

Magnetism and Matter — Assignment 2

Class 12 Physics · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
(2) Give all answers with correct SI units. $g = 10 \text{ m/s}^2$ unless stated.
(3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Bar Magnet and Magnetic Dipole

1. Derive the magnetic field on the axial line of a short bar magnet.
2. Compare the axial and equatorial fields of a short bar magnet at the same distance.
3. Define magnetic dipole moment and give its SI unit.

Torque and Work on a Magnetic Dipole

1. Derive the torque on a magnetic dipole in a uniform magnetic field.
2. Derive the potential energy of a magnetic dipole and state the equilibrium conditions.
3. A bar magnet of moment $2 \text{ A}\cdot\text{m}^2$ is at 30° to a 0.5 T field. Find the torque on it.

Earth's Magnetism

1. Define magnetic declination and the angle of dip.
2. Derive the relation between the total field and its horizontal and vertical components.
3. At a place $B_H = 0.4 \text{ G}$ and $\delta = 30^\circ$. Find the total field.

Magnetic Properties of Materials

1. Distinguish between diamagnetic, paramagnetic and ferromagnetic materials.
2. Define susceptibility and permeability and relate them.
3. Explain hard vs soft ferromagnetic materials.

Hysteresis

1. Define hysteresis and sketch the hysteresis loop.
2. Explain retentivity and coercivity from the B-H curve.
3. State which material is used for a transformer core and which for a permanent magnet.

Part B — Integrated problems (multi-topic)

1. Two short bar magnets of moments $1.2 \text{ A}\cdot\text{m}^2$ and $0.8 \text{ A}\cdot\text{m}^2$ are placed 0.3 m apart with like poles facing. Find the force between them.
2. A bar magnet of magnetic moment $4 \text{ A}\cdot\text{m}^2$ is freely suspended in a uniform field of 0.25 T . Find the torque when it makes 45° with the field and the work done in rotating it from 0° to 180° .

3. At a place, the vertical component of the earth's field is 0.5 G and the angle of dip is 60° . Find the horizontal component and the total intensity.
4. A magnetic material has a susceptibility of 599. Find its relative permeability and the fractional change in the magnetic field inside it when placed in an external field.
5. The hysteresis loop of a specimen has an area of 100 J/m^3 . Find the energy lost per cycle in a 0.02 m^3 core magnetised 50 times per second.

Answer Key

Bar Magnet and Magnetic Dipole

Axial field $B = \mu_0 2Mr / 4\pi(r^2 - l^2)^2$; for a short magnet $B = \mu_0 2M / 4\pi r^3$. Equatorial field $B = \mu_0 M / 4\pi r^3$. $M = m \times 2l$, SI unit $\text{A}\cdot\text{m}^2$.

Torque and Work on a Magnetic Dipole

$\tau = MB \sin\theta = 2 \times 0.5 \times \sin 30^\circ = 0.5 \text{ N}\cdot\text{m}$. $U = -MB \cos\theta$; minimum (stable) at $\theta = 0$, maximum (unstable) at $\theta = 180^\circ$.

Earth's Magnetism

$B_H = B \cos\delta$, $B_V = B \sin\delta$, $\tan\delta = B_V / B_H$. $B_H = 0.4 \text{ G}$, $\delta = 30^\circ$ $B \approx 0.46 \text{ G}$.

Magnetic Properties of Materials

$\mu_r = 1 + \chi$. Diamagnetic: χ small negative; paramagnetic: χ small positive; ferromagnetic: χ large positive. Hard magnets: wide loop, high coercivity; soft magnets: narrow loop.

Hysteresis

The loop area equals the energy lost per unit volume per cycle. Retentivity = remnant B at $H = 0$; coercivity = reverse H needed to reduce B to zero.

Integrated problems

1: $F = (\mu_0 / 4\pi)(6M_1 M_2 / r^4) \approx 7.1 \times 10^{-6} \text{ N}$. 2: $\tau = MB \sin 45^\circ \approx 0.71 \text{ N}\cdot\text{m}$; $W = 2MB = 2 \text{ N}\cdot\text{m}$. 3: $B_H = B_V / \tan\delta = 0.29 \text{ G}$; $B = B_V / \sin\delta \approx 0.58 \text{ G}$. 4: $\mu_r = 600$; B inside is 600 times larger. 5: Energy/cycle = $100 \times 0.02 = 2 \text{ J}$; per second = 100 W .