2. From positive terminal of battery, wire goes to plug key
3. From plug key, wire goes to ammeter (connected in series)
4. From ammeter, wire goes to resistor (R)
5. From resistor, wire returns to negative terminal of battery
6. Voltmeter is connected in parallel across the resistor (one terminal before R, other after R)

**Symbols to be used:**
- Battery (3 cells): Three sets of parallel lines (long and short)
- Plug key: Symbol showing open/closed switch
- Ammeter: Circle with 'A' inside
- Resistor: Rectangular box or zigzag line with 'R'
- Voltmeter: Circle with 'V' inside

- Connecting wires: Straight lines

**Important points:**
- Ammeter is always connected in series with the circuit
- Voltmeter is always connected in parallel across the component
- Positive terminal of ammeter/voltmeter should be connected towards positive of battery
- All connections should be tight and proper

**16.**

**(a) Difference between DC and AC:**

| Direct Current (DC) | Alternating Current (AC) |
|---|---|
| Current flows in one direction only | Current reverses direction periodically |
| Magnitude remains constant with time | Magnitude varies with time (sinusoidal) |
| Produced by batteries, solar cells | Produced by generators (dynamos) |
| Cannot be transmitted over long distances efficiently | Can be transmitted over long distances with less loss |
| Voltage cannot be easily changed | Voltage can be stepped up or down using transformers |

**(b) Type of current supplied to homes:**
AC (Alternating Current) is supplied to our homes at 220V with frequency 50 Hz.

**Reason:**
- AC can be easily generated using generators at power stations
- AC voltage can be stepped up for transmission over long distances, reducing power loss
- At our homes, it can be stepped down to safe 220V using transformers
- This makes AC transmission more economical and efficient than DC

**(c) One advantage of AC over DC:**
The main advantage of AC is that its voltage can be easily stepped up or down using transformers. This allows electricity to be transmitted at high voltage (reducing current and power loss) over long distances and then stepped down to safe voltage for domestic use. This is not easily possible with DC, making AC more suitable for power distribution.

**17.**

**Given:**
- Circular loop lying in the plane of the table
- Current flowing clockwise (when viewed from above)

**Using Right-Hand Thumb Rule:**
Curl the fingers of your right hand in the direction of current flow around the loop. The thumb, when stretched perpendicular to the fingers, points in the direction of magnetic field.

**(a) Direction inside the loop:**
When current flows clockwise (as seen from above the table):
- Curl the fingers of right hand in the clockwise direction
- The thumb points downward (into the table)
- Therefore, magnetic field inside the loop is directed **downward** (perpendicular to the plane of

table, going into it)
- The face of the loop from which field enters (top face) behaves as south pole

**(b) Direction outside the loop:**
Outside the loop, the magnetic field lines complete their path:
- Field lines emerge from the bottom face of the loop (north pole)
- They spread outward, curve around the loop
- Field lines merge back into the top face (south pole)
- The pattern outside is similar to a bar magnet placed vertically

**(c) Direction at the center of loop:**
At the center of the loop, the magnetic field is strongest and directed:
- **Perpendicular to the plane of the loop**
- **Downward** (into the table) when current is clockwise
- All parts of the circular loop contribute to the field at the center in the same direction

**Important Note:**
If the current direction were reversed (anticlockwise), the magnetic field would be upward (out of the table). The direction of field depends on the direction of current as given by the right-hand thumb rule.

## SECTION D - Answer to Long Answer Question

**18.**

**(a) Activity to demonstrate force on current-carrying conductor in magnetic field:**

**Materials required:**
- A small aluminium rod (about 5 cm long)
- Two connecting wires
- A stand to suspend the rod
- A strong horse-shoe magnet
- A battery (6V)
- A plug key
- A rheostat (variable resistance)

**Labeled Diagram:**
[The diagram would show:]
- Aluminium rod AB suspended horizontally by two wires from a stand
- Horse-shoe magnet positioned with rod between its poles
- North pole vertically below the rod, South pole vertically above
- Rod connected in series with battery, rheostat, and plug key
- Magnetic field direction shown by arrow (upward from N to S)
- Current direction shown by arrow (say, from B to A)
- Force/displacement direction shown by arrow (perpendicular to both)

**Procedure:**
1. Suspend the aluminium rod AB horizontally using two connecting wires from a stand
2. Place the horse-shoe magnet such that the rod lies between its poles
3. Position the magnet with north pole vertically below and south pole vertically above the rod
4. This makes the magnetic field direction vertically upward
5. Connect the rod in series with battery, key, and rheostat
6. Close the key to allow current to flow through the rod (say, from B to A)

**Observation:**
- When current flows through the rod, it gets displaced (say, towards left)
- This displacement shows that a force is acting on the rod
- When we reverse the direction of current (now A to B), the rod displaces in opposite direction (towards right)
- When we reverse the magnetic field (interchange magnet poles), the displacement direction again reverses
- Increasing current (by adjusting rheostat) increases the displacement, indicating greater force

**Conclusion:**
A current-carrying conductor placed in a magnetic field experiences a force. The direction of force depends on both the direction of current and the direction of magnetic field.

**(b) Rule to find direction of force - Fleming's Left-Hand Rule:**

**Statement:**
Stretch the thumb, forefinger (first finger), and middle finger (second finger) of your left hand such that they are mutually perpendicular to each other.

- If **forefinger** points in the direction of magnetic **Field**
- And **middle finger** points in the direction of **Current**
- Then **thumb** points in the direction of **Force** (or Motion)

**Application to the activity:**
- Forefinger points upward (direction of magnetic field from N to S)
- Middle finger points from B to A (direction of current)
- Thumb points towards left (direction of force)

This matches our observation that the rod displaces towards left.

**(c) Factors on which magnitude of force depends:**

The magnitude of force on a current-carrying conductor in magnetic field depends on:

**1. Magnetic field strength (B):**
Force is directly proportional to the strength of magnetic field. Stronger field produces greater force. This is why we use a strong horse-shoe magnet in the experiment.
$F \propto B$

**2. Current in the conductor (I):**
Force is directly proportional to the current flowing through the conductor. More current means more force. This can be verified by increasing current using rheostat.
$F \propto I$

**3. Length of conductor (L):**
Force is directly proportional to the length of conductor placed inside the magnetic field. Longer conductor experiences more force.
$F \propto L$

**4. Angle between current and field (θ):**
Force depends on the angle between the direction of current and magnetic field.
$F \propto \sin\theta$
- Maximum force when $\theta = 90°$ (perpendicular), as $\sin 90° = 1$
- Zero force when $\theta = 0°$ (parallel), as $\sin 0° = 0$

**Expression for force when current is perpendicular to magnetic field:**

When the conductor is placed perpendicular to the magnetic field ($\theta = 90°$):

**$F = B \times I \times L$**

Where:
- F = Force on the conductor (in Newton, N)
- B = Magnetic field strength (in Tesla, T)
- I = Current through the conductor (in Ampere, A)
- L = Length of conductor in the field (in meter, m)

Since $\sin 90° = 1$, the general formula $F = BIL \sin\theta$ becomes $F = BIL$ for perpendicular orientation.

This is the maximum force possible for given values of B, I, and L.

## SECTION E - Answers to Case Study Based Questions

**19.**

**(i) Principle of dynamo (generator):** (1 mark)
A dynamo or electric generator works on the principle of **electromagnetic induction**. According to this principle, when a conductor (or coil) moves in a magnetic field or when the magnetic field around a conductor changes, an electric current is induced in the conductor. In the dynamo, as the coil rotates in the magnetic field, the magnetic flux through the coil changes continuously, inducing current in the coil.

**(ii) Why lamps glow brighter when bicycle is ridden faster:** (1 mark)
The lamps glow brighter when the bicycle is ridden faster because:
- When Meera rides faster, the bicycle wheel rotates faster
- This makes the dynamo's coil rotate faster in the magnetic field
- The rate of change of magnetic flux through the coil increases
- According to Faraday's law of electromagnetic induction, the induced voltage (and current) is proportional to the rate of change of flux
- More current flows through the lamps, making them glow brighter
- Conversely, when she rides slowly, less current is generated and lamps glow dimly

**(iii) Difference between generator and motor - Energy conversion:** (2 marks)

**How generator differs from motor:**

| Generator (Dynamo) | Electric Motor |
|---|---|
| Converts mechanical energy to electrical energy | Converts electrical energy to mechanical energy |
| Works on principle of electromagnetic induction | Works on principle of magnetic force on current-carrying conductor |
| Coil is rotated mechanically (by external force) | Coil rotates due to magnetic force when current flows |
| Produces electric current (output) | Uses electric current (input) |
| External mechanical energy is required | Produces mechanical motion as output |

**Energy conversion in Generator:**
- Input: Mechanical energy (rotation of bicycle wheel)
- Process: Coil rotates in magnetic field → magnetic flux changes → current is induced
- Output: Electrical energy (current to light the lamps)
- Example in Meera's bicycle: Kinetic energy of rotation → Electrical energy for lamps

**Energy conversion in Motor:**
- Input: Electrical energy (current from battery or mains)
- Process: Current flows through coil in magnetic field → force acts on coil → coil rotates
- Output: Mechanical energy (rotation)
- Example: Electric fan converts electrical energy into rotational motion of blades

**Key point:**
Generator and motor are reverse processes of each other. The same device can work as both - if you rotate the coil mechanically, it acts as generator; if you supply current to it, it acts as motor. However, their designs are optimized for their specific purposes.

**20.**

**(i) Advantage of MCB over traditional fuse:** (1 mark)
The main advantages of MCB (Miniature Circuit Breaker) over traditional fuse are:
- MCB can be easily reset by switching it back on after the fault is removed, whereas a fuse wire needs to be replaced with a new one after it melts
- MCB is more convenient and saves time and cost of replacement
- MCB trips automatically when overload or short circuit occurs, and the tripping is more precise based on current rating
- MCB provides better protection as it operates faster than a fuse
- MCB can be used as a switch to manually disconnect supply when needed

**(ii) Why not touch electrical connections with wet hands:** (1 mark)
We should never touch electrical connections with wet hands because:
- Pure water is a poor conductor, but the water we use contains dissolved salts and minerals
- This impure water is a good conductor of electricity
- When hands are wet, our body's resistance decreases drastically (from ~1000Ω to ~100Ω or even less)
- This allows a larger current to flow through our body if we touch a live connection
- Even 0.05 A (50 mA) current through human body can be fatal
- With wet hands, dangerous current can flow through our body, causing severe electric shock or even death

**(iii) ELCB and its protection mechanism:** (2 marks)

**What is ELCB:**
ELCB stands for **Earth Leakage Circuit Breaker**. It is a safety device that protects people from electric shocks due to earth leakage (when current leaks to earth through an unintended path, like through a person's body).

**Working mechanism of ELCB:**

**Normal operation:**
- In a properly working circuit, the current flowing through the live wire equals the current returning through the neutral wire
- ELCB continuously monitors and compares the current in live wire and neutral wire
- When both are equal, the ELCB remains in the 'on' position

**When earth leakage occurs:**

**Step 1 - Leakage detection:**
- If someone touches a faulty appliance or live wire, current starts flowing through their body to the earth
- This creates an imbalance: Current in live wire > Current in neutral wire
- The difference is the leakage current flowing through the person's body

**Step 2 - Sensing:**
- ELCB has a sensing coil that detects this difference in currents
- It uses a differential current transformer that monitors the difference between live and neutral currents
- When this difference exceeds a preset value (typically 30 mA for domestic use), the ELCB detects it

**Step 3 - Tripping:**
- Within milliseconds (typically 30-40 milliseconds) of detecting the leakage
- ELCB automatically trips and disconnects the power supply
- This happens so fast that the person receives only a mild shock, not a fatal one

**How it protects against electrocution:**

**Protection mechanism:**
- ELCB detects even small leakage currents (as low as 30 mA) that can be dangerous
- It responds much faster than a regular fuse or MCB, which only operate when very large currents flow
- Regular fuses/MCBs protect equipment from overload/short circuit; ELCB protects human life
- Even if earthing fails, ELCB still provides protection by detecting the leakage

**Example scenario in the laboratory:**
- If a student accidentally touches the live part of equipment with faulty insulation
- Current starts flowing through student's body to earth (say 50 mA)
- ELCB detects this imbalance (50 mA difference between live and neutral)
- ELCB trips within 30 ms, cutting off power
- Student receives only a brief, mild shock instead of potentially fatal electrocution

**Important specifications:**
- Residential ELCB: 30 mA sensitivity, 30-40 ms tripping time
- Industrial ELCB: 100-300 mA sensitivity
- Must be tested regularly using the 'test' button on the ELCB

**Difference from regular MCB:**
- MCB protects against overcurrent (several amperes)
- ELCB protects against leakage current (milliamperes)
- ELCB is specifically designed for human safety
- Both are important and work together in modern electrical installations

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