🌟 MOVING CHARGES & MAGNETISM – FULL STUDY GUIDE (CLASS 12)

🎯 *Super simple → Visual → High-yield → Board-focused → Fun to learn!*

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1. THEORY IN SIMPLE WORDS (WITH VISUALS)

⭐ 1.1 What Produces Magnetism?

Moving charges create magnetic fields.

Visual (very important idea):

```
Static charge → only electric field
Moving charge → electric + magnetic field
```

⭐ 1.2 Magnetic Field (B)

It is the region around moving charges or magnets where magnetic effects are felt.

Unit: Tesla (T)

Analogy:
Magnetic field = "wind" around a moving charge.

⭐ 1.3 Magnetic Field Due to a Current-Carrying Wire

(A) Straight Long Wire

$$B = \frac{\mu_0 I}{2\pi r}$$

Visual:

```
Wire ↑
Circular field lines around it:
↻ ↻ ↻
```

Right-Hand Thumb Rule:

```
Thumb → current
Fingers curl → direction of B
```

(B) Circular Loop

$$B = \frac{\mu_0 I}{2R}$$

Visual:

```
Loop (top view)
Field at center = perpendicular to plane
```

(C) Solenoid

$$B = \mu_0 n I$$

(n = turns per unit length)

Visual:

```
||||| coil
Uniform field inside → →
```

⭐ 1.4 Force on a Moving Charge

$$\vec{F} = q\vec{v} \times \vec{B}$$

Magnitude:

$$F = qvB \sin\theta$$

Visual:

```
v ⊥ B → maximum force
v ∥ B → zero force
```

⭐ 1.5 Force on a Current-Carrying Conductor

$$F = BIL\sin\theta$$

⭐ 1.6 Lorentz Force

Total force = Electric + Magnetic

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

⭐ 1.7 Motion of a Charged Particle in Uniform B-Field

Particle moves in **circular path**.

Radius:

$$r = \frac{mv}{qB}$$

Time period:

$$T = \frac{2\pi m}{qB}$$

⭐ 1.8 Ampere's Circuital Law

$$\oint B dl = \mu_0 I$$

Used for:

- Solenoid
- Toroid

⭐ 1.9 Biot–Savart Law

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I d\vec{l} \times \hat{r}}{r^2}$$

Gives magnetic field due to small current element.

⭐ 1.10 Cyclotron

Device to accelerate charged particles using **electric force** (between Dee gaps) and **magnetic force** (inside Dees).

Cyclotron frequency:

$$f = \frac{qB}{2\pi m}$$

Visual:

```
Two D-shaped chambers (Dees)
Particle spirals outwards
```

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2. KEY CONCEPTS & FORMULAS (REVISION TABLE)

Topic	Formula	Memory Trick
Long wire	$B = \mu_0 I/2\pi r$	"Inversely with r"
Loop (center)	$B = \mu_0 I/2R$	Replace πr with R
Solenoid	$B = \mu_0 nI$	No R. No π. Easy!
Force on charge	$F = qvB \sin\theta$	q v B "sin rule"
Force on wire	$F = BIL \sin\theta$	Replace qv with IL
Radius	$r = mv/qB$	m↑ → r↑ ; B↑ → r↓
Cyclotron freq	$f = qB/2\pi m$	No radius involved
Ampere circuital	∮Bdl = μ_0I	Loop = current inside

🌈 MNEMONICS

- **Right-Hand Rule: "Thumb is the current king!"**

Thumb → I
Fingers → B

- **For force on charge:**

"q v B sin" → "Quick Vibration By Sine."

- **For radius in B-field:**

“m over qB”
(Heavier → bigger circle)

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3. SOLVED NUMERICAL PROBLEMS (STEPWISE)

⭐ Type 1: Magnetic field due to straight wire

Q: A 10 A current flows through a long wire. Find B at 5 cm.

$$B = \frac{\mu_0 I}{2\pi r}$$

$$= \frac{4\pi \times 10^{-7} \times 10}{2\pi \times 0.05}$$

$$B = 4 \times 10^{-5}\ \text{T}$$

✔ Tip: Cancel π early.

⭐ Type 2: Force on moving charge

Q: Charge = 2 μC, v = 2×10^5 m/s, B = 0.5 T, θ = 90°.
Find force.

$$F = qvB \sin\theta$$

$$= 2 \times 10^{-6} \times 2 \times 10^5 \times 0.5$$

$$= 0.2\ \text{N}$$

✔ Common mistake: forgetting μC → C.

⭐ Type 3: Radius of circular path

Q: Electron (m = 9.1×10^{-31} kg) enters perpendicular to B = 0.2 T at v = $1 \times 10^6 m/s$.
Find radius.

$$r = \frac{mv}{qB}$$

$$= \frac{9.1 \times 10^{-31} \times 10^6}{1.6 \times 10^{-19} \times 0.2}$$

$$r = 0.028\ \text{m}$$

⭐ Type 4: Force on wire

Q: A 0.5 m wire carries 4 A and is in a 0.3 T field at 90°.
Find force.

$$F = BIL$$

$$= 0.3 \times 4 \times 0.5 = 0.6\ \text{N}$$

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4. PAST-YEAR BOARD QUESTIONS (SOLVED)

(Generally repeated patterns from 2016–2024)

✔ Q1

State Biot–Savart law and write expression for B due to small current element.
(Repeated many years)

✔ Q2

Derive expression for magnetic field on axis of circular loop.
(Always 5–6 marks historically)

✔ Q3

Explain cyclotron principle.
(3-mark conceptual)

✔ Q4

Write Ampere's law. Use it to derive B inside a solenoid.
(VERY high-weightage)

✔ Q5 (Numerical)

Find force on a charge or wire in magnetic field.
(Guaranteed 1 numerical every year)

✔ Q6

Draw diagrams of:

- Right-hand thumb rule
- Field lines around a wire
- Solenoid magnetic field
  (Often asked for diagram marks)

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5. QUICK REVISION NOTES (1–2 PAGES)

⭐ Magnetic Field Basics
- Produced by moving charges
- Represented by field lines
- Direction via right-hand rule

⭐ Biot–Savart Law
- Field ∝ current
- Field ∝ $1/r^2$
- Cross product involved

⭐ Wire / Loop / Solenoid
- Long wire: circular field
- Loop: straight at center
- Solenoid: uniform inside

⭐ Force on Charge / Wire
- Perpendicular → maximum force
- Parallel → zero force
- Direction via Fleming Left-Hand Rule (for wires)

⭐ Motion in B-field
- Charged particle → circular motion
- $r = mv/qB$
- Time period depends only on m, q, B

⭐ Cyclotron
- Uses electric force (accelerates)
- Uses magnetic force (bends path)
- Frequency = constant

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6. PREDICTED / LIKELY QUESTIONS (2025 Boards)

Short Answer

- Define magnetic field, Lorentz force.
- State Biot–Savart law.
- State Ampere's law.
- What is cyclotron frequency?
- Draw field due to wire/loop/solenoid.

Long Answer

- Derive B for circular loop.
- Derive B inside solenoid.
- Explain cyclotron with diagram.

Numerical

- Force on wire
- Force on moving charge
- Radius in magnetic field
- B due to long wire

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7. EXAM TIPS & TRICKS

✔ Tip 1: Diagrams = free marks

Draw neat circles/loops with direction arrows.

✔ Tip 2: Check angle (θ)

Often students forget sinθ.

✔ Tip 3: μ_0 constant

$$4\pi \times 10^{-7}$$

Learn this by heart.

✔ Tip 4: For right-hand rule

Imagine holding the wire in your right hand.

✔ Tip 5: In circular motion problems

Use electron charge carefully (sign doesn't matter for radius).

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8. VISUAL & KID-FRIENDLY MEMORY TRICKS

🎨 Visual 1: Wire & Field

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Thumb ↑
Fingers curl ↻
```

Like hugging a pole.

🎨 Visual 2: Circular Path

```
Charge enters ⊥ B → perfect circle
```

🎨 Visual 3: Cyclotron

```
Spiral → → → outwards
```

🎨 Visual 4: Solenoid

```
||||| → uniform arrows inside → →
```