FREE NOTES · NCERT + JEE/NEET LEVEL

Moving Charges & Magnetism

Lorentz force, magnetic field me charge ka gol aur helical raasta, cyclotron, Biot-Savart, Ampere's law, solenoid, do taaron ke beech force, current loop pe torque aur galvanometer.

01 Magnetic force (Lorentz force)
02 Magnetic field me charge ki motion
03 Velocity selector & cyclotron
04 Current wali taar pe force
05 Biot-Savart law
06 Circular loop ka field
07 Ampere's circuital law
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01 Magnetic force (Lorentz force)

Oersted ne dekha: current wali taar ke paas compass ki sui ghoom jaati hai. Yaani **chalta hua charge magnetic field banata hai**, aur magnetic field **chalte** charge pe force lagata hai.

$$F = q\,(v \times B),\ |F| = q\,v\,B\,\sin\theta$$

Unit of B: tesla (T) = N/(A·m). 1 gauss = 10^{-4} T. Earth ka field ≈ 0.4 gauss. Electric field bhi ho toh $F = q(E + v \times B)$.

- Ruka hua charge (v = 0) pe magnetic force 0.
- v ∥ B ho toh force 0.
- Force hamesha v ke ⊥ ⇒ **magnetic force koi work nahi karta**, speed nahi badalti, sirf direction.

DIRECTION: FLEMING'S LEFT-HAND RULE

Left hand ki pehli ungli (Forefinger) = Field, beech wali (Middle) = current (positive charge ki velocity), angootha (thumb) = force. Electron ke liye force ulta.

02 Magnetic field me charge ki motion

V ⊥ B: CIRCLE

$$r = m v / (q B)$$

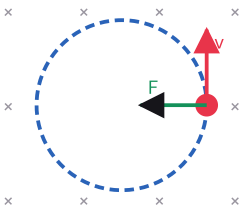
$T = 2\pi m / (q B)$, $f = qB/(2\pi m)$

Time period aur frequency **speed pe depend nahi karte** (cyclotron isi pe). r = p/(qB) = √(2mK)/(qB).

V AUR B KE BEECH ANGLE Θ: HELIX

$r = m v \sin\theta/(qB)$

$\text{Pitch} = v \cos\theta \times T = 2\pi m v \cos\theta/(qB)$



B kaagaz ke andar (×)

Force centre ki taraf ⇒ gol raasta

03 Velocity selector & cyclotron

VELOCITY SELECTOR

E aur B ek doosre ke ⊥, dono force ulte. Sirf wo charge seedha nikalta jiski $v = E/B$ (mass aur charge pe depend nahi).

CYCLOTRON

Do "dees" ke beech AC voltage, upar se B. Particle har aadhe chakkar pe energy leta, radius badhta. $f_c = qB/(2\pi m)$ = oscillator frequency (resonance). Max KE = $q^2B^2R^2/(2m)$. Electron ke liye kaam nahi karta (bahut halka, relativistic).

04 Current wali taar pe force

$$F = I (L \times B), |F| = B I L \sin\theta$$

Taar B ke parallel ho toh force 0. Band loop (koi bhi shape) uniform B me: net force 0.

05 Biot-Savart law

$$dB = (\mu_0/4\pi)\, I\, (dl \times \hat{r})/r^2\,,\ |dB| = (\mu_0/4\pi)\, I\, dl \sin\theta\ /\ r^2$$

$\mu_o = 4\pi \times 10^{-7}$ T·m/A (permeability of free space). Electric field ke Coulomb law jaisa, par direction cross product se.

Taar	Field
Infinite seedhi taar, doori r	$B = \mu_0 I/(2\pi r)$
Finite taar (angles α, β)	$B = \mu_0 I(\sin\alpha + \sin\beta)/(4\pi r)$
Semi-infinite, sire ke saamne	$\mu_0 I/(4\pi r)$

DIRECTION: RIGHT-HAND THUMB RULE

Right hand ka angootha current ki direction me, ungliyan jis taraf mudti = field lines ki direction (taar ke chaaron taraf gol circles).

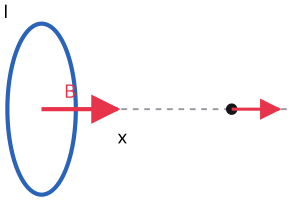
06 Circular loop ka field

Centre pe: $B = \mu_0\, I\ /\ (2R)$

N turns: $B = \mu_0\, N\, I\ /\ (2R)$

Axis pe doori x: $B = \mu_0\, I\, R^2\ /\ (2(R^2 + x^2)\text{^}(3/2))$

Arc (angle θ) ke centre pe: $B = \mu_0 I\theta/(4\pi R)$



Axis pe field loop ke ⊥

Loop ek **magnetic dipole** ki tarah: ek face North, doosra South. Current anticlockwise dikhe toh wo face North.

07 Ampere's circuital law

STATEMENT

$\oint B \cdot dl = \mu_o I_{enclosed}$

Kisi bhi band loop (Amperian loop) ke along B ka line integral = μ_o × loop se guzarne wala net current. Gauss's law jaisa: symmetry ho toh aasaan.

Case	Andar (r < R)	Bahar (r > R)
Mota solid cylinder taar (uniform I)	$B = \mu_0 Ir/(2\pi R^2)$	$\mu_0 I/(2\pi r)$
Hollow pipe taar	0	$\mu_0 I/(2\pi r)$

08 Solenoid & toroid

LAMBA SOLENOID

$$B = \mu_0 \, n \, I$$

n = turns per metre. Andar uniform, bahar ≈ 0. Sire pe field aadha ($\mu_o nI/2$). Bar magnet jaisa behave karta. Iron core daalo ⇒ electromagnet.

TOROID

$$B = \mu_0 \, N \, I \, / \, (2\pi r)$$

Gol solenoid (donut). Field sirf core ke andar; andar ke khaali hisse me aur bilkul bahar 0.

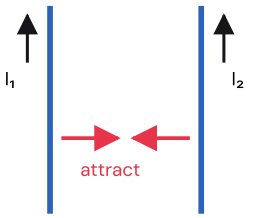
09 Do parallel taaron ke beech force

$$F/L = \mu_0 I_1 I_2 / (2\pi d)$$

Same direction current: **attract**. Ulti direction: **repel**. (Charges ke ulta!)

AMPERE KI DEFINITION

Do lambi parallel taaren 1 m door, barabar current, aur force 2×10^{-7} N/m ho, toh current = 1 A.



Same direction current ⇒ paas aate

10 Current loop pe torque

$$\tau = m \times B, \quad |\tau| = N I A B \sin\theta$$

Magnetic moment $m = N I A$ ($A \cdot m^2$), direction right-hand rule se

Potential energy $U = -m \cdot B$

θ = loop ke normal (m) aur B ke beech angle. Loop ka plane B ke parallel ⇒ torque max. Electric motor isi pe chalta hai.

ELECTRON KA ORBIT (BOHR)

Ghoomta electron = chhota current loop: $\mu = evr/2$. Bohr magneton $\mu_B = eh/(4\pi m) = 9.27 \times 10^{-24}$ A·m².

11 Moving coil galvanometer

Radial magnetic field me coil, current se torque, spring ka counter-torque. Balance pe: $NIAB = k\varphi \Rightarrow \varphi \propto I$.

Current sensitivity $= \varphi/I = NAB/k$

Voltage sensitivity $= \varphi/V = NAB/(kR_G)$

Turns double karo ⇒ current sensitivity double, par resistance bhi double ⇒ voltage sensitivity same.

GALVANOMETER → AMMETER

Parallel me **chhota shunt**: $S = I_g G/(I - I_g)$.

Ammeter ka resistance bahut kam. Series me lagta.

GALVANOMETER → VOLTMETER

Series me **bada resistance**: $R = V/I_g - G$.

Voltmeter ka resistance bahut zyada. Parallel me lagta.

12 JEE Extra + Tricks

JEE LEVEL

- B me charge: radius $r = mv/(qB) = \sqrt{(2mK)}/(qB)$; $T = 2\pi m/(qB)$ (speed se independent); helix pitch = $2\pi m\, v\cos\theta/(qB)$.
- θ angle ke arc ke centre pe: $B = \mu_0 I\theta/(4\pi R)$; poora loop $\mu_0 I/2R$; semicircle $\mu_0 I/4R$.
- Finite seedha taar: $B = (\mu_0 I/4\pi d)(\sin\alpha + \sin\beta)$.
- Parallel taar: per length force $\mu_0 I_1 I_2/(2\pi d)$; same disha ke current aakarshit.
- Galvanometer → ammeter: chhota shunt $S = I_g G/(I - I_g)$ parallel me; → voltmeter: bada $R = V/I_g - G$ series me.

13 Solved numericals ($\mu_0 = 4\pi \times 10^{-7}$)

Q1. Proton (1.6×10^{-19} C) 10^6 m/s se 0.5 T field me ⊥ chal raha. Force?
$F = qvB = 1.6 \times 10^{-19} \times 10^6 \times 0.5 = 8 \times 10^{-14}$ N. **Ans: 8×10^{-14} N**

Q2. Electron ($m = 9.1 \times 10^{-31}$ kg) 3×10^7 m/s se 10^{-3} T me ⊥. Radius?
$r = mv/(qB) = 9.1 \times 10^{-31} \times 3 \times 10^7/(1.6 \times 10^{-19} \times 10^{-3}) \approx 0.17$ m. **Ans: ≈ 17 cm**

Q3. Seedhi lambi taar me 10 A. 5 cm door B?
$B = 2 \times 10^{-7} \times 10/0.05 = 4 \times 10^{-5}$ T. **Ans: 4×10^{-5} T**

Q4. 100 turns, radius 10 cm ki coil me 1 A. Centre pe B?
$B = \mu_0 NI/(2R) = 4\pi \times 10^{-7} \times 100/0.2 = 2\pi \times 10^{-4} \approx 6.28 \times 10^{-4}$ T. **Ans: ≈ 6.3×10^{-4} T**

Q5. Solenoid: 50 cm lamba, 500 turns, 2 A. Andar B?
$n = 1000$/m. $B = 4\pi \times 10^{-7} \times 1000 \times 2 \approx 2.51 \times 10^{-3}$ T. **Ans: ≈ 2.5 mT**

Q6. Galvanometer G = 50 Ω, full scale 5 mA. 5 A ka ammeter banane ke liye shunt?
$S = 0.005 \times 50/(5 - 0.005) \approx 0.05$ Ω. **Ans: ≈ 0.05 Ω parallel**

Q7. Usi galvanometer se 10 V ka voltmeter?
$R = 10/0.005 - 50 = 1950$ Ω. **Ans: 1950 Ω series**

14 Common mistakes

- Magnetic force ko work karne wala maan lena (speed nahi badalti).
- Electron ke liye force ki direction ulti karna bhool jaana.
- Parallel currents me "same repel" laga dena (same direction current attract karte).
- Cyclotron ki frequency ko speed pe depend maan lena.
- Ammeter me series resistance aur voltmeter me shunt (ulta) laga dena.
- Solenoid me n ki jagah total N daal dena.

15 Formula sheet

Lorentz force	$F = q(v \times B),\ F = qvB\sin\theta$
Circular motion	$r = mv/qB,\ T = 2\pi m/qB$
Velocity selector	$v = E/B$
Force on wire	$F = BIL\sin\theta$
Straight wire	$B = \mu_0 I/2\pi r$
Loop centre / axis	$\mu_0 NI/2R$ / $\mu_0 IR^2/2(R^2 + x^2)\text{^}(3/2)$
Solenoid / toroid	$\mu_0 nI$ / $\mu_0 NI/2\pi r$
Parallel wires	$F/L = \mu_0 I_1 I_2/2\pi d$
Torque on loop	$\tau = NIAB\sin\theta,\ m = NIA$
Shunt / series R	$S = I_g G/(I - I_g),\ R = V/I_g - G$

16 Practice questions

1. Proton aur alpha same speed se $\perp$ B me. Radius ka ratio?
2. Do taaren 10 cm door, dono me 5 A same direction. Force per metre?
3. Loop ka radius 2 guna (current same). Centre pe B?
4. Charge B ke parallel chal raha hai. Raasta?
5. Ideal ammeter aur voltmeter ka resistance?

ANSWERS

1) $r \propto m/q \Rightarrow 1:2$ · 2) $2 \times 10^{-7} \times 25/0.1 = 5 \times 10^{-5}$ N/m (attract) · 3) Aadha · 4) Seedhi line (force 0) · 5) 0 aur ∞

17 Quick revision: exam se pehle 5 minute

FORCE

- F = qvB sin θ; work 0.
- r = mv/qB; T speed pe nahi.
- Velocity selector v = E/B.

FIELDS

- Taar $\mu_o I/2\pi r$; loop $\mu_o I/2R$.
- Solenoid $\mu_o nI$; toroid $\mu_o NI/2\pi r$.
- $\oint B \cdot dl = \mu_o I$.

WIRES & LOOPS

- Same current direction ⇒ attract.
- τ = NIAB sin θ; m = NIA.

GALVANOMETER

- Ammeter: chhota shunt parallel.
- Voltmeter: bada R series.
- $\varphi \propto I$ (radial field).

Doubt hai? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.