Magnetism and Matter

Class 12 · Physics · Quick Revision · **chapternotes.in**

NEET: 1-2 Qs (~4-8 marks) | Boards: 4-6 marks

Scan: practise free

A bar magnet is a magnetic dipole: reuse every electric-dipole result with $p \to m$. Earth is a tilted dipole (declination, dip, B_h), and matter splits into dia/para/ferro by susceptibility χ.

1. Bar Magnet as a Magnetic Dipole

Two equal, opposite poles; monopoles don't exist, so field lines are closed loops.

$$m = (\text{pole strength}) \times 2l$$
unit A·m² ; arrow S→N

$$m = N\,I\,A$$
equivalent solenoid/coil

MUST KNOW Magnetic monopoles do not exist - cut a magnet and each piece is a full dipole again.

MUST KNOW Field lines are continuous closed loops: N→S outside, S→N inside the magnet; they never intersect.

- Pole strength is A·m, magnetic moment is A·m² - different units, don't mix them up.

2. Field of a Dipole & Gauss's Law

Axial and equatorial fields, both $1/r^3$; net magnetic flux through any closed surface is zero.

$$B\_axial = (\mu_0/4\pi)(2m/r^3)$$
end-on; along m

$$B\_equator = (\mu_0/4\pi)(m/r^3)$$
broadside; opposite m

$$B\_axial = 2\ B\_equator$$
same r

$$\Phi = \oint B\cdot dA = 0$$
Gauss's law for magnetism

MUST KNOW Both fields fall as $1/r^3$ (dipole signature) - faster than a pole's $1/r^2$.

MUST KNOW $\Phi = 0$ because field lines are closed loops - no isolated magnetic charge, unlike electric Gauss's law.

- Null point: axis along N-S → nulls on equatorial line; axis along E-W → nulls on axial line.

3. Torque, Energy & Oscillations

A dipole in a uniform field feels only torque (no net force) and oscillates like a pendulum.

$$\tau = m \times B \ (|\tau| = mB \sin\theta)$$
max at 90°, zero at 0°/180°

$$U = -m\cdot B = -mB\cos\theta$$
min −mB at θ=0° (stable)

$$W = mB(\cos\theta_1 - \cos\theta_2)$$
work to rotate

$$T = 2\pi\sqrt{I/mB}$$
I = moment of inertia

MUST KNOW In a UNIFORM field the net force is zero - only torque acts. A net force needs a non-uniform field.

MUST KNOW Torque uses $\sin\theta$, energy uses $\cos\theta$. Stable at $\theta=0°$ ($U=-mB$), unstable at $\theta=180°$ ($U=+mB$).

- $T \propto 1/\sqrt{B}$, so 4× the field halves the period - vibration magnetometer standard.

4. Earth's Magnetism

Earth is a bar magnet tilted ~11.3°; three elements fix the field: declination, dip, horizontal component.

$$B_h = B\_E \cos I$$
horizontal component

$$B\_V = B\_E \sin I$$
vertical component

$$\tan I = B\_V/B_h$$
I = angle of dip

$$B\_E = \sqrt{B_h^2 + B\_V^2}$$
total field

MUST KNOW Earth's magnetic S-pole sits near geographic North - that's why a compass N-end points north.

MUST KNOW Magnetic equator: $I=0°$ → field horizontal, $B\_V=0$, $B_h=B\_E$. Magnetic poles: $I=90°$ → field vertical, $B_h=0$.

- Declination = horizontal angle (true vs magnetic N); dip = vertical tilt. Don't swap them.

5. Magnetisation, H & Susceptibility

Three vectors inside matter: applied H, response M, total B; χ and μ_r measure the response.

$B = \mu_0(H + M)$
total field inside

$M = \chi H$
χ = susceptibility (pure number)

$\mu_r = 1 + \chi$
$\mu = \mu_0\mu_r$

$B = \mu_0\mu_r H = \mu H$
packaged form

MUST KNOW H is the field you apply (A/m); B is the total field inside (tesla). M and H share unit A/m, so χ is dimensionless.

MUST KNOW $\mu_r = 1 + \chi$, NOT $\mu_r = \chi$ - the classic slip.

- χ small −ve → dia; small +ve → para; large +ve → ferro.

6. Dia, Para & Ferromagnetism + Hysteresis

Three classes by χ and temperature behaviour; ferromagnets show domains and a hysteresis loop.

Para: $\chi = C/T$
Curie's law (T in K)

Ferro: $\chi = C/(T - T_c)$
Curie-Weiss, above T_c

Superconductor: $\chi = -1$
perfect diamagnet (Meissner)

MUST KNOW Dia repelled (move to weak field), temperature-independent. Para & ferro attracted (move to strong field).

MUST KNOW Above the Curie temperature a ferromagnet becomes paramagnetic - domains scramble.

- Hysteresis: B lags H; loop area = energy lost per cycle. Soft iron = thin loop (electromagnets); steel = fat loop, high retentivity/coercivity (permanent magnets).

Diamagnetic vs Paramagnetic vs Ferromagnetic

	Diamagnetic	Paramagnetic	Ferromagnetic
In field	Weakly repelled	Weakly attracted	Strongly attracted
χ	Small −ve	Small +ve	Large +ve
μ_r	Slightly < 1	Slightly > 1	≫ 1
vs Temp	Independent	$\chi = C/T$	$\chi = C/(T-T_c)$
Example	Bi, Cu, water	Al, Na, O_2, Pt	Fe, Co, Ni, Gd

Soft vs Hard Magnetic Material

Property	Soft (soft iron)	Hard (steel)
Hysteresis loop	Thin (small area)	Fat (large area)
Retentivity	Low	High
Coercivity	Low	High
Use	Electromagnets, cores	Permanent magnets

Mnemonic - How each class responds in a magnetic field (repelled / weakly attracted / strongly attracted)
Dia = away, Para = pulled, Ferro = fiercely pulled

Common traps

- Axial field is the BIGGER one: $B_{axial} = 2 B_{equator}$. Don't flip the factor of 2.
- Torque uses sinθ ($\tau = mB\sin\theta$); potential energy uses cosθ ($U = -mB\cos\theta$). Swapping them is the classic error.
- $\mu_r = 1 + \chi$, not $\mu_r = \chi$. And χ is dimensionless - it carries no units.
- Curie's law needs ABSOLUTE temperature (kelvin), and a superconductor has $\chi = -1$, not 0.
- Declination is horizontal (true vs magnetic N); dip is the vertical tilt - keep cosI with B_h and sinI with B_V.

Most asked in NEET » Magnetic moment of bent wire/coil (NIA) | Work to rotate dipole $W = mB(\cos\theta_1 - \cos\theta_2)$ | Vibration magnetometer $T \propto 1/\sqrt{B}$ | Dip: $B_h = B_E \cos I$, $\tan I = B_V/B_h$ | Dia/Para/Ferro classification by χ | $\mu_r = 1 + \chi$; $M = \chi H$

Practise this chapter free

10+ real NEET PYQs with worked solutions, flashcards & a gamified app — all free at **chapternotes.in**