Part – 1: Introduction, Bar Magnet, Magnetic Dipole & Magnetic Field Lines

Learning Objectives

After studying this part, students will be able to:

- Understand the concept of magnetism.
- Describe the properties of a bar magnet.
- Explain magnetic poles.
- Define magnetic dipole and magnetic dipole moment.
- Understand magnetic field lines and their properties.
- Distinguish between electric dipoles and magnetic dipoles.

5.1 Introduction

Magnetism is a natural phenomenon associated with certain materials that enables them to **attract iron, cobalt and nickel** and to exert forces on moving charges and magnetic materials.
The study of magnetism is important because it forms the basis of many devices such as:

- Electric motors
- Generators
- Loudspeakers
- Transformers
- Magnetic storage devices
- MRI machines
- Compasses

5.2 Historical Background

Some naturally occurring minerals, known as **lodestones (magnetite, Fe_3O_4)**, were found to attract small pieces of iron.
These natural magnets led to the development of artificial magnets and modern magnetic devices.

5.3 What is a Magnet?

A **magnet** is a material that produces a magnetic field and attracts magnetic substances such as iron, cobalt and nickel.
Every magnet has two poles:

- North Pole (N)
- South Pole (S)

5.4 Types of Magnets

(A) Natural Magnets

Examples:

- Lodestone (Magnetite)

(B) Artificial Magnets
Examples:
- Bar magnet
- Horseshoe magnet
- Cylindrical magnet
- Ring magnet
- Disc magnet

5.5 Properties of Magnets

Property 1
A freely suspended magnet always aligns itself approximately along the **North–South direction**.

Property 2
Like poles repel each other.
Unlike poles attract each other.

Property 3
Magnetic poles always exist in pairs.
A single magnetic pole (magnetic monopole) has **not been observed** experimentally.

Property 4
The magnetic force is strongest near the poles and weakest near the centre of a bar magnet.

Property 5
When a magnet is broken into two pieces, each piece becomes a complete magnet with its own north and south poles.

5.6 Magnetic Poles
The two ends of a magnet where the magnetic effect is strongest are called **magnetic poles**.
They are:
- North Pole (N)
- South Pole (S)

5.7 Pole Strength
Pole strength is the ability of a magnetic pole to exert magnetic force.
Pole strength is a traditional model-based quantity used to represent the strength of an ideal magnetic pole.

SI Unit
Ampere metre (Am)
(Symbolically treated in school-level magnetism; detailed pole-strength models are mainly of historical interest.)

5.8 Magnetic Dipole
A magnetic dipole consists of two equal and opposite magnetic poles separated by a small distance.
A **bar magnet** behaves as a magnetic dipole.

5.9 Magnetic Dipole Moment
The magnetic dipole moment is a vector quantity that measures the strength of a magnet.
It is defined as the product of the pole strength and the magnetic length.

Formula
$$M = m(2l))$$

Where

- m = pole strength
- 2l = magnetic length

For a bar magnet, M = m (2l) in the magnetic-pole model. For a current loop, M = IA.

SI Unit: A m^2

Direction
The magnetic dipole moment is directed **from the South Pole to the North Pole inside the magnet**.

5.10 Magnetic Length and Geometrical Length
For a bar magnet,

- Geometrical Length = Actual physical length
- Magnetic Length = Distance between the effective magnetic poles

Approximately,
For a typical bar magnet, the magnetic length is approximately 0.84 times its geometrical length. This is an approximate relation and depends on the magnet's shape and magnetisation.

Formula
$$\boxed{Magnetic\ Length = 0.84 \times Geometrical\ Length}$$

5.11 Magnetic Field
A magnetic field is the region around a magnet or a current-carrying conductor where magnetic effects can be experienced.
The SI unit of magnetic field is
Tesla (T).

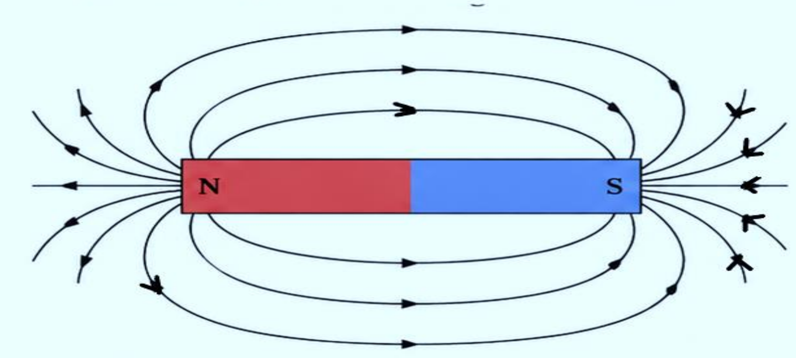
5.12 Magnetic Field Lines
Magnetic field lines are imaginary curves drawn so that the tangent at any point gives the direction of the magnetic field at that point.

Properties of Magnetic Field Lines

Property 1
Outside a magnet, field lines emerge from the **North Pole** and enter the **South Pole**.

Property 2
Inside the magnet, they travel from **South Pole to North Pole**, forming **closed loops**.
Property 3
No two magnetic field lines intersect.
Property 4
Closer field lines indicate a stronger magnetic field.
Property 5
Field lines are crowded near the poles and farther apart near the middle of the magnet.

Figure-2: Magnetic Field Lines around a bar Magnet



In the absence of magnetic monopoles, magnetic field lines form continuous closed loops
Note: No isolated magnetic monopole has been experimentally observed so far.

5.13 Comparison: Electric Dipole vs Magnetic Dipole

Electric Dipole	Magnetic Dipole
Two equal and opposite charges	Two opposite magnetic poles
Electric field lines begin on + and end on −	Magnetic field lines form closed loops
Isolated electric charges exist	Isolated magnetic poles have not been observed
Dipole moment: p = q(2a)	Dipole moment: M = m(2l)

Solved Example 1
A bar magnet has a pole strength of **4 Am** and a magnetic length of **8 cm**. Calculate its magnetic dipole moment.
Given
- m = 4 Am
- 2 l = 8 cm
Solution
Using
$$M = m(2l)$$
Hence,
$$\boldsymbol{M = (4)(0.08) = 0.32\ Am^2}$$
Answer: 0.32 Am^2

Solved Example 2

The geometrical length of a magnet is **10 cm**. Find its magnetic length.

Solution

Using

```
Magnetic Length = 0.84 × Geometrical Length
```

Hence,

$$Magnetic\ Length = 0.84 \times 10 = 8.4\ cm$$

Answer: 8.4 cm

Exam Tips

- Remember that **magnetic field lines always form closed loops**.
- The magnetic dipole moment is directed from **South to North inside the magnet**.
- Do not confuse **magnetic length** with **geometrical length**.
- Questions comparing electric and magnetic dipoles are common in Board and NEET examinations.

Common Mistakes

□ Writing the direction of magnetic dipole moment incorrectly.
□ Assuming magnetic field lines start or end in empty space.
□ Using geometrical length instead of magnetic length in numerical problems.
□ Forgetting to convert centimetres into metres.

JEE Insight (Beyond NCERT)

1. Why Don't Magnetic Monopoles Exist?

According to all current experimental evidence, magnets always have **both a north pole and a south pole**. If a bar magnet is cut into smaller pieces, each piece still has two poles. Although some modern theoretical models predict magnetic monopoles, **no magnetic monopole has been experimentally confirmed** so far.

2. Why Are Magnetic Field Lines Closed?

Unlike electric charges, which can exist independently as positive or negative charges, isolated magnetic poles have not been observed. Therefore, magnetic field lines **never start or end**; they always form **continuous closed loops**.

5.14 Potential Energy Stored in Dipole

$$U = -MB\cos\theta$$

5.15 Work done to rotate a dipole

Let a dipole is rotated from angle θ_1 to angle $\theta_2$in the uniform magnetic field. Then,

Potential energy at θ_1

$$U_1 = -MB\cos\theta_1 - - - (1)$$

Potential energy at θ_2

$$U_2 = -MB\cos\theta_2 - - - (2)$$

Now,
Work done by conservative force

$$W = -\Delta U = U_i - U_f = U_1 - U_2 - - - (3)$$

Therefore,

$$\boxed{W = MB(\cos\theta_2 - \cos\theta_1)}$$

Similarly,
Work done against the conservative force,

$$W = \Delta U = U_f - U_i = U_2 - U_1 - - - - (4)$$

Therefore,

$$\boxed{W = MB(\cos\theta_1 - \cos\theta_2)}$$

5.16Torque on Magnet

$$\boxed{\tau = MB\sin\theta}$$

Solved Example-1

A bar magnet of dipole moment M is rotated in the uniform magnetic field B from unstable equilibrium position to stable equilibrium position. Find the work done.

Solution

Since, potential energy is

$$U = -MB\cos\theta$$

Given, $\theta_i = 180^0$ in unstable equilibrium; $\theta_f = 0^0$ in stable equilibrium

Since, by external agent, work done is

$$W = MB\left(\cos\theta_i - \cos\theta_f\right)$$

Therefore,

$$W = MB(\cos 180^0 - \cos 0^0) = MB(-1-1) = -2MB$$

Answer: $\boxed{W_{ext} = -2MB}$ -2MB by external agent (quasistatic work)

By Magnetic field,

$\boxed{W_{magnetic} = +2MB}$

Solve Example-2

A bar magnet of length 5 cm and magnetic dipole moment 0.5 Am^2 is along the uniform magnetic field of magnitude 0.01 T. Determine the

- Torque and
- Pole strength, and
- Potential energy stored

Solution

Given,

2l = 5 cm = $5 \times 10^{2} m$, M = 0.5 Am^2, B = 0.01 T, $\theta = 0^0$, then

(i) Torque on magnet

$$\tau = MB\sin\theta = MB\sin 0^0 = 0$$

Answer: 0

(ii) Pole strength

Since,

$$M = m(2l)$$

Or

$$m = \frac{M}{2l} = \frac{0.5}{5 \times 10^{-2}} = 10\ Am$$

Answer: 10 Am

(iii) Potential Energy stored

Since,

$$U = -MB\cos\theta = -(0.5)(0.01) \times \cos 0^0 = -5 \times 10^{-3} J$$

Answer: -5 mJ

Part – 2: Bar Magnet as an Equivalent Solenoid & Magnetic Field due to a Bar Magnet

Learning Objectives

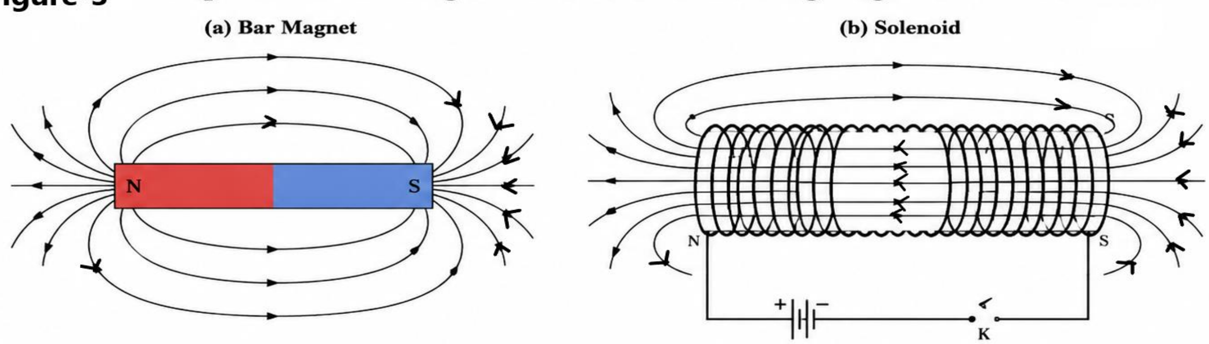
After studying this part, students will be able to:

- Explain why a bar magnet behaves like a solenoid.
- Understand the magnetic field produced by a bar magnet.
- Derive the magnetic field at axial and equatorial positions.
- Compare the magnetic field of a bar magnet with that of an electric dipole.
- Solve Board, NEET and JEE numerical problems.

5.17 Bar Magnet as an Equivalent Solenoid

According to **Ampere's Molecular Current Hypothesis**, tiny circulating currents exist inside magnetic materials. As a result, a bar magnet behaves like a **large number of closely wound current loops**, i.e., a **solenoid**.
Therefore, a bar magnet and a current-carrying solenoid produce **similar magnetic field patterns**.

Figure-3 **Comparison of Bar Magnet and a Solenoid Showing Magnetic Field Lines**



Magnetic field lines emerge from North pole (N) and enter South pole (S) outside the magnet. Inside the magnet, they go from S to N.

Magnetic field lines are similar to a bar magnet. Inside the solenoid, field lines are straight, parallel and closely spaced.

Important Conclusion

- A current-carrying solenoid behaves like a bar magnet.
- A bar magnet can be considered equivalent to a solenoid carrying current.

5.18 Similarities between a Bar Magnet and a Solenoid

Bar Magnet	Solenoid
Has North and South poles	Has North and South poles
Produces magnetic field	Produces magnetic field
Field lines form closed loops	Field lines form closed loops
Strong field at poles	Strong field at ends
Magnetic dipole moment	Magnetic dipole moment

5.19 Magnetic Field due to a Bar Magnet

A bar magnet behaves as a **magnetic dipole**.
The magnetic field depends on:

- Magnetic dipole moment (M)
- Distance from the centre (r)
- Position of the observation point
- Magnetic length 2l

The two important positions are:

1. Axial Position
2. Equatorial Position

5.20 Magnetic Field at an Axial Point

An **axial point** lies on the axis of the bar magnet.

Formula

$$B_{axial} = \frac{\mu_0}{4\pi}\left(\frac{2M}{r^3}\right)$$

Where

- M = magnetic dipole moment
- r = distance from the centre

When, $r \gg l$

Direction

The magnetic field is in the **same direction as the magnetic dipole moment**.

5.21 Magnetic Field at an Equatorial Point

An equatorial point lies on the **perpendicular bisector** of the magnet.

Formula

$$B_{equatorial} = \frac{\mu_0}{4\pi}\left(\frac{M}{r^3}\right)$$

When, $r \gg l$

Direction

The magnetic field is **opposite to the magnetic dipole moment**.

5.22 Comparison of Axial and Equatorial Fields

Axial Position	Equatorial Position
$B_{axial} = \frac{\mu_0}{4\pi}\left(\frac{2M}{r^3}\right)$	$B_{axial} = \frac{\mu_0}{4\pi}\left(\frac{2M}{r^3}\right)$
Along dipole moment	Opposite to dipole moment
Stronger field	Weaker field

Hence,

$$B_{axial} = 2B_{equatorial}$$

5.23 Variation of Magnetic Field with Distance

Both axial and equatorial magnetic fields vary as

$$\boldsymbol{B \propto \frac{1}{r^3}}$$

Important: This inverse cube law is frequently tested in **NEET** and **JEE**.

5.24 Comparison with Electric Dipole

Electric Dipole	Magnetic Dipole
Dipole moment p = q(2a)	Dipole moment M = m(2l)
Electric field	Magnetic field
Axial field ∝ $2p/r^3$	Axial field ∝ $2M/r^3$
Equatorial field ∝ p/r^3	Equatorial field ∝ M/r^3

Solved Example 1

A bar magnet has a magnetic dipole moment of M = 5 Am^2. Find the magnetic field at an axial point r = 0.20 m. Take $\mu_0 / 4\pi = 10^{-7}$ T m A^{-1}

Solution

Using

$$B_{axial} = \frac{\mu_0}{4\pi}\left(\frac{2M}{r^3}\right)$$

Hence,

$$B_{axial} = 10^{-7} \times 2 \times \frac{5}{(0.2)^3} = 1.25 \times 10^{-4}T$$

Answer

1.25×10^{-4} T

Solved Example 2

The magnetic field at the equatorial point of a magnet is 2×10^{-5} T. Find the magnetic field at the axial point at the same distance.

Solution

Since

$$B_{axial} = 2B_{equatorial}$$

Hence

$$B_{axial} = 2 \times 2 \times 10^{-5} = 4 \times 10^{-5}T$$

Answer

$4 \times 10^{-5}T$

Exam Tips

- Remember that the axial field is **twice** the equatorial field at the same distance.
- Both fields decrease as **$1/r^3$**
- Always specify the **direction** of the magnetic field in theory questions.
- The analogy between a **bar magnet** and a **solenoid** is a favourite conceptual question.

Common Mistakes

 Using the axial formula for an equatorial point.
 Forgetting that the equatorial field is opposite to the dipole moment.
 Confusing magnetic dipole moment with pole strength.
 Ignoring SI units while solving numerical.

JEE Insight (Beyond NCERT)

1. Why is the Axial Field Twice the Equatorial Field?

The magnetic field of a dipole has different vector components along different directions. On the axis, these components add to produce a field that is exactly **twice** the field at the equatorial position (for the same distance from the centre).

2. Validity of the Dipole Formula

The formulas

$$B_{axial} = \frac{\mu_0}{4\pi}\left(\frac{2M}{r^3}\right)$$

And

$$B_{equatorial} = \frac{\mu_0}{4\pi}\left(\frac{M}{r^3}\right)$$

are valid only when the observation point is **far from the magnet**, i.e., r ≫ length of the magnet. This approximation is often used in **JEE Advanced** conceptual and numerical problems.

Try Yourself:

1. A short bar magnet has magnetic length 10 cm and pole strength 4 Am. Find the magnetic field at distance 100 cm from the centre of dipole at
   (a) Axial position and
   (b) Equatorial position

   Find also the torque acting in each case.

Part – 3: Definitions of Terms Used and Magnetic Materials

Learning Objectives

After studying this part, students will be able to

- Define magnetisation, magnetic intensity, susceptibility and permeability.
- Classify magnetic materials.
- Solve Board, NEET and JEE numerical and conceptual problems.

5.25 Magnetisation (Intensity of Magnetisation)

Magnetisation is defined as the **magnetic dipole moment per unit volume** of a material.

Formula

$$I = \frac{M}{V}$$

where

- I = intensity of magnetisation
- M = magnetic dipole moment
- V = volume

SI Unit: Am^{-1}

5.26 Magnetic Intensity (Magnetising Field)

Magnetic intensity (H) is the magnetic field produced by external currents that tends to magnetise a material.

Or

Magnetic field intensity or magnetising field H is the magnetic field strength responsible for magnetising a material.

For linear isotropic magnetic material,

$$\boxed{H = \frac{B}{\mu}}$$

SI unit of B is T (tesla) and SI unit of μ is Tm/A

But in magnetised material, more fundamental SI relation: **(JEE enrichment)**

$$\boxed{\vec{B} = \mu_0(\vec{H} + \vec{M})}$$

SI Unit of $\vec{H}$: A m^{-1}

5.27 Magnetic Susceptibility

Magnetic susceptibility (χ_m) is the ratio of magnetisation to magnetic intensity.

Formula

$$\chi_m = \frac{I}{H}$$

SI Unit: Dimensionless (No unit)

5.28 Magnetic Permeability

Magnetic permeability (μ) indicates how easily magnetic field lines pass through a material.

Formula

$$\mu = \frac{B}{H}$$

SI Unit: H m^{-1} (or equivalently N A^{-2})

5.29 Relative Permeability

Relative permeability is defined as

$$\mu_r = \frac{\mu}{\mu_0}$$

It has **no unit**.

Derive the relation between relative permeability and magnetic susceptibility

To derive: $\mu_r = 1 + \chi_m$

Since,

$$B = \mu_0(H + I)$$

Or

$$\mu H = \mu_0(H + I)$$

Or

$$\mu_0\mu_r = \mu_0\left(1 + \frac{I}{H}\right)$$

Or

$$\mu_r = 1 + \chi_m$$

Hence, for a linear, isotropic magnetic material,

$$\boxed{\mu_r = 1 + \chi_m}$$

5.30 Classification of Magnetic Materials

(A) Diamagnetic Materials

Examples:

- Bismuth
- Copper
- Silver
- Gold
- Water

Properties

- Weakly repelled by a magnetic field.
- Relative permeability is slightly less than 1.
- Susceptibility is small and negative.

(B) Paramagnetic Materials

Examples:

- Aluminium
- Platinum
- Oxygen

Properties

- Weakly attracted by a magnetic field.
- Relative permeability is slightly greater than 1.
- Susceptibility is small and positive.

(C) Ferromagnetic Materials

Examples:

- Iron
- Cobalt
- Nickel
- Steel

Properties

- Strongly attracted by a magnetic field.
- Very high permeability.
- Large positive susceptibility.
- Can retain magnetisation.

Or

Ferromagnetic Materials have very large positive susceptibility and generally high permeability, depending on field and material condition

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5.31 Diamagnetic, Paramagnetic and Ferromagnetic Materials

Property	Diamagnetic	Paramagnetic	Ferromagnetic
Susceptibility (χm)	Small negative	Small positive	Very large positive
Relative Permeability (μ_r)	Slightly less than 1	Slightly greater than 1	Much greater than 1
Attraction by Magnet	Weakly repelled	Weakly attracted	Strongly attracted
Permeability	$\mu < \mu_0$	$\mu > \mu_0$	$\mu \gg \mu_0$
Temperature dependence	susceptibility approximately temperature-independent	Curie law: $\chi_m \propto \frac{1}{T}$	strongly temperature dependent; above Curie temperature it becomes paramagnetic-like
Examples	Copper, Bismuth	Aluminium, Platinum	Iron, Cobalt, Nickel

Note:

Above Curie temperature, Curie-Weiss behaviour:

$$\boxed{\chi = \frac{C}{T - T_C}}$$

Where,

- C= Curie Constant
- T_C = Curie temperature

Solved Example

A magnetic material has

- Magnetisation I = 600 A m−1
- Magnetic intensity H = 200 A m^{-1}.

Find the magnetic susceptibility.

Solution

Using

$$\chi_m = \frac{I}{H}$$

Hence,

$$\chi_m = \frac{600}{200} = 3$$

Answer: χ_m=3

Exam Tips

- Learn the differences between **diamagnetic**, **paramagnetic**, and **ferromagnetic** materials in tabular form.
- Remember that **susceptibility is dimensionless**.
- Questions on **neutral points** are frequently asked in CBSE and NEET.

Common Mistakes

 Confusing magnetisation with magnetic intensity
 Forgetting that diamagnetic substances have **negative susceptibility**
 Assuming all magnetic materials retain magnetism permanently
 Confusing permeability with permittivity (ε)

JEE Insight

- **Ferromagnetic materials** consist of tiny regions called **magnetic domains**. In an unmagnetised specimen, these domains are randomly oriented. On applying an external magnetic field, many domains align, producing strong magnetisation.
- In **diamagnetic materials**, the induced magnetic moment is always **opposite** to the applied magnetic field, which explains their weak repulsion.

Part – 4: Magnetic Domains

Learning Objectives

After studying this part, students will be able to:

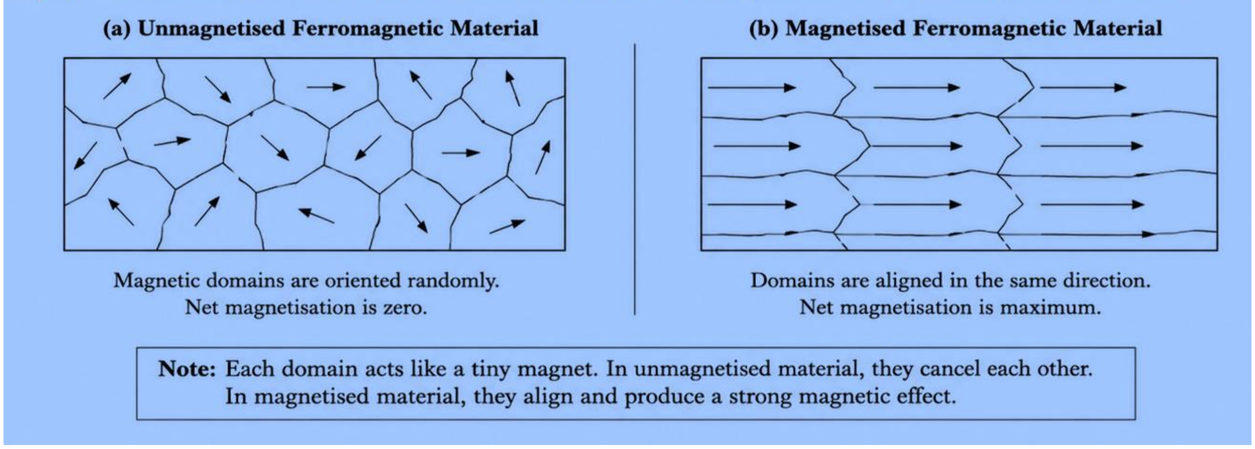
- Understand practical applications of magnetic materials.

5.32 Magnetic Domains

According to **Weiss Domain Theory**, a ferromagnetic material consists of a large number of tiny regions called **magnetic domains**.

- Each domain behaves like a small magnet.
- In an unmagnetised specimen, domains are randomly oriented.
- When an external magnetic field is applied, many domains align in the same direction, causing magnetisation.

Figure-7: Domain Structure in an Unmagnetised and Magnetised Ferromagnetic Material



Key Point

The alignment of domains is responsible for the strong magnetic behaviour of ferromagnetic materials.

Appendix – A: Advanced Concepts, JEE Insights & Conceptual Notes

A.1 Why Can't an Isolated Magnetic Pole Exist?

Unlike electric charges, magnetic poles **always exist in pairs (North and South)**.
If a bar magnet is cut into two pieces:

- Each piece becomes a smaller magnet.
- Every new magnet again has both North and South poles.

Hence,
Magnetic monopoles have not been observed experimentally.
JEE Insight: According to Maxwell's equations,

$$\nabla \cdot B = 0$$

This means magnetic field lines have no beginning or end; they always form closed loops.

A.2 Why Do Magnetic Field Lines Form Closed Loops?

Magnetic field lines:

- Emerge from the **North Pole** outside the magnet.
- Enter the **South Pole** outside the magnet.
- Continue **inside the magnet from South to North**.

Thus, they form **continuous closed loops**.

A.3 Why is a Solenoid Equivalent to a Bar Magnet?

A current-carrying solenoid produces a magnetic field similar to that of a bar magnet.

Similarities

- North and South poles appear at the ends.
- Magnetic field lines have the same pattern.
- Both possess a magnetic dipole moment.

Applications

- Electromagnets
- Relays
- Electric bells
- Lifting cranes

A.4 Why Does Earth's Magnetic Field Change Slowly?

The Earth's magnetic field is produced by the **geodynamo effect**, arising from the motion of molten iron and nickel in the outer core.
Therefore:

- Magnetic poles slowly shift over time.
- Declination and dip change from place to place.
- The magnetic field strength also changes gradually.

A.5 Magnetic Domains
A ferromagnetic material consists of tiny regions called **magnetic domains**.

Before Magnetisation
- Domains are randomly oriented.
- Net magnetic moment is nearly zero.

After Magnetisation
- Most domains align in one direction.
- Strong magnetisation is produced.

Section A: Most Important Numerical
Numerical 1
A magnetic dipole has M = 6 A m^2. Find the magnetic field at an axial point r=0.30 m
Given $\mu_0/4\pi=10^{-7}$ T m A^{-1}
Since,

$$B=\frac{\mu_0}{4\pi}\left(\frac{2M}{r^3}\right)$$

Or,

$$B=10^{-7}\times\frac{2\times 6}{(0.3)^3}=4.44\times 10^{-5}T$$

Answer:
Baxial=4.44×10−5 T

Numerical 2
A material has
- Magnetisation = 800 A m^{-1}
- Magnetic Intensity = 400 A m^{-1}

Find magnetic susceptibility.

$$\chi_m=\frac{I}{H}=\frac{800}{400}=2$$

Answer
χm=2

Numerical 3
The magnetic field at an equatorial point is 5×10^{-5} T. Find the axial field at the same distance.
Since,

$$B_{axial}=2B_{equatorial}$$

Therefore,

$$B_{axial}=2\times 5\times 10^{-5}=1\times 10^{-4}\ T$$

Answer
1×10−4 T

A.6 Frequently Asked Conceptual Questions

Q1. Why do magnetic field lines never intersect?

Answer: At any point, the magnetic field has only one definite direction. If two field lines intersected, the field would have two directions at the same point, which is impossible.

Q2. Why does a magnetic field do no work on a moving charged particle?

Answer: The magnetic force is always perpendicular to the velocity of the particle. Hence, it changes only the direction of motion, not the speed or kinetic energy.

Q3. Why is the Earth's magnetic field weaker than that of a bar magnet near its poles?

Answer: Although the Earth acts like a giant magnet, its magnetic field is spread over a very large volume. Therefore, the magnetic field at the Earth's surface is relatively weak (about 10^{-5} T).

A.7 JEE Advanced Insight

Similarity Between Electric and Magnetic Dipoles

Electric Dipole	Magnetic Dipole
Dipole Moment: p = q(2a)	Dipole Moment: M=m(2l)
Field decreases as 1/r3	Field decreases as 1/r3
Electric field lines begin and end on charges	Magnetic field lines form closed loops

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Common Mistakes Made by Students

Mistake

Using axial field formula at an equatorial point.

✔ Always identify the observation point first.

JEE Advanced Notes

Important Approximation

The formulas for axial and equatorial magnetic fields are applicable when

$$r \gg length\ of\ the\ magnet$$

Students should clearly mention this condition whenever writing derivations.

Domain Theory

Magnetisation occurs due to the alignment of magnetic domains under an external magnetic field.

Appendix – B
Chapter Summary, Mind Map, Memory Tricks

Section A: One-Page Chapter Summary

Magnetism and Matter at a Glance

- A bar magnet behaves like a **magnetic dipole**.
- A current-carrying solenoid produces a magnetic field similar to that of a bar magnet.
- The Earth's magnetic field is approximately dipolar.
- Magnetic field lines always form **closed loops**.
- Magnetic monopoles have not been observed.
- Ferromagnetic materials contain **magnetic domains**.

Section B : Concept Mind Map

```
Magnetism and Matter
│
├── Bar Magnet
│       ├── Magnetic Dipole
│       ├── Magnetic Moment
│       ├── Axial Field
│       └── Equatorial Field
│
├├── Magnetic Materials
│       ├── Diamagnetic
│       ├── Paramagnetic
│       └── Ferromagnetic
│
├── Domains
│
```

Section C: Memory Tricks (Mnemonics)

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1. Diamagnetic Material

Mnemonic: Dia = Dislike Magnet
(Weakly repelled)

---

2. Paramagnetic Material

Mnemonic: Para = Partial Attraction

---

3. Ferromagnetic Material

Mnemonic: Ferro = Forcefully Attracted

Section D: Board Examination Strategy

Before the Exam

✔Learn the standard NCERT/CBSE terminology and understand each definition precisely.

✔ Practice labelled diagrams.

✔ Memorise all important formulas.

✔ Revise derivations:

- Axial field
- Equatorial field

✔ Revise differences:

- Soft Iron vs Steel
- Permanent Magnet vs Electromagnet
- Diamagnetic vs Paramagnetic vs Ferromagnetic

Section E: NEET & JEE Quick Strategy

NEET

Focus on:

- Direct formulas
- Properties of magnetic materials
- Conceptual MCQs

JEE Main

Focus on:

- Mixed numerical problems
- Formula application
- Graph interpretation
- Concept-based questions

JEE Advanced

Focus on:

- Combined concepts
- Approximation conditions
- Domain theory
- Higher-order reasoning
- Multi-step numerical
