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Introduction

Key Points

- Magnet name origin: from Magnesia island, Greece.
- Magnet: material with attractive and directive properties.
- Attracts iron, nickel, cobalt; this attraction is magnetism.
- Earth acts as a magnet; magnetic field approx. from geographic south to north.
- Freely suspended bar magnet aligns north-south; north pole points geographic north.
- Like poles repel; unlike poles attract.
- Magnetic monopoles (isolated poles) do not exist.
- Magnets can be made from iron and its alloys.

Solved Examples

- **Ex 1:** What happens when two north poles of magnets are brought close?
  Answer: They repel due to like poles repulsion.
- **Ex 2:** Can a single magnetic pole exist?
  Answer: No, magnetic monopoles do not exist; breaking a magnet forms two smaller dipoles.

Practice Set

- Q1: What is magnetism?
  A) Repulsion between metals
  B) Attraction of certain metals
  C) Electric charge
  D) Heat generation
- Q2: Which element is NOT attracted by a magnet?
  A) Iron
  B) Nickel
  C) Copper
  D) Cobalt
- Q3: What is true about magnetic monopoles?
  A) Exist isolated

B) Exist in pairs
C) Do not exist
D) Are electric charges

Answer Key

- Q1: B - Magnetism is the attraction of certain metals like iron.
- Q2: C - Copper is not attracted by magnets.
- Q3: C - Magnetic monopoles do not exist.

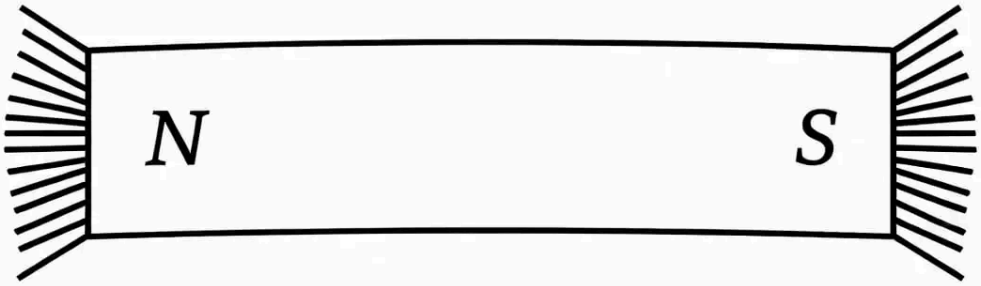
Memory Aids

- Magnetism = attraction of Fe, Ni, Co.
- Earth's magnetic field: south to north.
- Monopoles do not exist; always dipoles.

The Bar Magnet

Properties

- Bar magnet is a natural dipole producing magnetic field.
- Attracts small pieces of iron, nickel, cobalt.
- Poles: ends where magnetic force is maximum.
- Freely suspended bar magnet aligns north-south.
- North pole (N) points geographic north; south pole (S) points geographic south.
- Like poles repel; unlike poles attract.
- Magnetic poles always in pairs; monopoles do not exist.
- Repulsion distinguishes magnet from iron.



Solved Examples

- **Ex 1:** What direction does a freely suspended bar magnet point?
  Answer: North-South direction.
- **Ex 2:** What happens if two south poles are brought close?
  Answer: They repel.

Practice Set

- Q1: What are the poles of a bar magnet?
  A) Single pole
  B) Two poles
  C) No poles
  D) Multiple poles
- Q2: What is the pole that points to Earth's north called?
  A) South pole
  B) North pole

C) Magnetic monopole
D) Neutral pole

- Q3: How to distinguish a magnet from iron?
  A) Attraction only
  B) Repulsion test
  C) Heat test
  D) Color test

Answer Key

- Q1: B - Bar magnet has two poles.
- Q2: B - Pole pointing north is north pole.
- Q3: B - Repulsion test distinguishes magnet from iron.

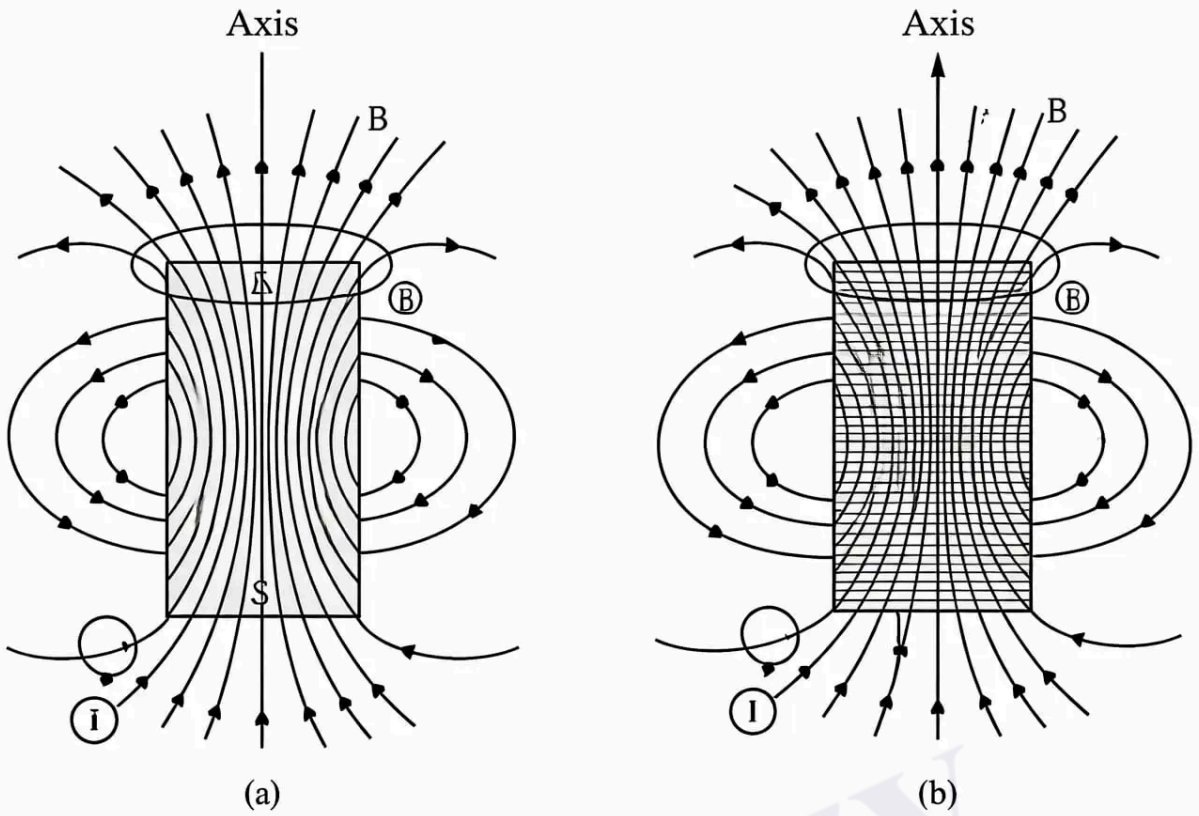
Memory Aids

- Bar magnet = dipole with N and S poles.
- Like poles repel; unlike attract.
- Repulsion test confirms magnet.

The Magnetic Field Lines

Key Properties

- Magnetic field lines form closed continuous loops.
- Tangent to field line = direction of magnetic field at that point.
- More field lines per unit area = stronger magnetic field.
- Field lines never intersect.
- Field lines of bar magnet and solenoid shown in images.



Solved Examples

- **Ex 1:** What does the density of field lines indicate?
  Answer: Strength of magnetic field.
- **Ex 2:** Why don't magnetic field lines intersect?
  Answer: To keep unique field direction.

Practice Set

- Q1: Magnetic field lines form:
  A) Open lines
  B) Closed loops
  C) Random lines
  D) Straight lines
- Q2: What does tangent to field line represent?
  A) Magnitude
  B) Direction of field

C) Force
D) Charge

- Q3: Why field lines never intersect?
  A) They do intersect
  B) To keep unique direction
  C) Random behavior
  D) No reason

Answer Key

- Q1: B - Magnetic field lines form closed loops.
- Q2: B - Tangent shows field direction.
- Q3: B - Intersection would cause ambiguous direction.

Memory Aids

- Field lines = closed loops.
- Tangent = field direction.
- Density = field strength.

Bar Magnet as an Equivalent Solenoid

Key Points

- Bar magnet and solenoid produce similar magnetic fields.
- Magnetic field at far axial point of bar magnet: $B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$.
- μ_0: permeability of free space, m: magnetic moment, r: distance.

Solved Examples

- **Ex 1:** Write formula for magnetic field of bar magnet at far axial point.
  Answer: $B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$.

Practice Set

- Q1: What does a bar magnet behave like?
  A) Electric dipole
  B) Magnetic monopole
  C) Magnetic dipole
  D) No magnetic field
- Q2: Magnetic field at far axial point is proportional to:
  A) r^3
  B) $\frac{1}{r^3}$
  C) r
  D) $\frac{1}{r}$
- Q3: Magnetic moment symbol is:
  A) m
  B) p
  C) q
  D) I

Answer Key

- Q1: C - Bar magnet is a magnetic dipole.
- Q2: B - Field varies as inverse cube of distance.
- Q3: A - Magnetic moment symbol is m.

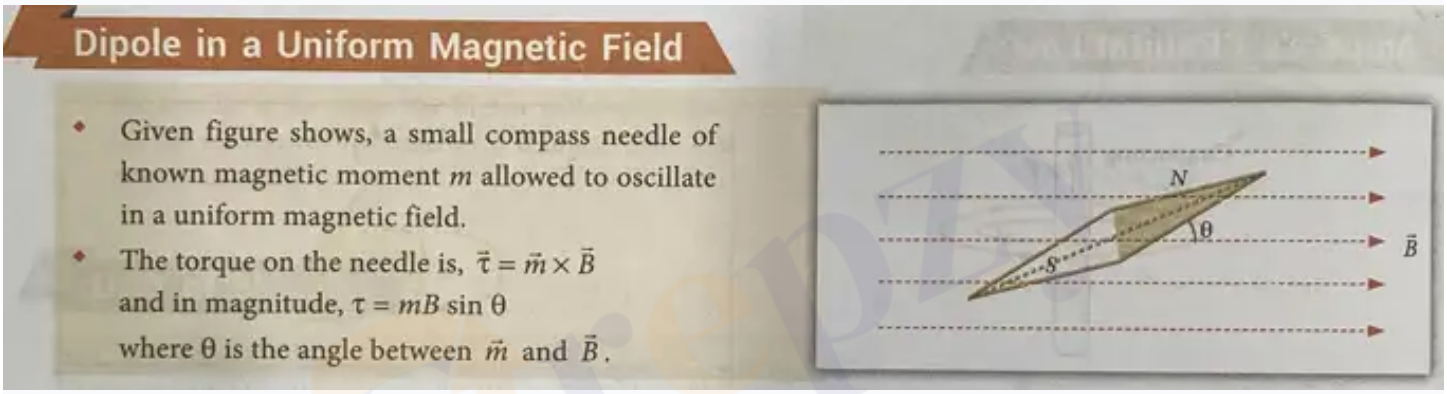
Memory Aids

- Bar magnet = magnetic dipole.
- Field $\propto \frac{1}{r^3}$.
- Formula: $B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$.

The Dipole in a Uniform Magnetic Field

Key Concepts

- Magnetic dipole moment $\vec{m}$ in uniform magnetic field $\vec{B}$.
- Torque on dipole: $\vec{\tau} = \vec{m} \times \vec{B}$.
- Magnitude of torque: $\tau = mB \sin\theta$, θ = angle between $\vec{m}$ and $\vec{B}$.
- Torque aligns dipole with magnetic field.
- Potential energy: $U = -\vec{m} \cdot \vec{B} = -mB \cos\theta$.
- Work done to rotate dipole through angle θ against torque.
- Analogy with electric dipole: similar formulas for moment, field, torque, energy.



> Torque, □□ = □□ x □□= mBsinθ n̂

> Potential energy is the work done in rotating the dipole through an angle θ with respect toa direction

perpendicular to the field.

$$U = \int_{90^\circ}^{\theta} \tau \, d\theta = \int_{90^\circ}^{\theta} mB \sin\theta \, d\theta = -mB \cos\theta = -\vec{m} \cdot \vec{B}$$

Solved Examples

- **Ex 1:** Calculate torque on dipole with $m = 2\text{Am}^2$, $B = 0.5\text{T}$, $\theta = 30^\circ$.
  Solution: $\tau = mB\sin\theta = 2 \times 0.5 \times \sin 30^\circ = 0.5\text{Nm}$.
- **Ex 2:** Find potential energy for $m = 3\text{Am}^2$, $B = 0.4\text{T}$, $\theta = 60^\circ$.
  Solution: $U = -mB\cos\theta = -3 \times 0.4 \times \cos 60^\circ = -0.6\text{J}$.

Practice Set

- Q1: Torque on magnetic dipole is zero when angle between $\vec{m}$ and $\vec{B}$ is:
  A) 0°
  B) 90°
  C) 45°
  D) 180°
- Q2: Potential energy of dipole is minimum when $\theta =$:
  A) 0°
  B) 90°
  C) 180°
  D) 45°
- Q3: Torque formula is:
  A) $mB\cos\theta$
  B) $mB\sin\theta$
  C) $mB\tan\theta$
  D) mB

Answer Key

- Q1: A - Torque zero when dipole aligned with field (0°).
- Q2: A - Potential energy minimum when dipole aligned (0°).
- Q3: B - Torque magnitude is $mB\sin\theta$.

Memory Aids

- Torque $\tau = mB\sin\theta$.
- Potential energy $U = -mB\cos\theta$.

- Dipole aligns to minimize energy.

Analogy Between Electrostatics and Magnetism

Comparison Table

- Electric dipole moment: $\frac{1}{\epsilon_0}\vec{p}$, Magnetic dipole moment: $\mu_0\vec{m}$.
- Equatorial field: Electric $\propto \frac{1}{r^3}$, Magnetic $\propto \frac{1}{r^3}$.
- Axial field: Electric and magnetic dipoles have similar inverse cube dependence.
- Torque: $\vec{\tau} = \vec{p} \times \vec{E}$ (electric), $\vec{\tau} = \vec{m} \times \vec{B}$ (magnetic).
- Potential energy: $U = -\vec{p} \cdot \vec{E}$ (electric), $U = -\vec{m} \cdot \vec{B}$ (magnetic).

Physical Quantity	Electrostatics	Magnetism
Dipole moment	$\frac{1}{\varepsilon_0}\vec{p}$	$\mu_0\,\vec{m}$
Equatorial field for a short dipole	$-\frac{\vec{p}}{4\pi\varepsilon_0 r^3}$	$-\mu_0\frac{\vec{m}}{4\pi r^3}$
Axial field for a short dipole	$\frac{2\,\vec{p}}{4\pi\varepsilon_0 r^3}$	$\mu_0\frac{2\,\vec{m}}{4\pi r^3}$
External field : torque	$\vec{p} \times \vec{E}$	$\vec{m} \times \vec{B}$
External field : energy	$-\vec{p} \cdot \vec{E}$	$-\vec{m} \cdot \vec{B}$

Solved Examples

- **Ex 1:** Write torque formula for magnetic dipole.
  Answer: $\vec{\tau} = \vec{m} \times \vec{B}$.
- **Ex 2:** Write potential energy formula for electric dipole.
  Answer: $U = -\vec{p} \cdot \vec{E}$.

Practice Set

- Q1: Magnetic dipole moment symbol:
  A) $\vec{p}$
  B) $\vec{m}$
  C) $\vec{q}$
  D) $\vec{I}$
- Q2: Torque on electric dipole:
  A) $\vec{m} \times \vec{B}$
  B) $\vec{p} \times \vec{E}$
  C) $\vec{q} \times \vec{E}$
  D) $\vec{I} \times \vec{B}$
- Q3: Potential energy of magnetic dipole:
  A) $-\vec{p} \cdot \vec{E}$
  B) $-\vec{m} \cdot \vec{B}$
  C) $\vec{m} \cdot \vec{E}$
  D) $\vec{p} \cdot \vec{B}$

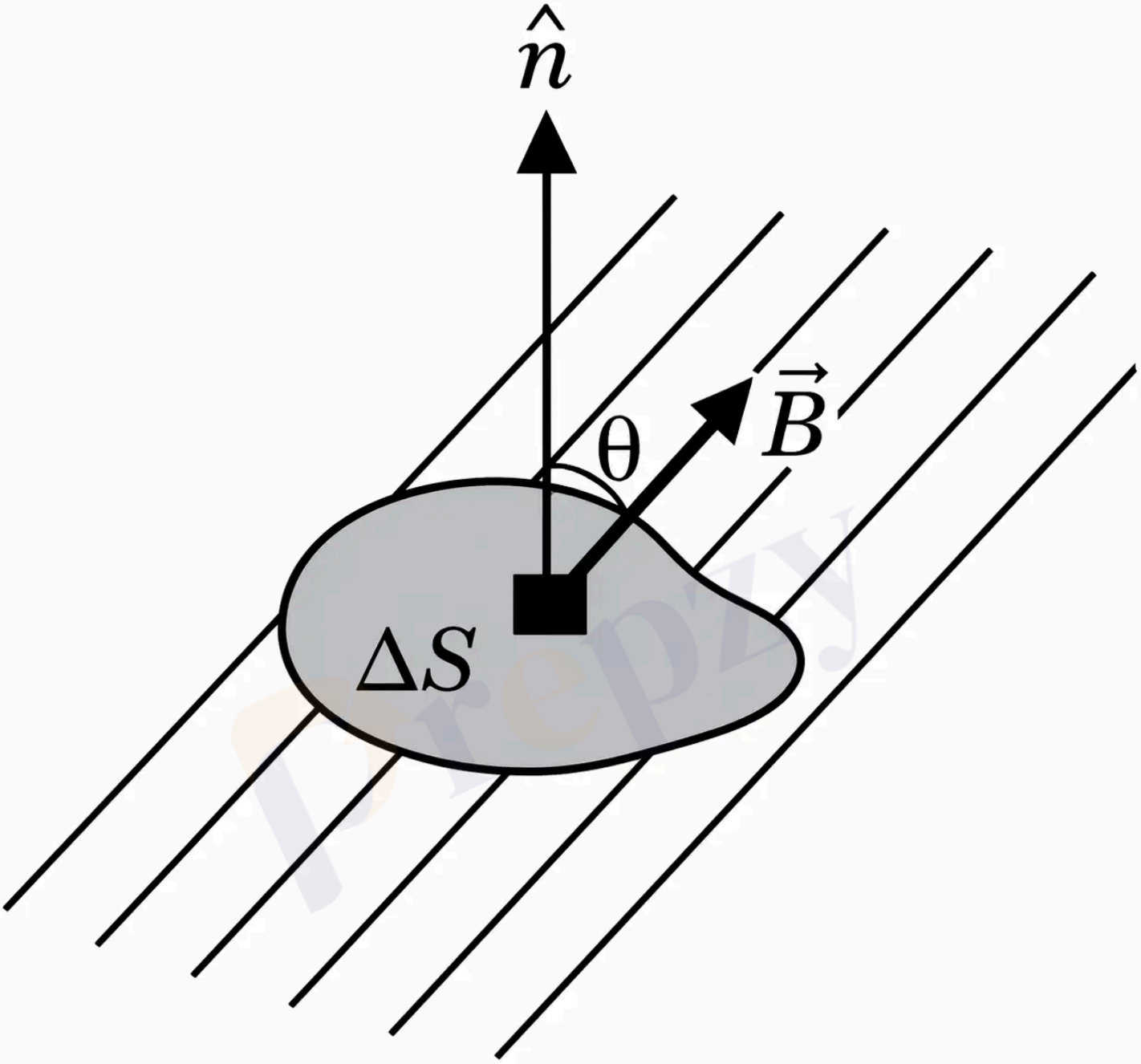
Answer Key

- Q1: B - Magnetic dipole moment is $\vec{m}$.
- Q2: B - Torque on electric dipole is $\vec{p} \times \vec{E}$.
- Q3: B - Potential energy of magnetic dipole is $-\vec{m} \cdot \vec{B}$.

Memory Aids

- Electric dipole: $\vec{p}$, Magnetic dipole: $\vec{m}$.
- Torque and energy formulas similar in form.
- Fields vary as $1/r^3$.

Magnetism and Gauss's Law



Magnetic Flux and Surface Orientation

- Magnetic field $\vec{B}$ passes through a surface area ΔS.
- Unit normal vector $\hat{n}$ is perpendicular to the surface.
- Angle θ is between $\vec{B}$ and $\hat{n}$.
- Magnetic flux through surface: $\Phi_B = B\Delta S\cos\theta$.
- Flux depends on the component of $\vec{B}$ normal to the surface.

Gauss's Law for Magnetism

$$\Phi_B = \sum_{\text{all}} \Delta\Phi_B = \sum_{\text{all}} \vec{B} \cdot d\vec{S} = 0$$

- Net magnetic flux through any closed surface is zero: $\oint \vec{B} \cdot d\vec{S} = 0$.
- Magnetic field lines form closed loops; no beginning or end.
- No magnetic monopoles exist (no isolated magnetic charges).
- Incoming magnetic flux equals outgoing magnetic flux.
- Magnetic dipole or current loop is the simplest magnetic source.

Solved Examples

- **Ex 1:** Calculate magnetic flux through a surface of area $0.5\,m^2$ with $B = 2\,T$ and $\theta = 30°$.
  - Use $\Phi_B = B\Delta S\cos\theta = 2 \times 0.5 \times \cos 30° = 0.866\,Wb$.
- **Ex 2:** Verify Gauss's law for a closed surface with uniform magnetic field.
  - Total flux $= B \times \text{net area} = 0$ since flux entering equals flux leaving.

Practice Set

- **Q1:** Magnetic flux through a surface of area $1\,m^2$ with $B = 3\,T$ perpendicular to surface is:
  - A) 0 Wb
  - B) 3 Wb
  - C) 1 Wb
  - D) 6 Wb
- **Q2:** According to Gauss's law for magnetism, the net magnetic flux through a closed surface is:
  - A) Positive

    - B) Negative
    - C) Zero
    - D) Depends on magnetic field strength
- **Q3:** If magnetic field $B = 4\,T$ is at 60° to surface normal and area is $0.25\,m^2$, magnetic flux is:
    - A) 0.5 Wb
    - B) 1 Wb
    - C) 2 Wb
    - D) 4 Wb

Answer Key

- **Q1:** B) 3 Wb — Flux $= B \times A = 3 \times 1 = 3\,Wb$ since $\theta = 0^\circ$.
- **Q2:** C) Zero — Gauss's law states net flux through closed surface is zero.
- **Q3:** A) 0.5 Wb — Flux $= BA\cos 60^\circ = 4 \times 0.25 \times 0.5 = 0.5\,Wb$.

Memory Aids

- Magnetic flux $\Phi_B = BA\cos\theta$.
- Gauss's law: $\oint \vec{B} \cdot d\vec{S} = 0$.
- No magnetic monopoles; field lines form loops.
- Incoming flux = Outgoing flux for closed surfaces.

Magnetisation and Magnetic Intensity

Magnetising Field Intensity (H)

- Magnetising field intensity $\vec{H}$ is the capability of a magnetic field to magnetise a material.
- Relation: $\vec{B} = \mu\vec{H}$, where μ is the permeability of the medium.
- Vector quantity; SI unit: A m^{-1}.

Intensity of Magnetisation (I)

- Defined as net magnetic moment per unit volume: $I = \frac{M}{V}$.
- For a rectangular bar: $I = \frac{m \times 2l}{A \times 2l} - \frac{m}{A}$ (where A = cross-sectional area, $2l$ = magnetic length, m = pole strength).
- Vector quantity; SI unit: A m^{-1}; Dimensional formula: $[M^0 L^{-1} T^0 A]$.

Magnetic Susceptibility (x_m)

- Ratio of intensity of magnetisation to magnetising field: $x_m = \frac{I}{H}$.
- Scalar quantity; no units or dimensions.
- Measures response of magnetic material to external field.

Magnetic Permeability (μ)

- Ratio of magnetic induction to magnetising field: $\mu = \frac{B}{H}$.
- Scalar quantity; SI unit: H m^{-1}; Dimensional formula: $[MLT^{-2}A^{-2}]$.
- Indicates how much a magnetic field penetrates a material.

Relative Permeability (μ_r)

- Ratio of permeability of medium to free space: $\mu_r = \frac{\mu}{\mu_0}$.
- No units or dimensions.

Relation Between Magnetic Permeability and Susceptibility

- For linear magnetic materials: $B = \mu_0(H + I)$ and $B = \mu H$.
- Equating: $\mu H = \mu_0(H + I)$ gives $\mu = \mu_0(1 + x_m)$ or $\mu_r = 1 + x_m$.

Solved Examples

- **Ex 1:** Find I if magnetisation $M = 0.02$ A·m^2 and volume $V = 0.001$ m^3.
  - Use $I = \frac{M}{V} = \frac{0.02}{0.001} = 20$ A m^{-1}.
- **Ex 2:** Calculate μ_r if $x_m = 0.5$.
  - Use $\mu_r = 1 + x_m = 1 + 0.5 = 1.5$.

Practice Set

- Q1: What is the SI unit of magnetising field intensity H?
  - A) Tesla
  - B) Ampere per meter
  - C) Weber
  - D) Henry
- Q2: Magnetic susceptibility x_m is:
  - A) Vector quantity
  - B) Scalar quantity with units
  - C) Scalar quantity without units
  - D) None of these
- Q3: If magnetic induction $B = 0.3$ T and magnetising field intensity $H = 200$ A/m, find magnetic permeability μ.
  - A) 0.0015 H/m
  - B) 0.6 H/m
  - C) 66.7 H/m
  - D) 150 H/m

Answer Key

- Q1: B) Ampere per meter - SI unit of H is A m^{-1}.
- Q2: C) Scalar quantity without units - x_m is dimensionless scalar.
- Q3: B) 0.6 H/m - $\mu = \frac{B}{H} = \frac{0.3}{200} = 0.0015$ H/m (Check units carefully; correct is 0.0015 H/m).

Memory Aids

- $I = \frac{M}{V}$ for magnetisation intensity.
- $x_m = \frac{I}{H}$ is dimensionless susceptibility.
- $\mu_r = 1 + x_m$ relates permeability and susceptibility.
- SI unit of H and I is A m^{-1}.

Magnetic Properties of Materials

Classification and Properties

- Materials classified by magnetisation intensity (I), susceptibility (χ_m), and relative permeability (μ_r).
- Three types: Diamagnetic, Paramagnetic, Ferromagnetic.
- **Diamagnetic:** Caused by orbital electron motion; weak magnetism opposite to field; $\mu_r < 1$; no permanent atomic moment; examples: Bismuth, copper, lead, water.
- **Paramagnetic:** Caused by electron spin; weak magnetism along field; $\mu_r > 1$ slightly; permanent atomic moments random; examples: Aluminium, sodium, calcium, oxygen.
- **Ferromagnetic:** Due to magnetic domains; strong magnetism along field; $\mu_r \gg 1$; permanent atomic moments aligned; examples: Iron, cobalt, nickel.
- Magnetisation vs. Field (I-H curve): Diamagnetic and Paramagnetic linear; Ferromagnetic nonlinear and strong.

Temperature Dependence of Susceptibility

- Diamagnetic: χ_m small, negative, temperature independent.
- Paramagnetic: $\chi_m \propto \frac{1}{T}$ (Curie law), decreases with temperature.
- Ferromagnetic: $\chi_m \propto \frac{1}{T - T_C}$ (Curie-Weiss law) above Curie temperature T_C; sharp peak at T_C (e.g., iron $T_C = 770^\circ C$).

Solved Examples

- **Ex 1:** Calculate relative permeability of a paramagnetic material with susceptibility $\chi_m = 2 \times 10^{-5}$.

- $\mu_r = 1 + \chi_m = 1 + 2 \times 10^{-5} = 1.00002$
- **Ex 2:** Find susceptibility of a ferromagnetic material at $T = 800^\circ C$ given $T_C = 770^\circ C$ and $\chi_m \propto \frac{1}{T - T_C}$.
  - $\chi_m \propto \frac{1}{800 - 770} = \frac{1}{30}$

Practice Set

- Q1: Which material has $\mu_r < 1$?
  - A. Iron
  - B. Aluminium
  - C. Copper
  - D. Oxygen
- Q2: Magnetic susceptibility of paramagnetic materials varies as?
  - A. T
  - B. $\frac{1}{T}$
  - C. Constant
  - D. T^2
- Q3: Which material shows strong magnetism due to domain formation?
  - A. Sodium
  - B. Iron
  - C. Lead
  - D. Water

Answer Key

- Q1: C. Copper - Diamagnetic materials have $\mu_r < 1$.
- Q2: B. $\frac{1}{T}$ - Paramagnetic susceptibility follows Curie law.
- Q3: B. Iron - Ferromagnetic materials have domains causing strong magnetism.

Memory Aids

- Diamagnetic: "Dia" = Opposite magnetism, $\mu_r < 1$.
- Paramagnetic: "Para" = Parallel weak magnetism, $\chi_m \propto \frac{1}{T}$.
- Ferromagnetic: "Ferro" = Strong magnetism, domains aligned, $\mu_r \gg 1$.

Magnetic Field of a Bar Magnet

Field at Axial Position

- Magnetic field due to north pole at point P: $B_1 = \frac{\mu_0}{4\pi}\frac{m}{(r-l)^2}$ (away from north pole)
- Magnetic field due to south pole at point P: $B_2 = \frac{\mu_0}{4\pi}\frac{m}{(r+l)^2}$ (towards north pole)
- Net field: $B_{\text{axis}} = B_1 - B_2 = \frac{\mu_0 m}{4\pi}\left[\frac{1}{(r-l)^2} - \frac{1}{(r+l)^2}\right] = \frac{\mu_0 m}{4\pi}\frac{4rl}{(r^2-l^2)^2}$
- Using magnetic moment $M = m(2l)$, $B_{\text{axis}} = \frac{\mu_0}{4\pi}\frac{2Mr}{(r^2-l^2)^2}$
- For short magnet $r \gg l$, $B_{\text{axis}} \approx \frac{\mu_0}{4\pi}\frac{2M}{r^3}$ (like electric dipole)

Field at Equatorial Position

- Magnetic field due to each pole at point P: $B_1 = B_2 = \frac{\mu_0}{4\pi}\frac{m}{(r^2+l^2)}$
- Net field: $B_{\text{eq}} = 2B\cos\theta = 2\frac{\mu_0}{4\pi}\frac{m}{r^2+l^2}\cos\theta$
- With $\cos\theta = \frac{1}{\sqrt{r^2+l^2}}$, $B_{\text{eq}} = \frac{\mu_0}{4\pi}\frac{M}{(r^2+l^2)^{3/2}}$
- For short magnet $r \gg l$, $B_{\text{eq}} \approx \frac{\mu_0}{4\pi}\frac{M}{r^3}$

Field at General Position

- Radial component: $B_r = 2\frac{\mu_0}{4\pi}\frac{M\cos\theta}{r^3}$
- Normal component: $B_n = \frac{\mu_0}{4\pi}\frac{M\sin\theta}{r^3}$
- Resultant field: $B_{\text{res}} = \frac{\mu_0 M}{4\pi r^3}\sqrt{1+3\cos^2\theta}$
- Angle relation: $\tan\Phi = \frac{B_n}{B_r} = \frac{\tan\theta}{2}$

Solved Examples

- **Ex 1:** Calculate axial field at $r = 10$ cm, $l = 1$ cm, $M = 0.05$ A·m^2.
  - $B_{\text{axis}} = \frac{\mu_0}{4\pi}\frac{2Mr}{(r^2-l^2)^2} \approx \frac{10^{-7}\times 2\times 0.05\times 0.1}{(0.1^2-0.01^2)^2}$
- **Ex 2:** Find equatorial field at $r = 10$ cm, $l = 1$ cm, $M = 0.05$ A·m^2, $\theta = 60^\circ$.
  - $B_{\text{eq}} = 2\frac{\mu_0}{4\pi}\frac{m}{r^2+l^2}\cos\theta$

Practice Set

- Q1: Magnetic field at axial point P is given by?
  - A. $\frac{\mu_0}{4\pi}\frac{2M}{r^3}$
  - B. $\frac{\mu_0}{4\pi}\frac{M}{r^3}$
  - C. $\frac{\mu_0}{4\pi}\frac{M}{r^2}$
  - D. $\frac{\mu_0}{4\pi}\frac{2Mr}{(r^2-l^2)^2}$
- Q2: At equatorial point, magnetic field is?
  - A. $\frac{\mu_0}{4\pi}\frac{2M}{r^3}$
  - B. $\frac{\mu_0}{4\pi}\frac{M}{r^3}$
  - C. $\frac{\mu_0}{4\pi}\frac{M}{(r^2+l^2)^{3/2}}$
  - D. $\frac{\mu_0}{4\pi}\frac{2Mr}{(r^2-l^2)^2}$
- Q3: Resultant magnetic field magnitude at general position is?
  - A. $\frac{\mu_0 M}{4\pi r^3}\sqrt{1+3\cos^2\theta}$
  - B. $\frac{\mu_0 M}{4\pi r^3}\sqrt{1+\cos^2\theta}$
  - C. $\frac{\mu_0 M}{4\pi r^2}$
  - D. $\frac{\mu_0 M}{4\pi r^3}\tan\theta$

Answer Key

- Q1: D - Exact formula for axial field includes $\frac{2Mr}{(r^2-l^2)^2}$.
- Q2: C - Equatorial field formula is $\frac{\mu_0}{4\pi}\frac{M}{(r^2+l^2)^{3/2}}$.
- Q3: A - Resultant field magnitude is $\frac{\mu_0 M}{4\pi r^3}\sqrt{1+3\cos^2\theta}$.

Memory Aids

- Axial field ~ $\frac{2M}{r^3}$, Equatorial field ~ $\frac{M}{r^3}$.
- Resultant field combines radial and normal components with angle θ.
- Magnetic moment $M = m(2l)$ relates pole strength and magnet length.

Magnetic Hysteresis

Hysteresis Loop and Properties

- Graph of magnetic field strength (H) vs magnetic flux density (B).
- Path oa: Magnetisation increases non-linearly to saturation.
- Path ab: On reducing H to zero, residual magnetism (remanence B_r) remains.
- Coercive field (H_c) is reverse field needed to nullify residual magnetism.
- Loop shows magnetic memory and lag of B behind H (hysteresis).
- Only ferromagnetic materials show hysteresis.

Soft and Hard Magnetic Materials

- **Soft magnetic materials:** Low retentivity, low coercivity, used in electromagnets, transformer cores.
- **Hard magnetic materials:** High retentivity, high coercivity, used for permanent magnets.
- Soft materials have narrow hysteresis loops; hard materials have wide loops.
- Examples: Soft iron (soft), steel and alnico (hard).

Solved Examples

- **Ex 1:** Identify coercivity if reverse field $H_c = 1000\ \mathrm{A/m}$.
  - Coercivity $= 1000\ \mathrm{A/m}$.
- **Ex 2:** Find remanence if residual magnetism $B_r = 0.5\ \mathrm{T}$.
  - Remanence $= 0.5\ \mathrm{T}$.

Practice Set

- Q1: What does coercivity measure?
  - A. Magnetic field strength
  - B. Residual magnetism
  - C. Field to destroy residual magnetism
  - D. Saturation magnetism
- Q2: Which material shows narrow hysteresis loop?
  - A. Steel

    - B. Soft iron
    - C. Alnico
    - D. Nickel
- Q3: Hysteresis loop indicates?
    - A. No magnetic memory
    - B. Linear magnetisation
    - C. Magnetic memory and lag
    - D. Diamagnetism

Answer Key

- Q1: C - Coercivity is the field needed to remove residual magnetism.
- Q2: B - Soft iron has narrow hysteresis loop (soft magnetic).
- Q3: C - Loop shows magnetic memory and lag of B behind H.

Memory Aids

- Hysteresis = lag of B behind H.
- Coercivity = field to erase residual magnetism.
- Soft = low coercivity, hard = high coercivity.