Moving Charges and Magnetism

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

NEET: 2-3 Qs (~8-12 marks) | Boards: 6-8 marks

Scan: practise free

A moving charge makes a magnetic field and feels one. Master the Lorentz force, the circle it bends charges into, the field of wires and solenoids, and the torque that runs every meter and motor.

1. Lorentz Force & Circular Motion

A moving charge in B feels a sideways force that bends it into a circle but does no work.

$F = qvB \sin\theta$
θ = angle between v and B

$F = qv \times B$
always ⊥ to v and B

$F = BIL \sin\theta$
force on a current-carrying wire

$r = mv/(qB) = p/(qB)$
radius of circular path

$T = 2\pi m/(qB)$, $f = qB/(2\pi m)$
independent of v and r

MUST KNOW Magnetic force is always ⊥ to velocity, so it does NO work: speed and KE never change, only direction.

MUST KNOW Force is max (qvB) when v ⊥ B and zero when v ∥ B. A stationary charge feels no magnetic force.

- $r = \sqrt{2mK}/(qB)$, so $r \propto \sqrt{K}$. If KE becomes 4× then r becomes 2×.

2. Helical Path & the Cyclotron

An angled entry gives a helix; the speed-independent period powers the cyclotron.

pitch = $v_\parallel T = v \cos\theta \cdot 2\pi m/(qB)$
advance per revolution

$f = qB/(2\pi m)$
cyclotron frequency

$K(max) = q^2B^2R^2/(2m)$
R = dee radius

MUST KNOW Period T is independent of speed and radius: a fast particle on a big circle takes the same time as a slow one on a small circle. This is why the cyclotron works.

- Velocity along B is unaffected, so v at an angle to B traces a helix (circle + steady drift).
- Cyclotron cannot accelerate electrons (too light, relativistic) or neutral particles.

3. Biot-Savart Law & Field of a Wire

Every current element sprays a field; summed for a long wire it falls off as 1/a.

$dB = (\mu_0/4\pi) \cdot I\, dl \sin\theta/r^2$
$\mu_0/4\pi = 10^{-7}$ T·m/A

$B = \mu_0 I/(2\pi a)$
long straight wire, $B \propto 1/a$

$B = \mu_0 Ir/(2\pi a^2)$
inside a solid wire, r < a

MUST KNOW The single element field goes as $1/r^2$, but the long straight wire field goes as 1/a. Don't mix them up.

- Field wraps around the wire in circles (right-hand grip rule); it is zero straight off the element's tip.
- $\mu_0/4\pi = 10^{-7}$ but $\mu_0/2\pi = 2\times10^{-7}$. A constant slip is the classic numerical error.

4. Ampere's Law, Loops & Solenoids

For symmetric currents, the loop integral of B gives the field in one line.

$\oint B \cdot dl = \mu_0 I(enc)$
only enclosed current counts

$B = \mu_0 NI/(2R)$
centre of N-turn loop

$B = \mu_0 NIR^2/[2(R^2+x^2)^{3/2}]$
on the axis at distance x

$B = \mu_0 nI$ (solenoid)
n = turns per metre, uniform inside

$B = \mu_0 NI/(2\pi r)$
toroid, mean radius r

MUST KNOW Inside a long solenoid B is uniform; outside it is ≈0. At the END the field is half: $B = \mu_0 nI/2$.

MUST KNOW Currents OUTSIDE the Amperian loop add zero to $\oint B \cdot dl$. Coaxial cable / hollow pipe: B = 0 inside the cavity.

- Solenoid uses n (turns per length); toroid uses total N over 2πr. Divide turns by length first.

5. Force Between Parallel Currents

Each wire sits in the other's field; same-direction currents attract.

$$F/l = \mu_0 I_1 I_2/(2\pi d)$$
force per unit length, $\propto 1/d$

$$F/l = 2\times10^{-7}\ \mathrm{N/m}$$
for $I_1=I_2=1$ A, d=1 m (defines the ampere)

MUST KNOW Parallel (same-direction) currents ATTRACT; antiparallel (opposite) currents REPEL. This is the reverse of static charges.

MUST KNOW The forces on the two wires are equal and opposite even when $I_1 \neq I_2$ (Newton's third law).

- Dependence is 1/d, not 1/d². Remember it is force per unit length; multiply by l for total.

6. Torque on a Loop & Galvanometer

A current loop is a magnetic dipole; the field twists it, running every meter and motor.

$$m = NIA$$
magnetic moment, normal to loop

$$\tau = NIAB\sin\theta = mB\sin\theta$$
θ = angle between normal and B

$$U = -mB\cos\theta = -m\cdot B$$
min U = -mB when m ∥ B

$$\varphi = (NAB/k)\ I$$
galvanometer, radial field

MUST KNOW θ is measured from the NORMAL to the loop, not its plane. Torque is max (NIAB) when the plane is parallel to B.

MUST KNOW Galvanometer to AMMETER: low shunt in PARALLEL. To VOLTMETER: high resistance in SERIES.

- Current sensitivity = NAB/k; voltage sensitivity = NAB/(kR). Adding turns may raise R, so the gain can cancel.

Magnetic Field Formulas at a Glance

Source	Field B	Where
Long straight wire	$\mu_0 I/(2\pi a)$	distance a
Centre of N-turn loop	$\mu_0 NI/(2R)$	at centre
Inside solenoid	$\mu_0 nI$	uniform
End of solenoid	$\mu_0 nI/2$	at the mouth
Toroid	$\mu_0 NI/(2\pi r)$	inside core only

Parallel vs Antiparallel Currents

Currents	Force	Note
Same direction (parallel)	Attract	opposite of charges
Opposite direction (antiparallel)	Repel	$F/l = \mu_0 I_1 I_2/2\pi d$
Equal & opposite ($I_1 \neq I_2$)	Equal magnitude	Newton's third law

Mnemonic - Direction of the magnetic force F = qv×B on a positive charge (flip for electrons)
FBI / right hand: thumb = v (current), fingers = B, palm pushes = F

Common traps

- Magnetic force does NO work - it can never change a charged particle's speed or kinetic energy, only its direction. If a field 'speeds up' a charge, an electric field is doing the work.
- Time period T = 2πm/qB is independent of speed and radius; only the radius r scales with v. Don't say the period depends on v.
- Same-direction currents ATTRACT, opposite-direction REPEL - the reverse of electric charges. And the force is 1/d, not 1/d².
- Torque angle θ is from the NORMAL to the loop, not the plane. Max torque is when the plane is parallel to B (θ = 90° from normal).

Most asked in NEET » Lorentz force: no work / v ∥ B gives zero · r = mv/qB and r ∝ √K · Cyclotron period independent of speed · B = μ_0nI for solenoid + half at the end · Field of N-turn coil from fixed-length wire (n² scaling) · Force between parallel wires & ampere definition · Torque max condition & galvanometer to ammeter/voltmeter