
Physics Mega Revision #3
MEC,
Magnetism & Matter,
EMI & AC
Superfast Revision
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Complete Physics Mega Revision Timetable

15 Feb
Electrostatics
Current electricity
Capacitor
🎁 Surprise Gift 🎁

16 Feb
Calorimetry
Elasticity
Thermal Expansion
Heat Transfer
KTG
Thermodynamics
Fluid Mechanics

17 Feb
Magnetic effect of current
Magnetism and matter
Emi
AC

Exam Tips

18 Feb
UD
Vector
Kinematics 1D
Kinematics 2D
NLM
Friction
Circular motion
Work power energy
COM
Rotation motion

19 Feb
Ray optics
Optical Instruments
Wave optics
EM Waves
Errors in measurement

20 Feb
Gravitation
SHM
Wave on string
Sound wave

21 Feb
Dual nature of radiation
X-rays
Nuclear physics
Radioactivity
Semi conductor
Communication system

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Faculty of the Series

Saransh Gupta Sir

eSaral Physics HoD

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Magnetic Effect of Current

Superfast Revision

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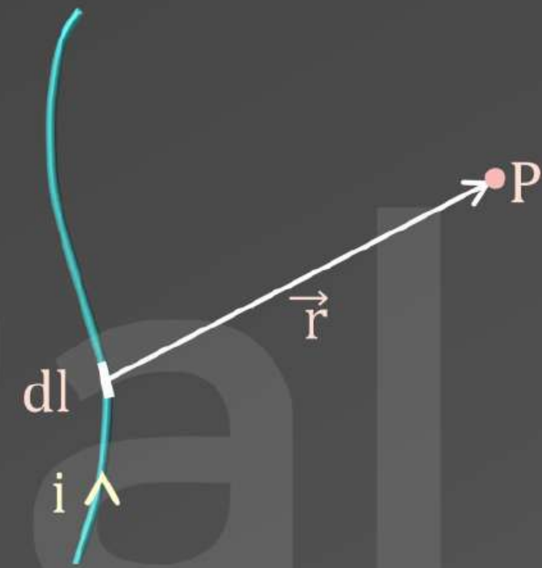
Biot-Savart Law

Then according to Biot–Savart law

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i\,d\vec{\ell} \times \vec{r}}{r^3}$$



$\mu_0 \rightarrow$ Permeability of Free Space

$\mu_0 = 4\pi \times 10^{-7}$ Tm/A

SI unit of magnetic field ($\vec{B}$) is Tesla (T)

Smaller unit of magnetic field ($\vec{B}$) is Gauss

1Gauss = 10^{-4} T

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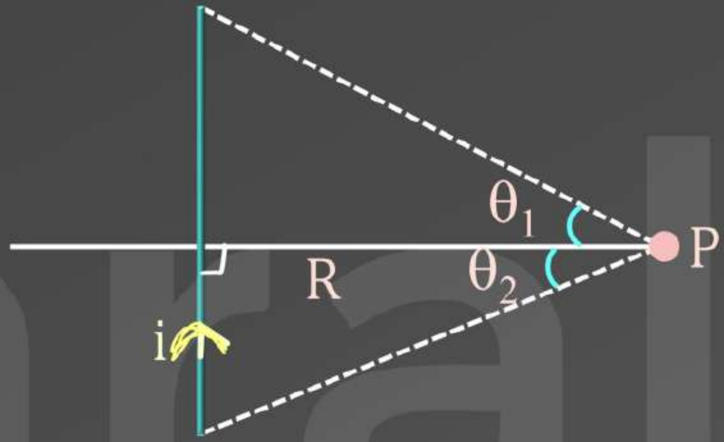
Magnetic Field Intensity due To Straight Current Carrying Wire



In this case Magnetic field lines are circular with their centres on the wire.

Magnetic field lines form continuous closed loops.

$$B = \frac{\mu_0 i}{4\pi R}(\sin\theta_1 + \sin\theta_2)$$

R is perpendicular distance of P from wire

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MFI Due To Semi ∞ Wire

$$B = \frac{\mu_0 i}{4\pi R}$$

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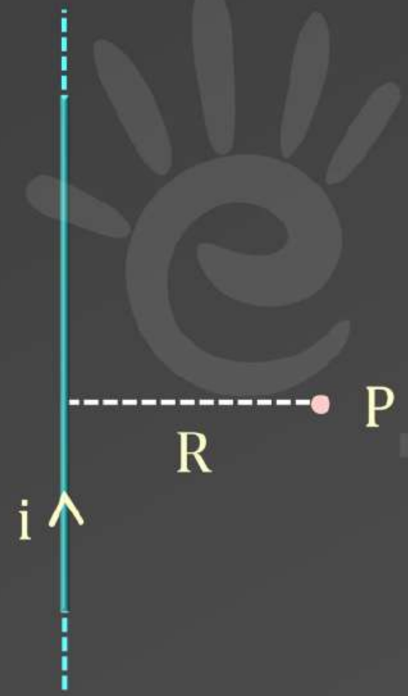
MFI Due To ∞ Wire



$$B = \frac{\mu_0 i}{2\pi R}$$

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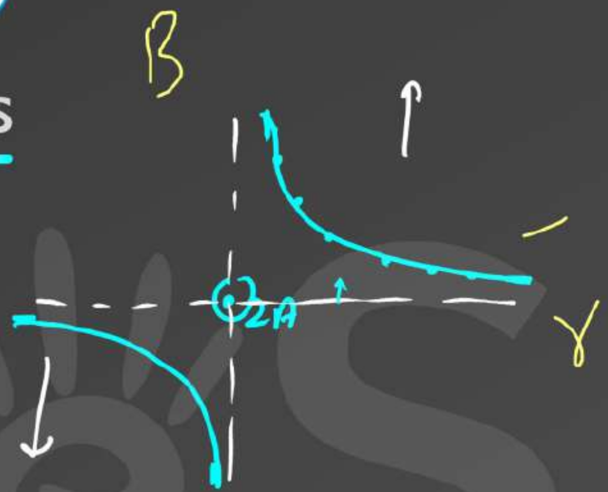
Graphs



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

$r \to 0 \quad B \to \infty$

$r \to \infty \quad B \to 0$

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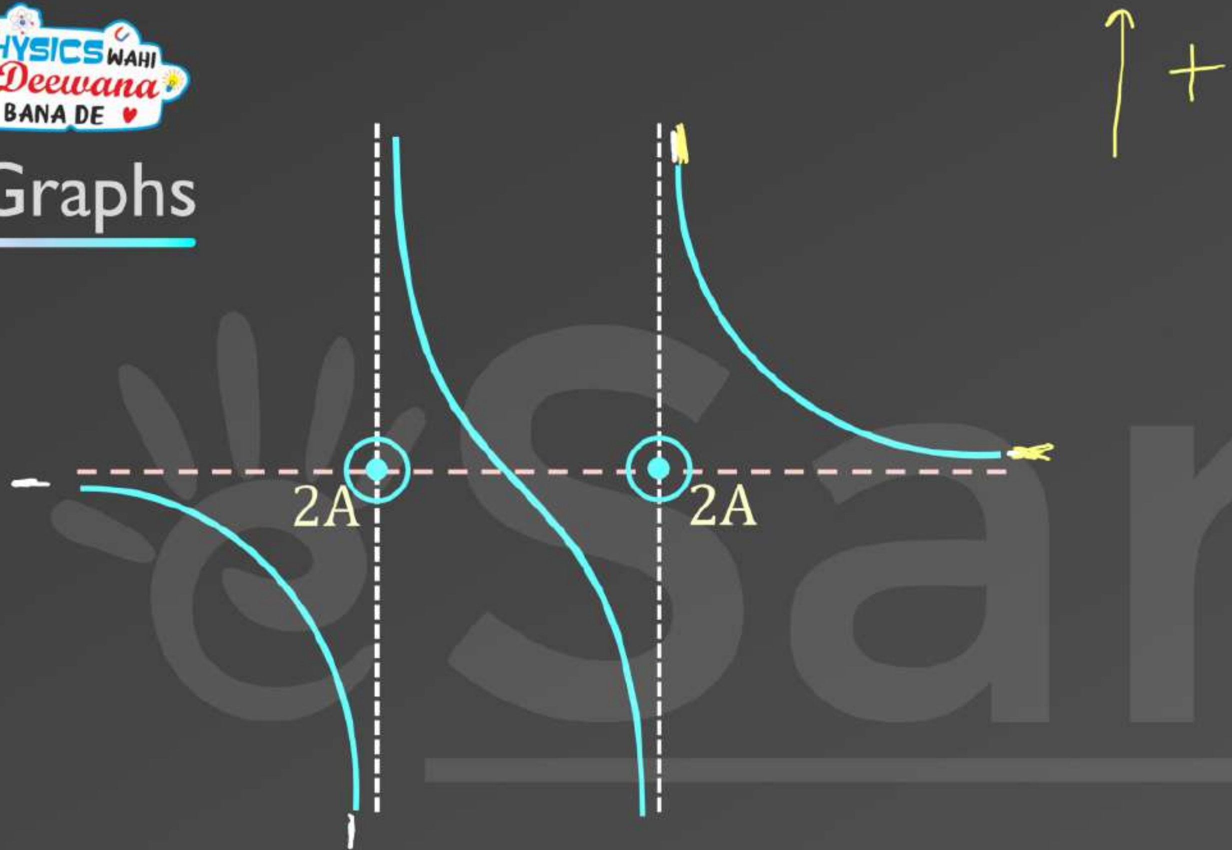
Graphs



$\gamma \to 0 \quad B \to \infty$

$\gamma \to \infty \quad B \to 0$

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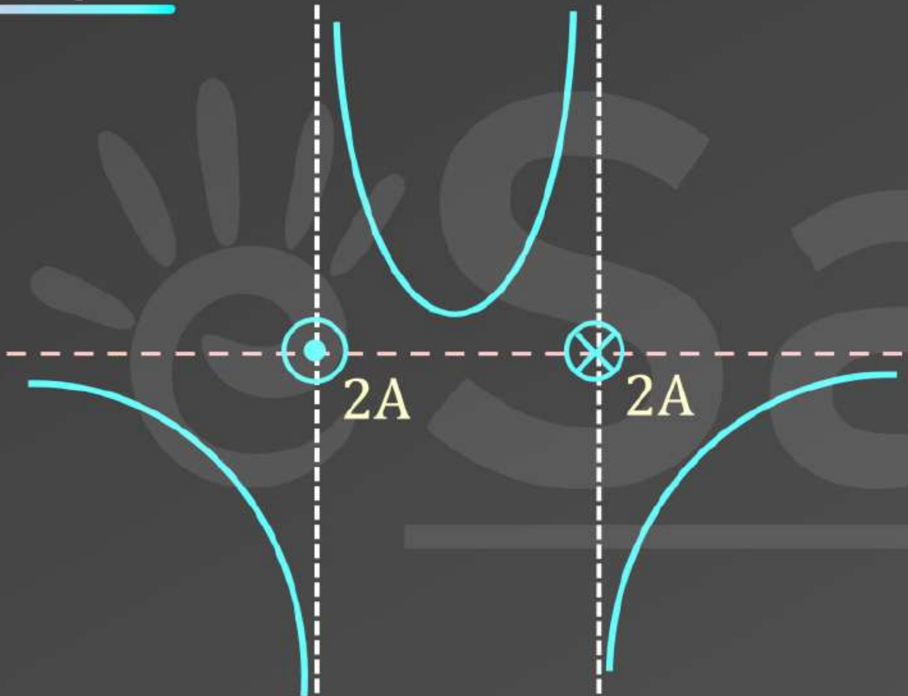
Graphs



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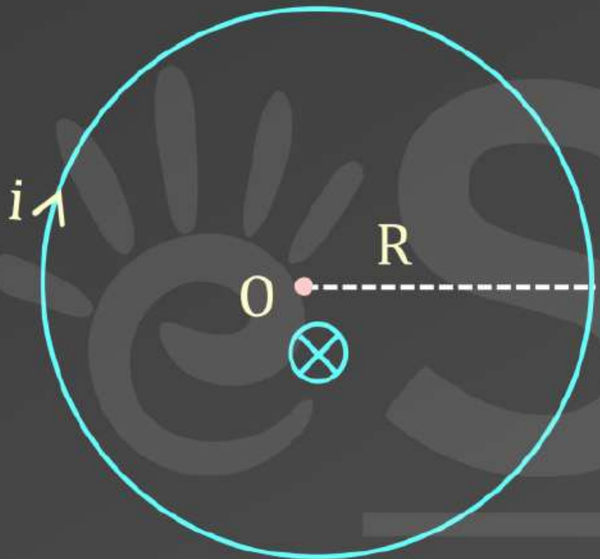
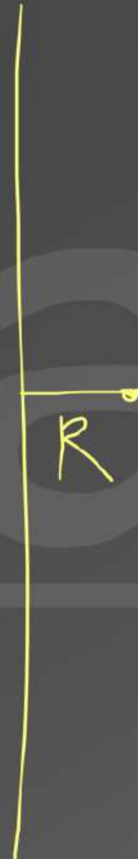
Magnetic Field at Centre of Current Carrying Circular Loop



TRICK

1, 2

$$B_0 = \frac{\mu_0 i}{2R}$$



$$\frac{\mu_0 i}{2\pi R}$$

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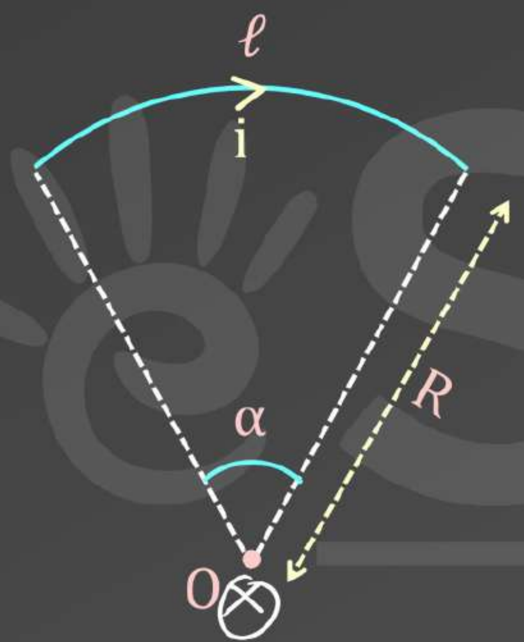
Magnetic Field at the Centre of Current Carrying Circular Arc



$$B = \frac{\mu_0 i}{2R}\left(\frac{\alpha}{2\pi}\right) \otimes$$

$$\frac{\mu_0 i}{2R}\left(\frac{\alpha}{2\pi}\right)$$

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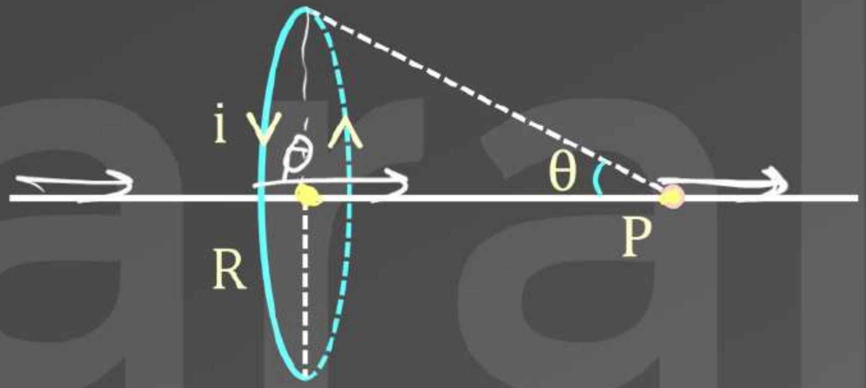
MFI on the Axis of Current Carrying Circular Loop

$$B = \frac{\mu_0 i}{2R} (\sin^3\theta)$$



$$B_0 = \frac{\mu_0 i}{2R}$$

Trick $\theta \rightarrow 90^\circ \Rightarrow$ at center

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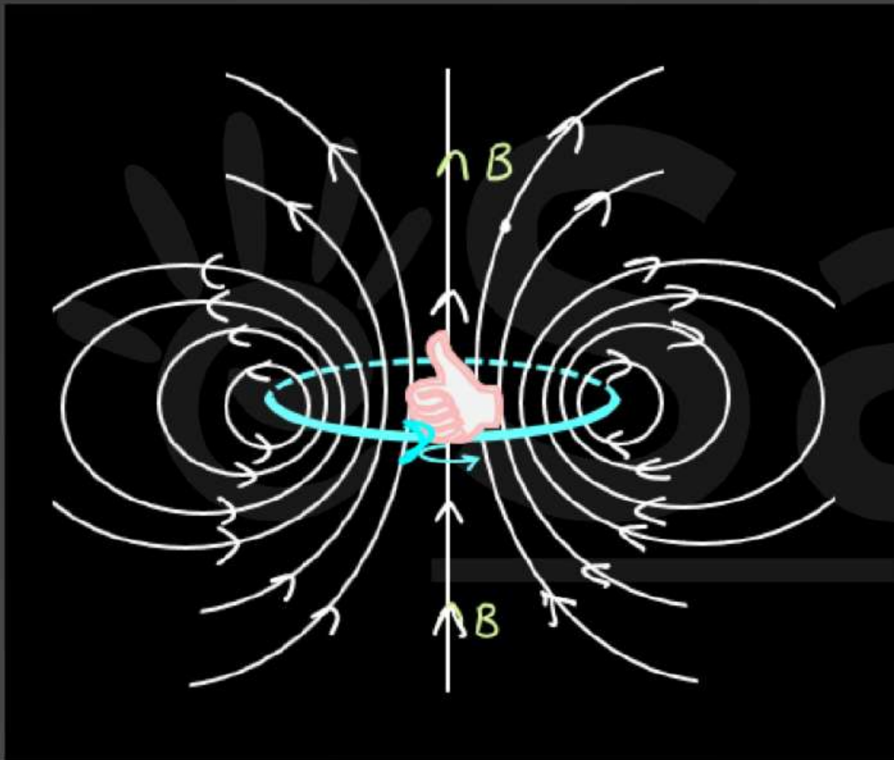
Magnetic Field Lines due to a Current Carrying Loop



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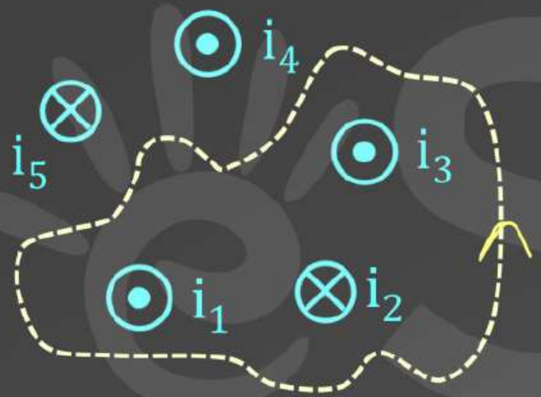
Ampere's Circuital Law



$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 \sum i_{inc}$$

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 (i_1 - i_2 + i_3)$$

$\vec{B}$ → due to all i

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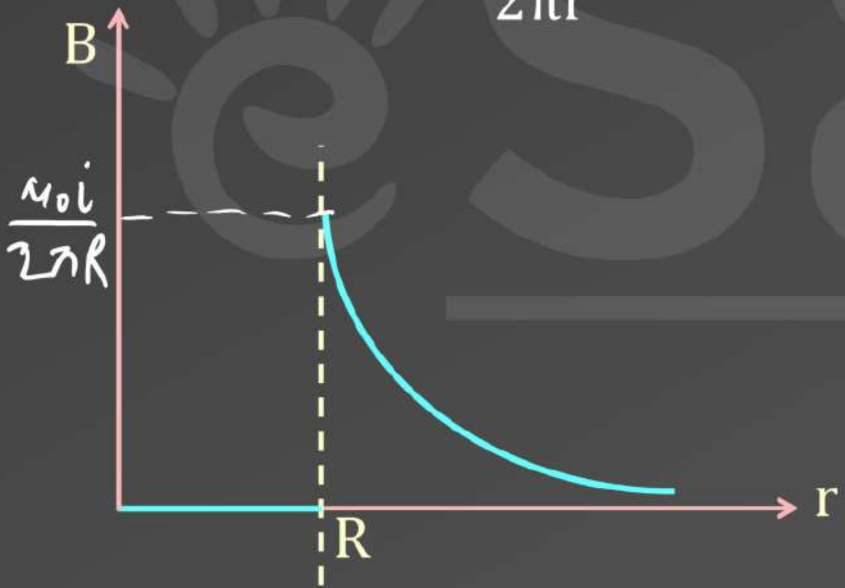
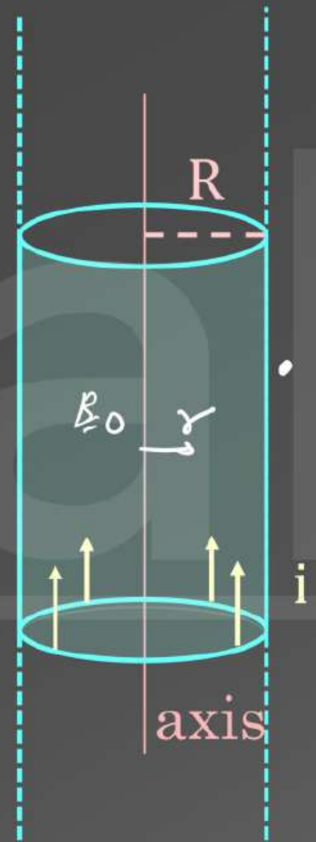
MFI due to Current Carrying ∞ Long Hollow Cylinder

$r \angle R \quad B = 0$

$r > R \quad B = \frac{\mu_0 i}{2\pi r}$





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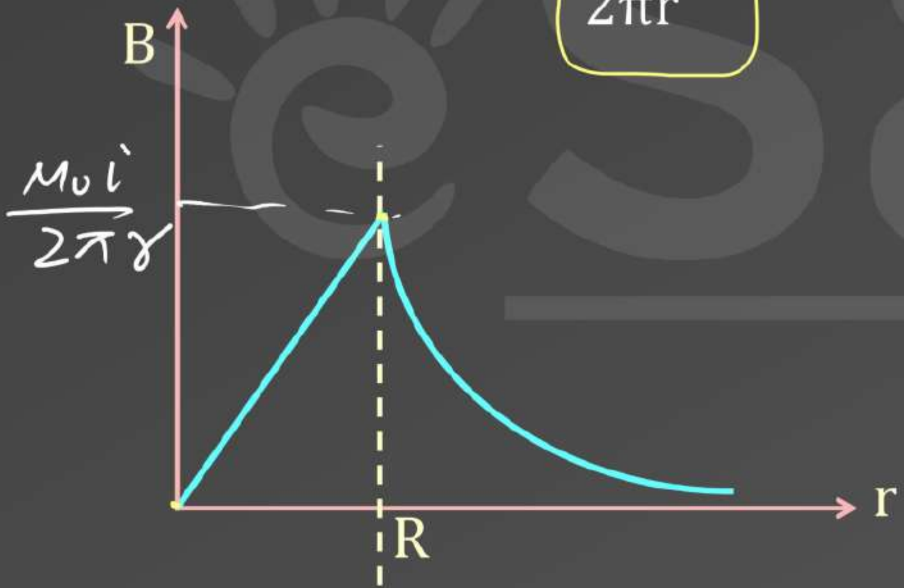
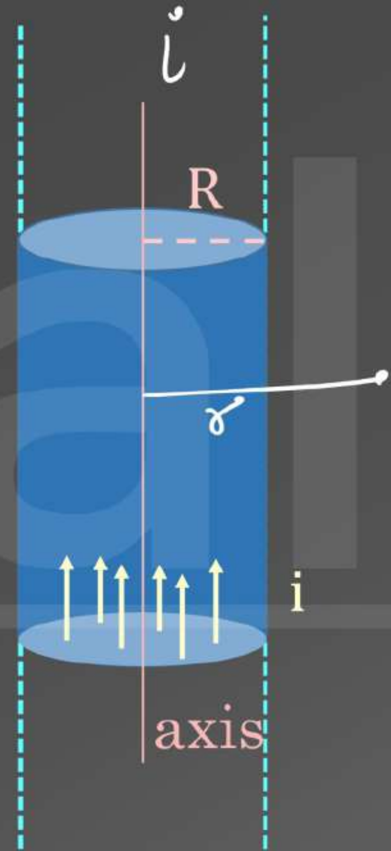
MFI due to Current Carrying ∞ Long Solid Cylinder

$r < R \rightarrow B = \frac{\mu_0 j}{2} r$

$r > R \rightarrow B = \frac{\mu_0 i}{2\pi r}$

$\vec{j} = \frac{i}{\pi R^2}$





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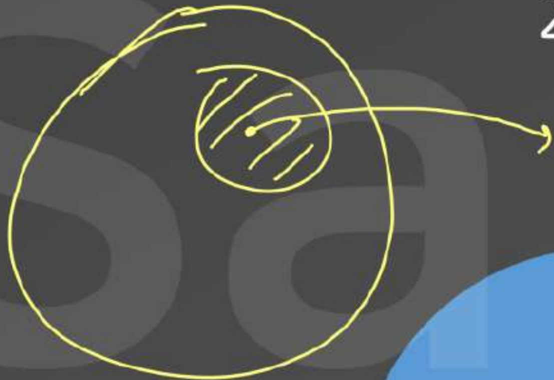
Q) Find $\vec{B}$ inside long cylindrical cavity in long solid cylinder.

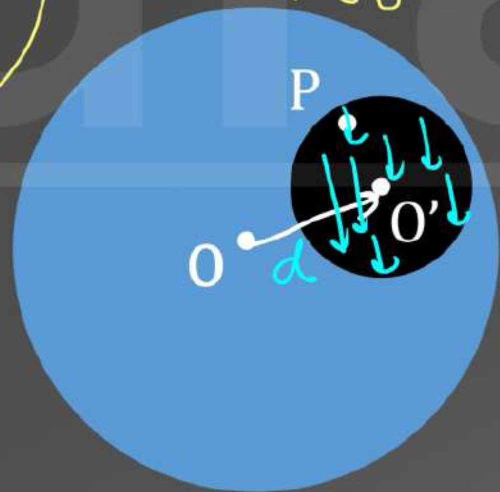
Sol. $\frac{\mu_0 \vec{j}}{2} \times \overrightarrow{OO'}$

$\frac{\mu_0 j}{2}$



$\frac{\rho d}{3\epsilon_0}$

$\frac{\mu_0 j d}{2}$



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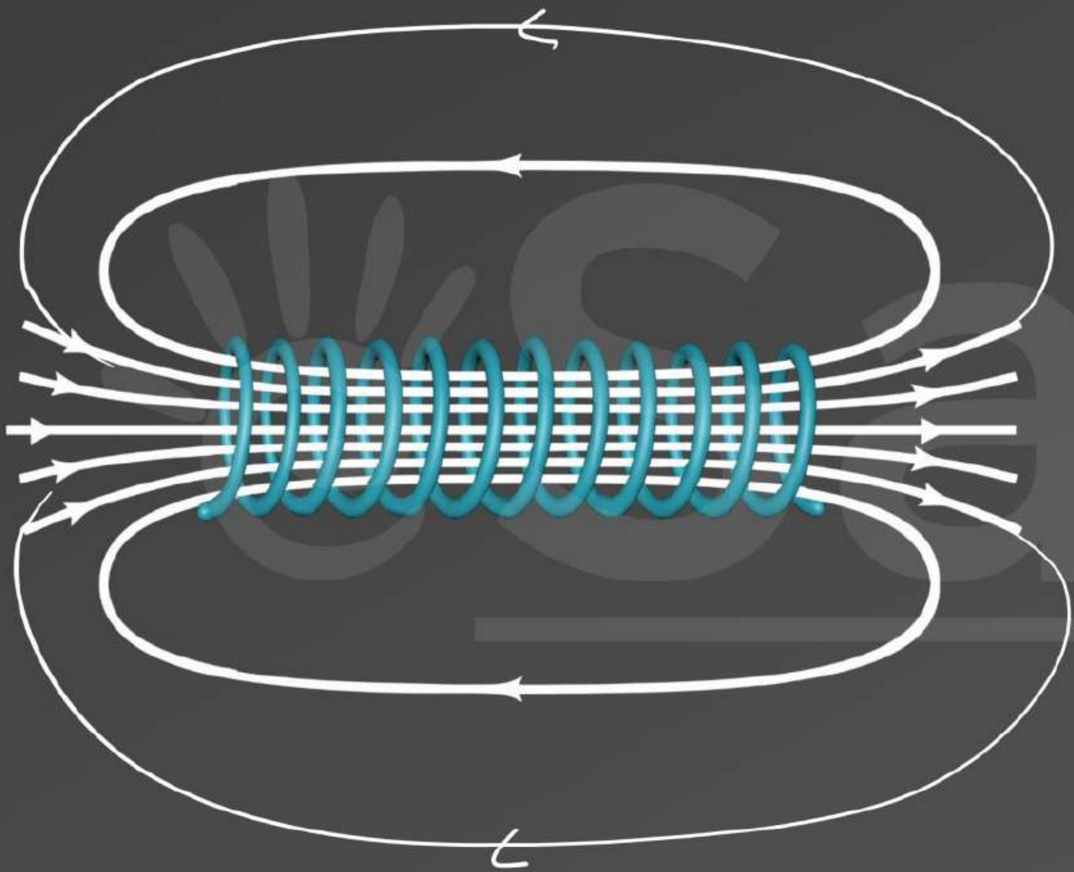
Solenoid



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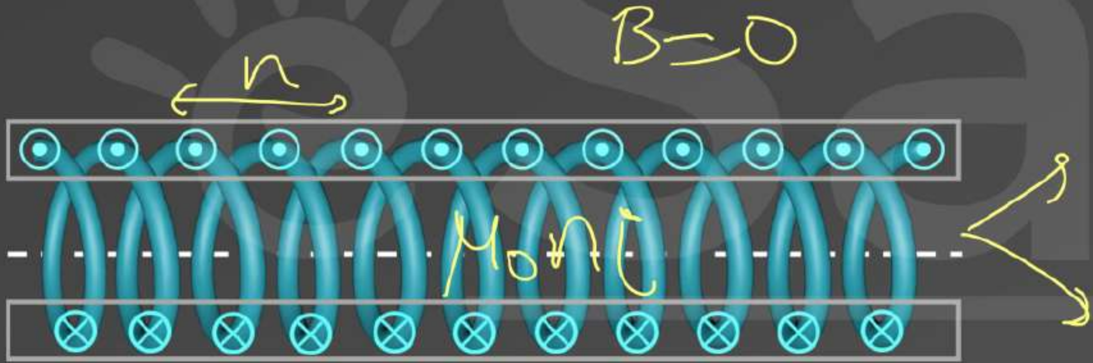
Long Solenoid

Solenoid's length is large compared to its radius (L >> r).



'n' turns per unit length.

MFI inside is uniform and axial $B = \mu_0 n i$

MFI outside solenoid is zero.

MFI at ends is $\frac{\mu_0 n i}{2}$

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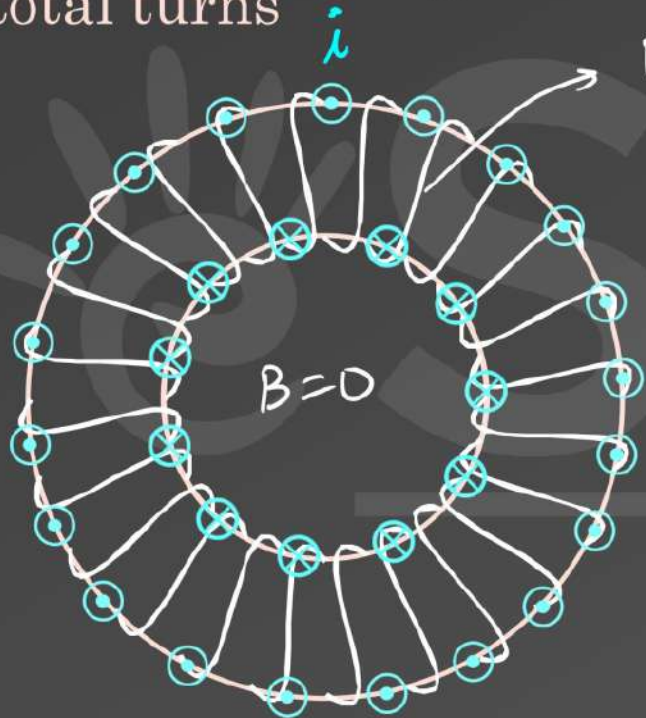
Toroid

'N' total turns



$B = \frac{\mu_0 N i}{2\pi r}$

$\mu_0 n i$

n_0 / length

$\frac{N}{2\pi r}$

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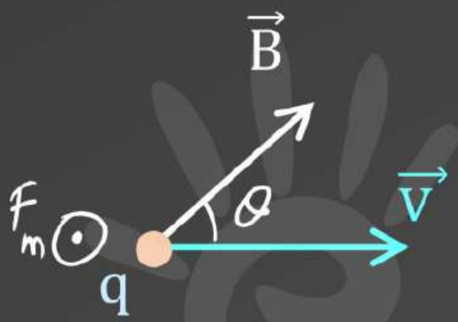
Magnetic Force on a Moving Charge Particle



$$\vec{F}_m = q(\vec{v} \times \vec{B}) \Rightarrow |\vec{F}_m| = qvB\sin\theta$$

As per the equation

$\vec{F} \perp \vec{v}$ $\quad$ $\vec{F} \perp \vec{B}$

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$$p = \vec{F} \cdot \vec{v} = 0$$

Work done by magnetic force is always zero.

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

$$\vec{F} \perp \vec{v}$$

That means speed of a particle moving in magnetic field region alone remains constant.

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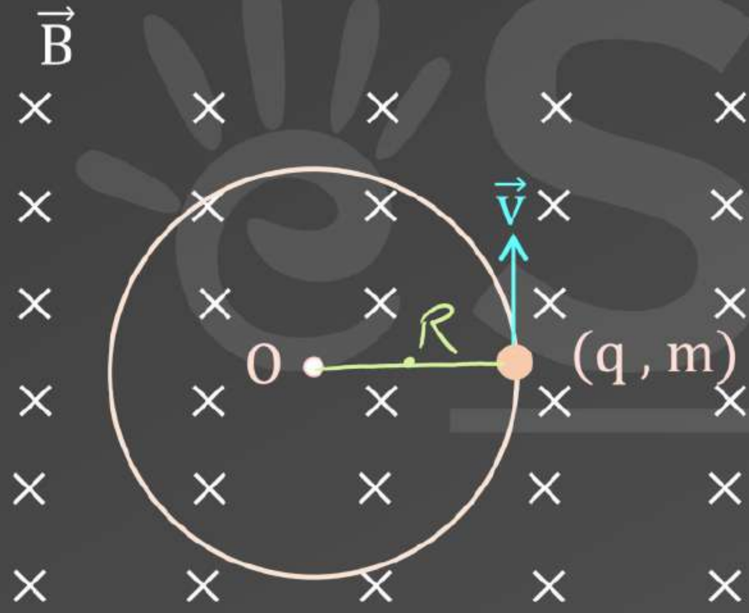
Case 1: Motion of particle in plane ⊥ to $\vec{B}$



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

$$T = \frac{2\pi R}{v} = \frac{2\pi m}{qB} \qquad f = \frac{1}{T} = \frac{qB}{2\pi m}$$

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

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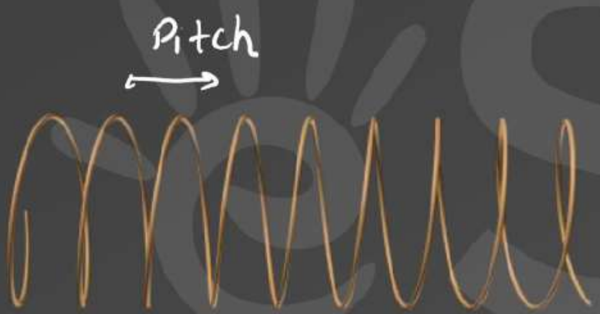
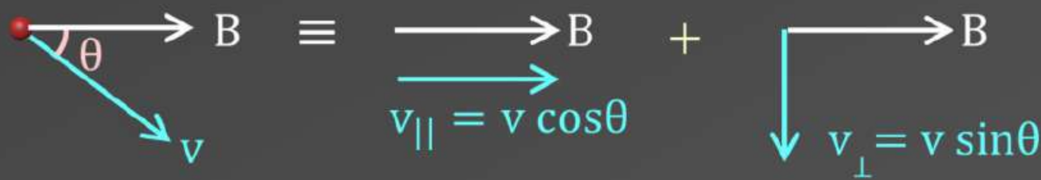
Magnetic Force on a Moving Charged Particle

Case 2: If $\vec{v}$ is not ⊥ to $\vec{B}$





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

Radius of Helix (R) is radius of circular component of motion.

$$R = \frac{mv_{\perp}}{qB} = \frac{mv\sin\theta}{qB}$$

$$\text{Pitch} = (v\cos\theta)\,T$$

$$= \frac{2\pi mv\cos\theta}{qB}$$

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Motion of Charged Particle in Presence of Both $\vec{E}$ and $\vec{B}$

$$\vec{F} = \vec{F}_E + \vec{F}_B$$

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

↓

Lorentz force

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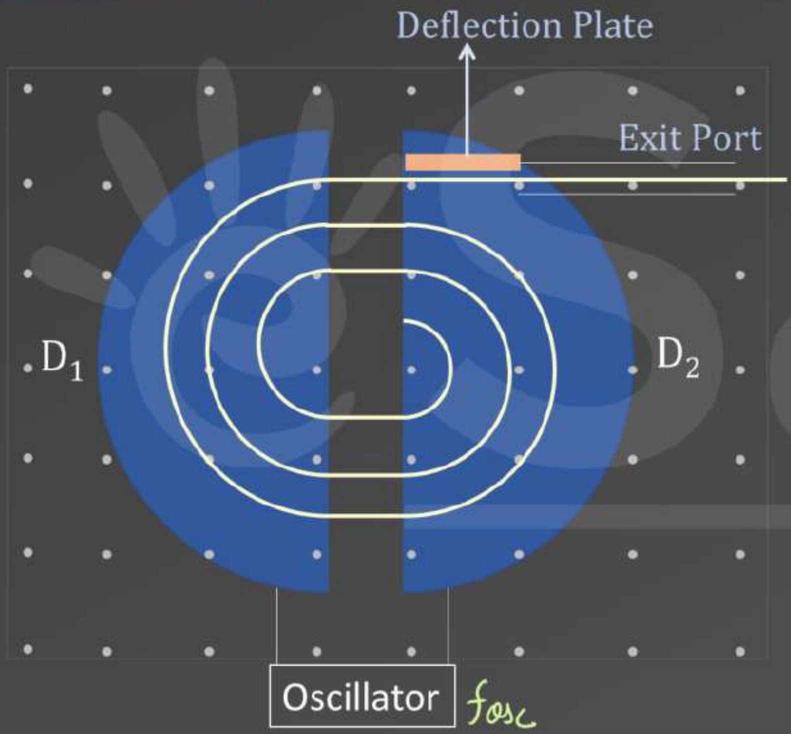
Cyclotron



Cyclotron frequency

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

Cyclotron uses the fact that frequency of revolution of charged particle in magnetic field is independent of its speed or radius of orbit.

$$f_{osc} = f_c$$

Resonance Condition

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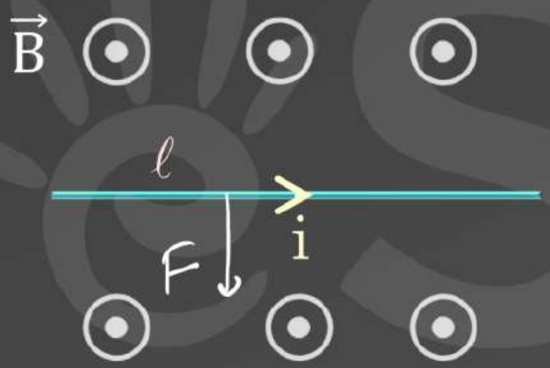
Magnetic Force on a Current Carrying Wire Kept in Magnetic Field

$\vec{B}$ is Uniform and Wire is Straight



$\vec{F} \perp \vec{\ell}$

$\vec{F} \perp \vec{B}$

$\vec{F} = i\,\vec{\ell} \times \vec{B}$

$i\ell B \sin\theta$

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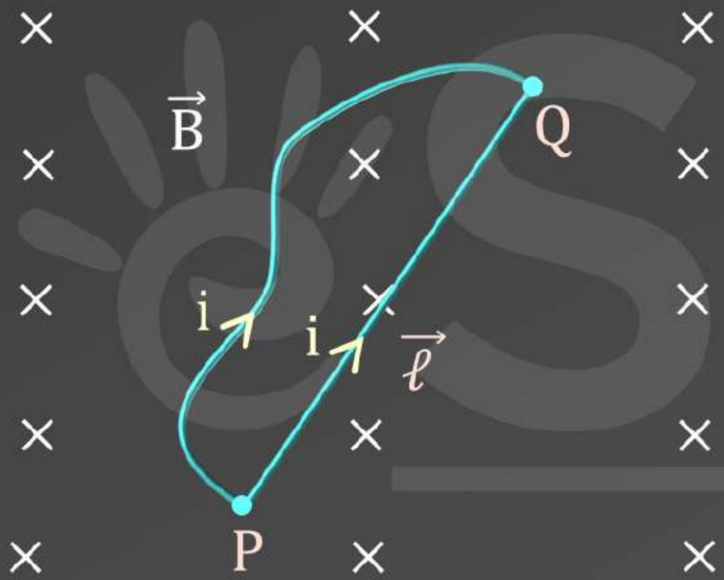
$\vec{B}$ Uniform and Arbitrary Shaped Wire



$\vec{F} = i\,\vec{\ell} \times \vec{B}$

$\vec{\ell}$ → Vector joining end points

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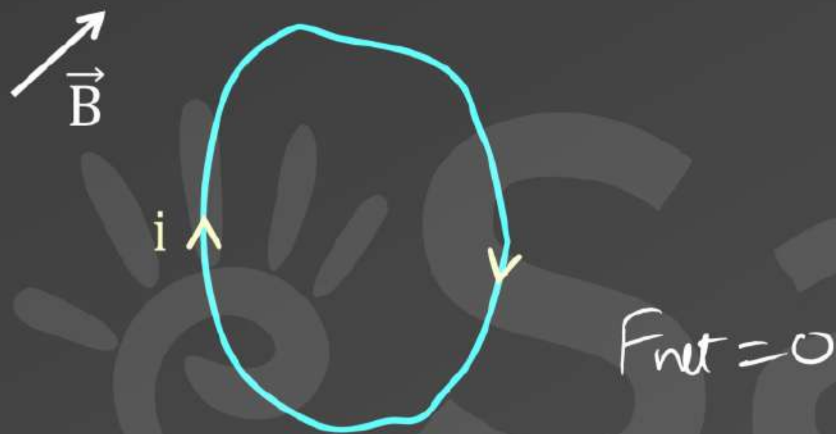

KEY POINT

Net magnetic force on closed loop due to uniform $\vec{B}$ is zero.

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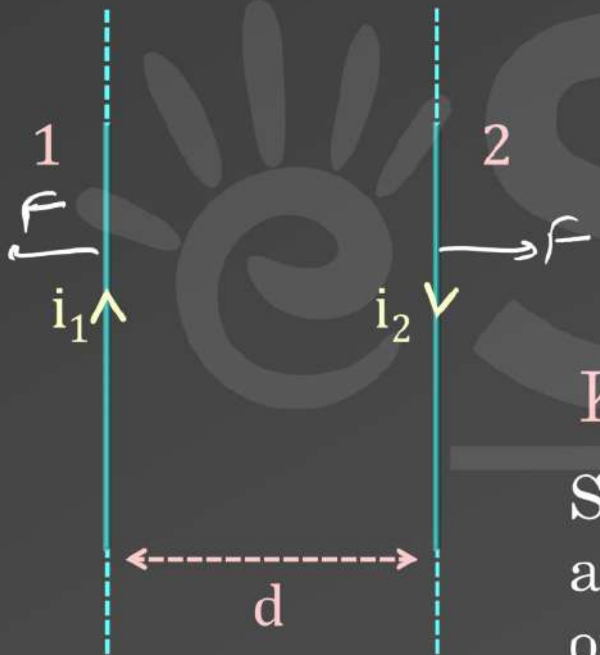
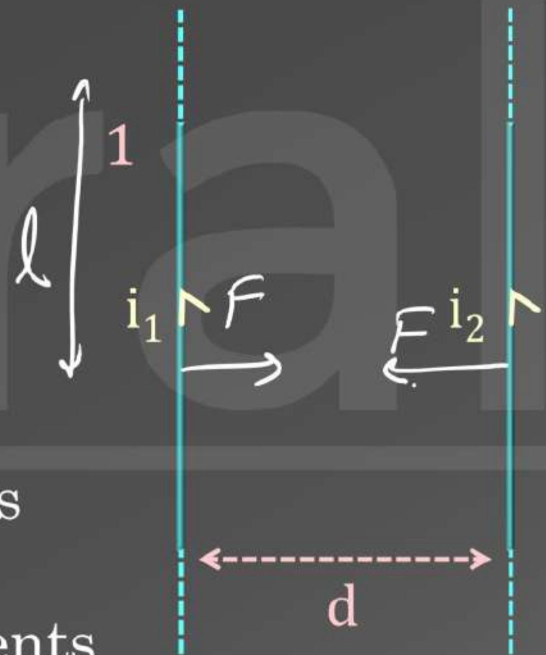
Magnetic Force Between Two Current Carrying Wires

Case 1 When wires are parallel to each other



$$\frac{F}{\ell} = \frac{\mu_0 \, i_1 i_2}{2\pi d}$$



Key Point

Same direction currents attract each other and opposite direction currents repel each other.

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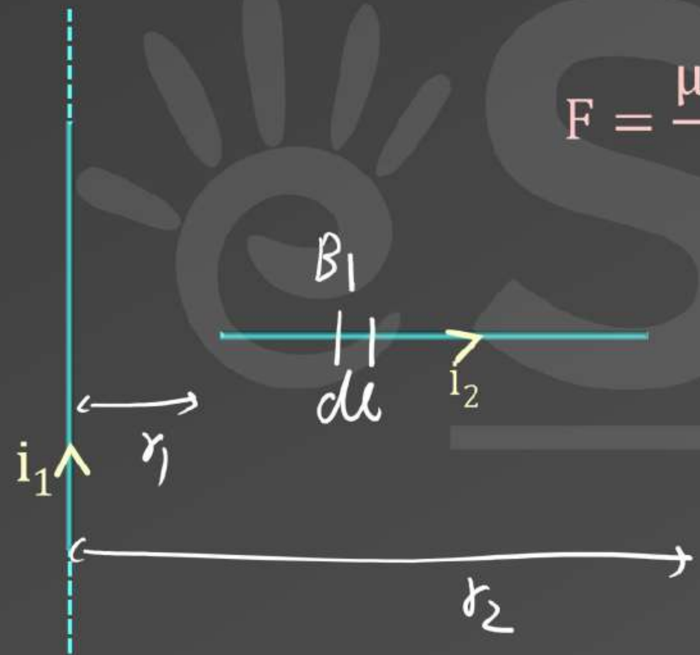
Case 2 When wires are perpendicular to each other.



$$F = \frac{\mu_0 i_1 i_2}{2\pi} \ell n \frac{r_2}{r_1}$$

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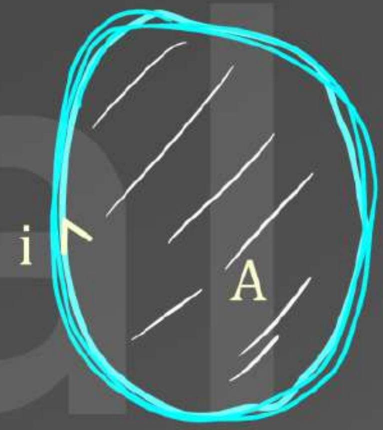
Magnetic Moment

$\vec{\mu} = N i \vec{A}$ → Area vector of the loop

↓

Magnetic Moment of the loop



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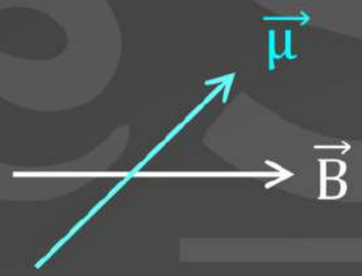
Key Point

Magnetic field try to align $\vec{\mu}$ along $\vec{B}$ from smaller angle side.



$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

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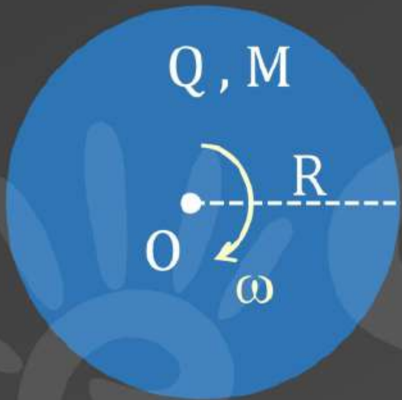
Magnetic Moment due to Rotation of Charge



Ang mom.

$$\frac{\mu}{L} = \frac{Q}{2m}$$ → Holds for all uniformly charged and mass bodies

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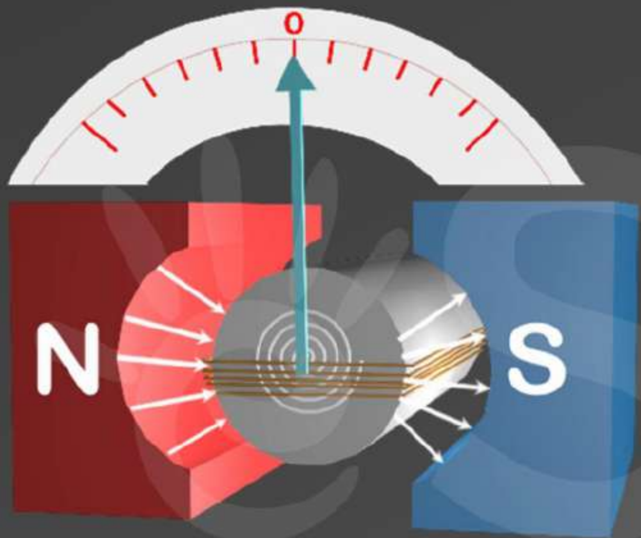
Moving Coil Galvanometer



Cylindrical soft iron core makes field radial and also increases its strength.

$$\tau = NIAB = k\theta$$

$$\text{Deflection in G } \theta = \frac{NIAB}{k}$$

$$\text{Current Sensitivity} = \frac{\theta}{I} = \frac{NAB}{k}$$

$$\text{Voltage Sensitivity} = \frac{\theta}{V} = \frac{NAB}{kR}$$

R → Total Resistance of Coil

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Lets Meditate !!

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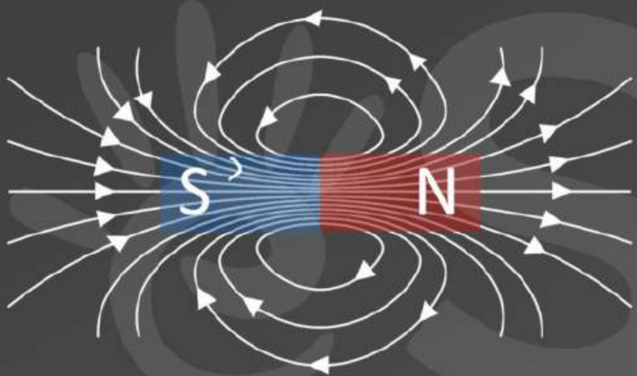
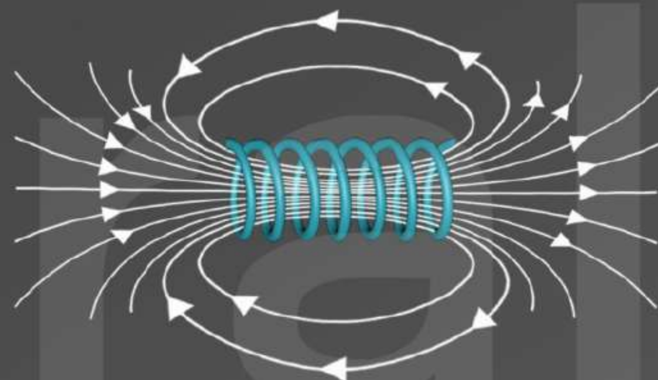
Magnetic Field Lines



The magnetic field lines of a magnet form continuous closed loops.



The magnetic field lines of a solenoid form continuous closed loops.

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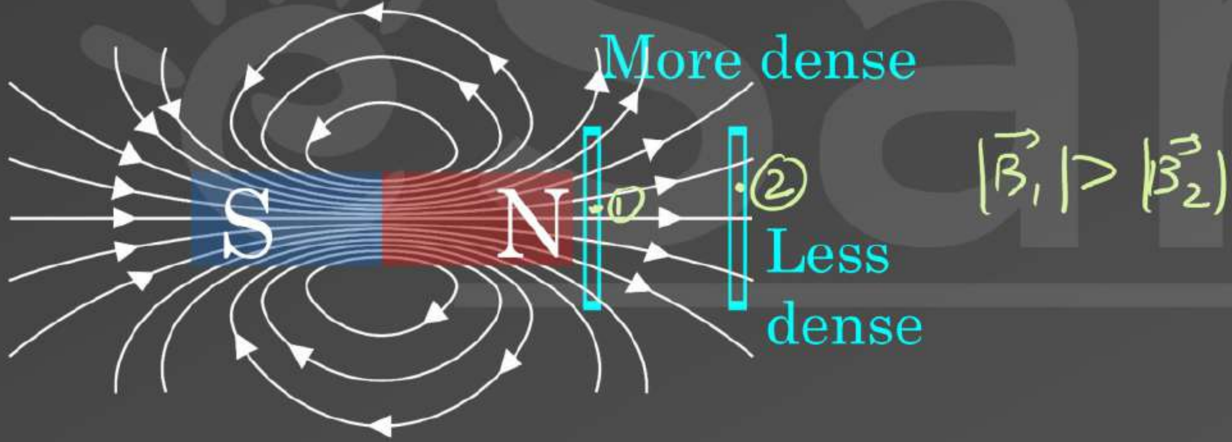
Magnetic Field Lines

The magnetic field lines do not intersect.



Magnetic field lines always form closed loops.

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Electrostatic Analog

$\vec{B}$	$\vec{E}$
$\vec{m}$	$\vec{p}$
μ_0	$\frac{1}{\varepsilon_0}$
$\vec{B}_{axial} = \frac{\mu_0}{4\pi}\frac{2\vec{m}}{r^3}$	$\vec{E}_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3}$
$\vec{B}_{eq} = -\frac{\mu_0}{4\pi}\frac{\vec{m}}{r^3}$	$\vec{E}_{eq} = -\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3}$

$\frac{K2\vec{P}}{r^3}$

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Electrostatic Analog

$\vec{B}$	$\vec{E}$
$\vec{\tau} = \vec{m} \times \vec{B}$	$\vec{\tau} = \vec{p} \times \vec{E}$
$U = -\vec{m}.\vec{B}$	$U = -\vec{p}.\vec{E}$

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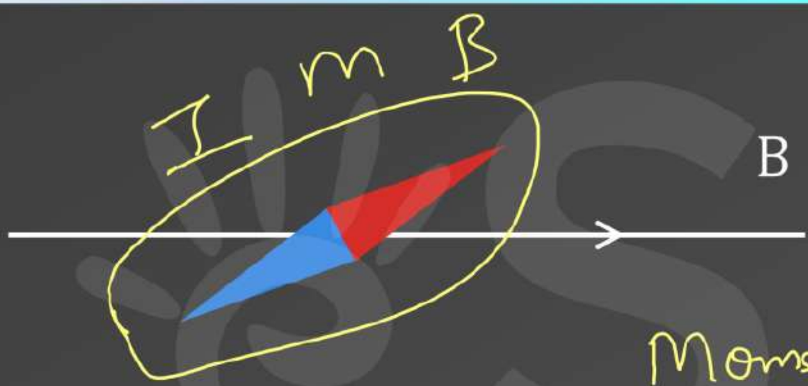
Dipole in Uniform Magnetic Field



$\vec{p}$, $\vec{E}$

$\vec{\tau} = \vec{\mu} \times \vec{B}$

Moment of Inertia

Time Period $T = 2\pi\sqrt{\frac{I}{mB}}$

$\sqrt{\frac{I}{mB}}$

$T = 2\pi\sqrt{\frac{I}{pE}}$

$T = 2\pi\sqrt{\frac{I}{mdg}}$

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Q) A magnetic needle of magnetic moment 6.7×10^{-2} Am^2 and moment of inertia 7.5×10^{-6} Kg m^2 is performing simple harmonic oscillation in a magnetic field of 0.01 T. Time taken for 10 complete oscillations is

(1) 6.98 s (2) 8.76 s (3) 6.65 s (4) 8.89 s

JEE Main 2017

Sol.

10T

$$T = 2\pi\sqrt{\frac{I}{mB}}$$

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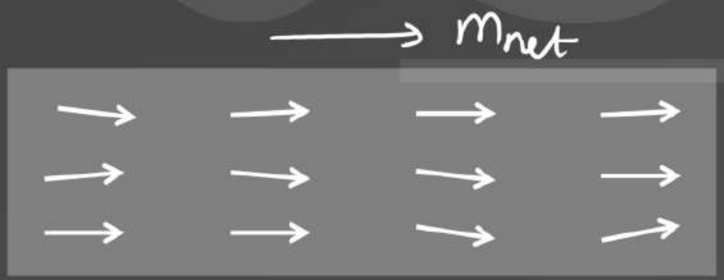
Magnetisation

$$\vec{M} = \frac{\vec{m}_{net}}{V} = \frac{\text{Net Magnetic Moment}}{\text{Volume}}$$

↓

Magnetisation



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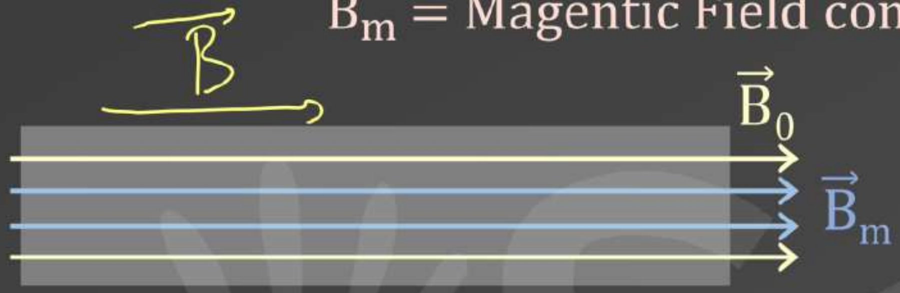
$\vec{B}$ = Net Magnetic Field

$\vec{B}_0$ = External Magnetic Field

$\vec{B}_m$ = Magentic Field contributed by the material core



$\frac{\epsilon}{\epsilon_0} = \epsilon_r$ $\frac{\mu}{\mu_0} = \mu_r$

μ_0 = Permeability of Vacuum

$\vec{H}$ = Magnetic Intensity

$\vec{M}$ = Magnetisation

χ = Magnetic Susceptibility

μ_r = Relative Permeability of medium w.r.t. vacuum

μ = Permeability of Medium

$$\vec{B} = \mu_0 (1 + \chi)\vec{H}$$

$$\vec{B} = \mu_0 \mu_r \vec{H}$$

$$\vec{B} = \mu \vec{H}$$

$$\mu\vec{H} \quad \mu_0\vec{H} \quad \mu_0\vec{M}$$

$$\vec{B} = \vec{B}_0 + \vec{B}_m$$

$$\vec{B} = \mu_0 (\vec{H} + \vec{M})$$

$$\vec{M} = \chi \vec{H}$$

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Classification of Magnetic Materials

$\mu_r = 1 + \chi$ $\quad \frac{\mu}{\mu_0} = \mu_r$

Properties	Diamagnetic	Paramagnetic	Ferromagnetic
χ μ_r μ	$-1 \leq \chi < 0$ $0 \leq \mu_r < 1$ $\mu < \mu_0$	$0 < \chi < k$ $1 < \mu_r < 1 + k$ $\mu > \mu_0$	$\chi >> 1$ $\mu_r >> 1$ $\mu >> \mu_0$
Magnetisation	Weak Magnetisation in opposite direction	Weak Magnetisation in Same direction	Strong Magnetisation in Same direction

B_0 $\quad B_m$ $\quad B_0$ $\quad B_m$

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Properties	Diamagnetic	Paramagnetic	Ferromagnetic
Movement in magnetic field	(Weak tendency) From strong to weak magnetic field	(Weak tendency) From weak to strong magnetic field	(Strong tendency) From weak to strong magnetic field
Magnet	Weak Repulsion	Weak Attraction	Strong Attraction

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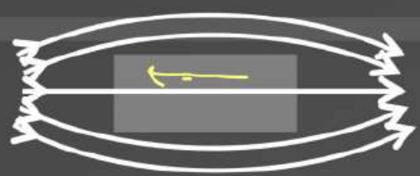
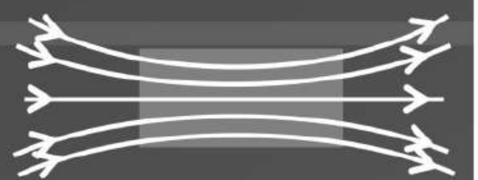
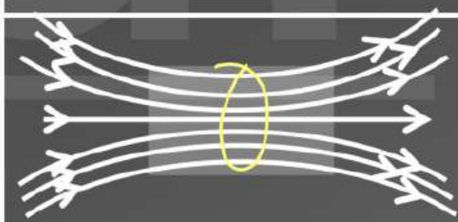
Properties	Diamagnetic	Paramagnetic	Ferromagnetic
E.g.	Bi, Au, Pb, Si, H_2O, NaCl, N_2 (STP)	Al, Na, Ca, O_2(STP)	Fe, Co, Ni,Gd
Magnetic Field Lines			

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Q) Magnetic susceptibility is negative for: NEET 2016

(1) Diamagnetic material only
(2) Paramagnetic material only
(3) Ferromagnetic material only
(4) Paramagentic and Ferromagnetic Materials

Ans 1

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Q) A diamagnetic material in a magnetic field moves

AIPMT 2003

(1) From stronger to the weaker parts of the field

(2) From weaker to the stronger parts of the field

(3) Perpendicular to the field

(4) In none of the above directions

Ans 1

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Q) There are four light–weight rod sample A,B,C,D separately by threads. A bar magnet is slowly brought near each sample and the following observations are noted:–

AIPMT (pre) 2011

(i) A is feebly repelled
(ii) B is feebly attracted
(iii) C is strongly attracted
(iv) D remains unaffected

Which one of the following is true?

(1) B is of a paramagnetic material
(2) C is of a diamagnetic material
(3) D is of a ferromagnetic material
(4) A is of a non–magnetic material

Ans 1

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Paramagnetic

$$\chi = C\,\frac{\mu_0}{T} \qquad \chi \propto \frac{1}{T}$$

→ Kelvin

Curie Law

C = Curie's constant

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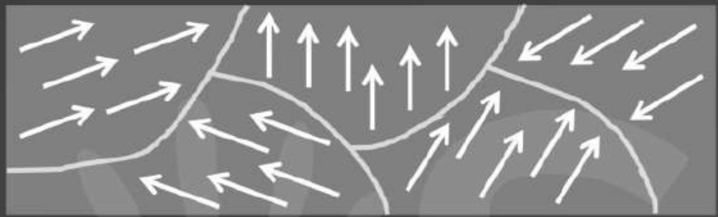
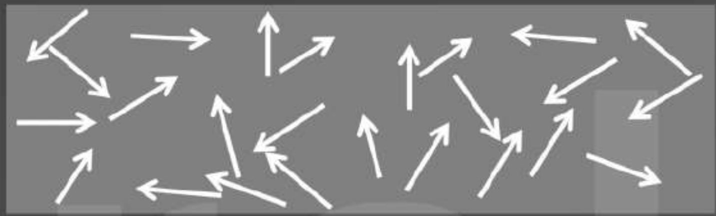
Ferromagnetic





At high enough temperature, a ferromagnet becomes a paramagnet.

This temperature of transition from ferromagnetic to paramagnetic is called Curie Temperature T_C.

Above Curie Temperature in paramagnetic phase,

$$\chi \propto \frac{1}{T - T_C} \qquad \chi \propto \frac{1}{T} \qquad T > TC$$

$$\chi = \frac{C}{T - T_C} \qquad \chi \propto \frac{1}{T - T_C}$$

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Q) A paramagnetic material has 10^{28} atoms/m^3. Its magnetic susceptibility at temperature 350 K is 2.8×10^{-4}. Its susceptibility at 300 K is :

JEE Main 2019 (12 Jan Shift 2)

(1) 3.672×10^{-4} (2) 3.726×10^{-4} (3) 3.267×10^{-4} (4) 2.672×10^{-4}

Sol. $\chi \propto \frac{1}{T_C}$ Curie law for Paramagnetic substance

$$\frac{\chi_1}{\chi_2} = \frac{T_{C_2}}{T_{C_1}}$$

Ans 3

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Q) Nickel shows ferromagnetic property at room temperature. If the temperature is increased beyond Curie temperature then it will show :

AIPMT 2007

(1) Diamagnetism
(2) Paramagnetism
(3) Anti ferromagnetism
(4) No magnetic property

Ans 2

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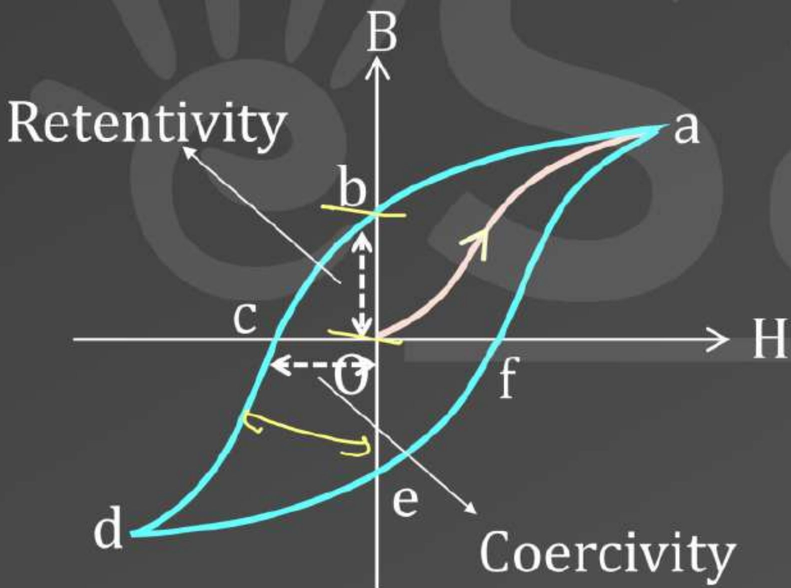
Magnetic Hysteresis



Retentivity (or Remanence): The value of magnetic field (B) at H=0.

Coercivity: It is the value of H applied in opposite direction to destroy residual magnetism.

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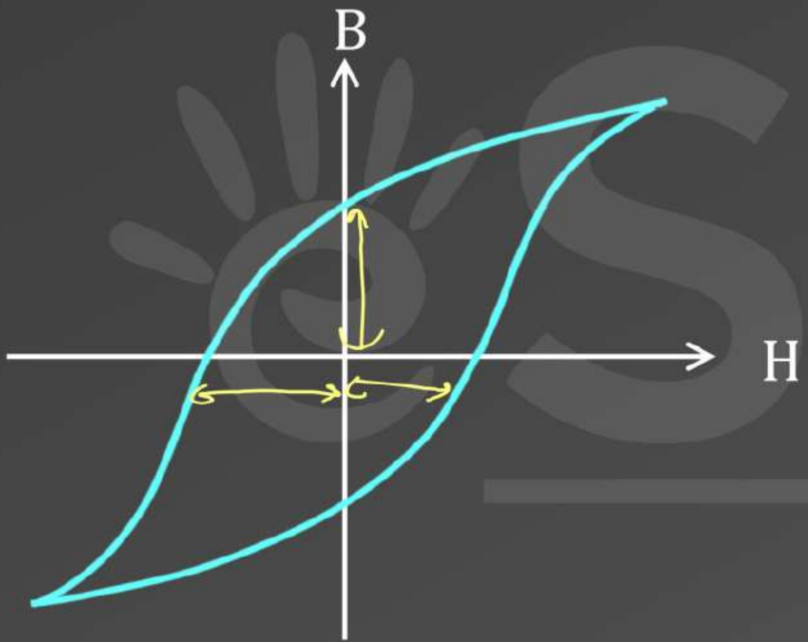
Permanent Magnets



High Retentivity

High Coercivity

E.g. Steel

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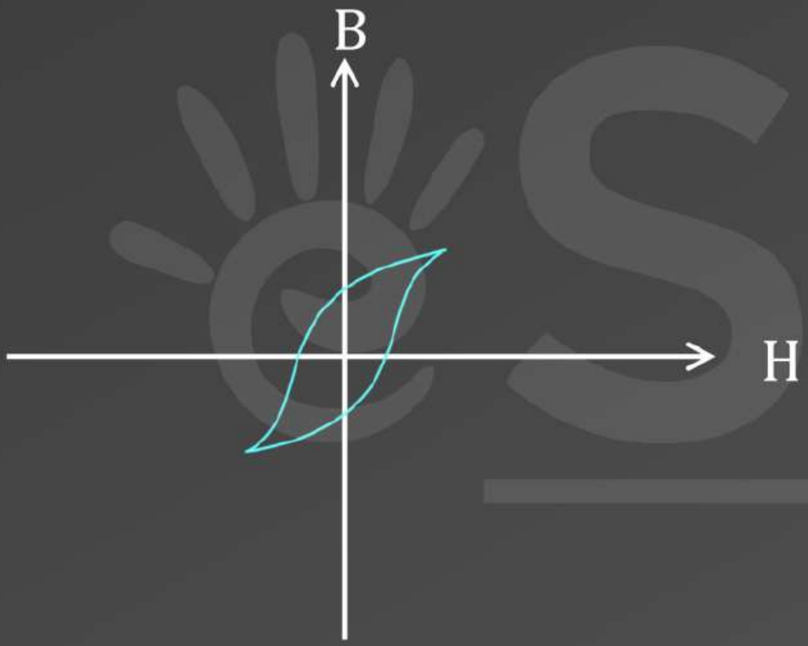
Electromagnets



Low Retentivity

Low Coercivity

E.g. Soft Iron

Uses: Electromagnet, Transformer, Motor, Generator Cores.

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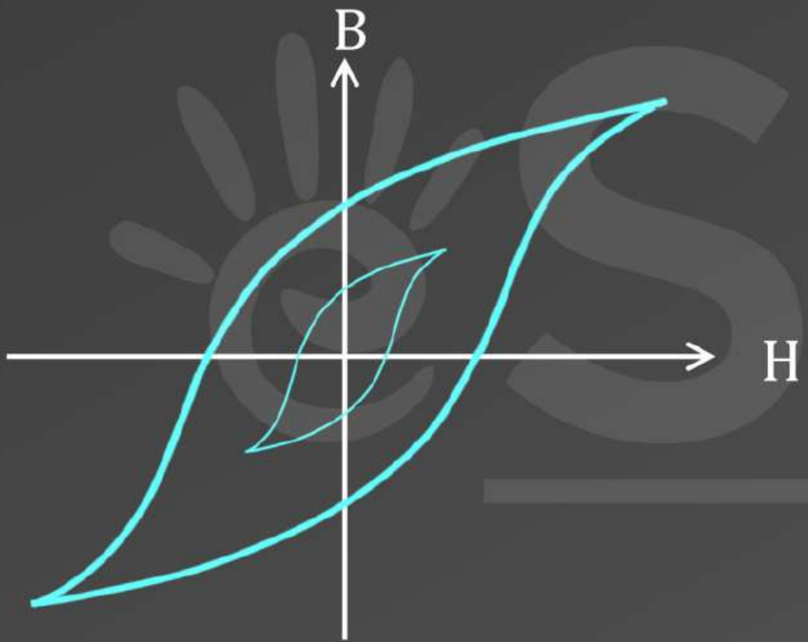
Hysteresis Loss



Hysteresis Loss: It is the energy lost in form of heat during a complete cycle of magnetization and demagnetization.

Area of hysteresis loop is proportional to the energy loss per unit volume.

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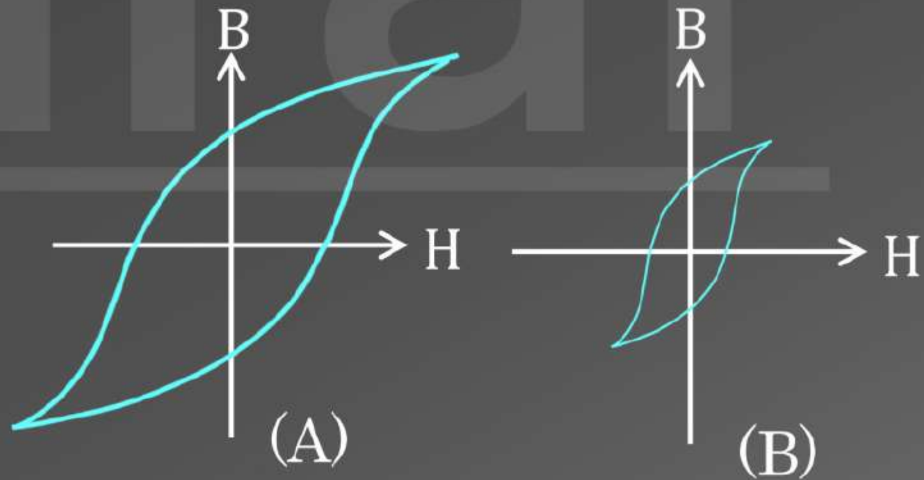
JEE Main 2016

Q) Hysteresis loops for two magnetic materials A and B are given below. These materials are used to make magnets for electric generators, transformer core and electromagnet core. Then it is proper to use.

(1) B for electromagnets and transformers.
(2) A for electric generators and transformers.
(3) A for electromagnets and B for electric transformers.
(4) A for transformers and B for electric generators.



Ans 1

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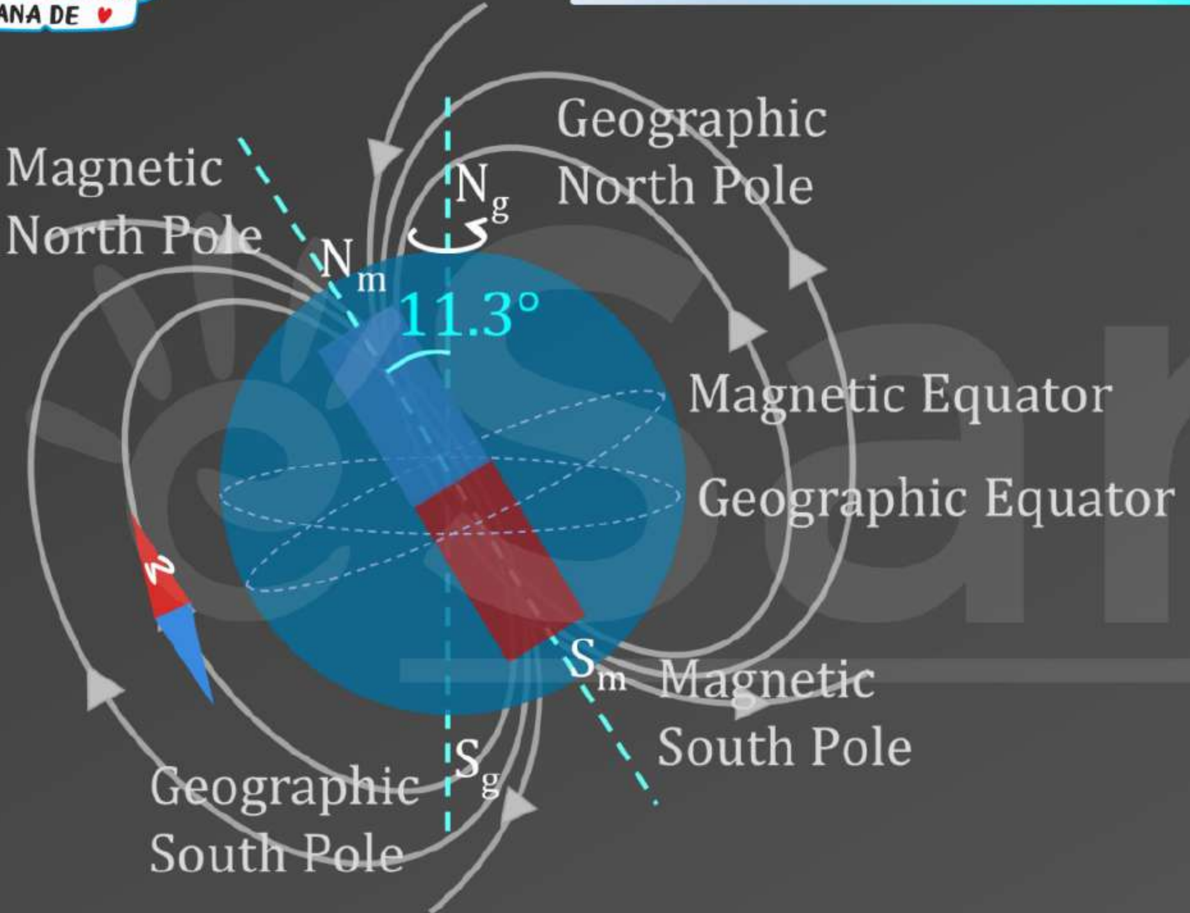
Earth's Magnetic Field



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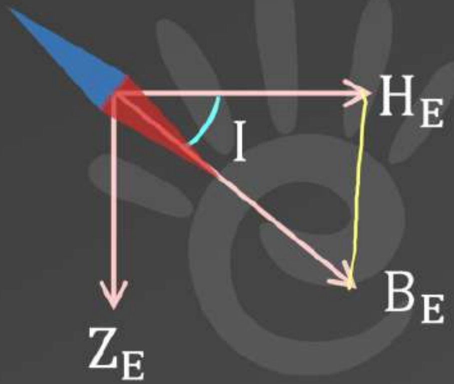
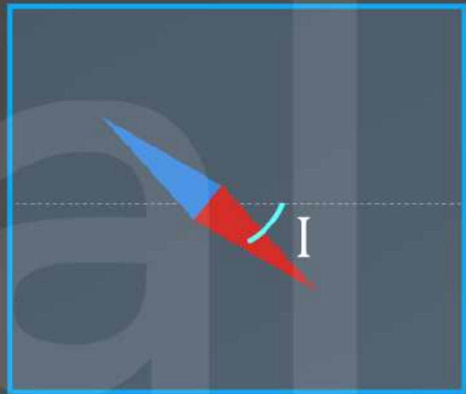
Angle of dip (inclination) $\tan I = \frac{Z_E}{H_E}$



Horizontal component of Earth's magnetic field



Vertical component of Earth's magnetic field

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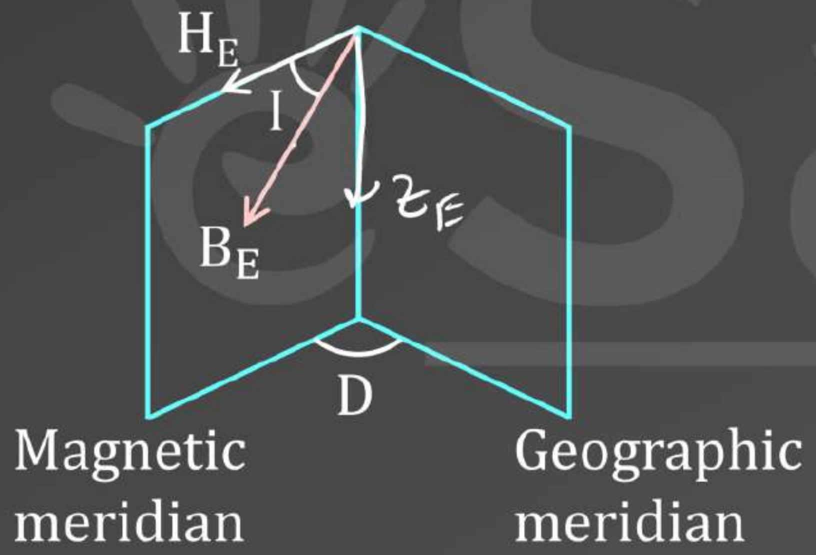
Elements of Earth's magnetic field:

1) Declination (D)
2) Angle of dip (I)
3) Horizontal component of Earth's field (H_E)



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- **ARR-46**, RPMT
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- **Ex HoD Biology**, Resonance, Kota
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Electromagnetic Induction

Superfast Revision

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Electromagnetic Induction

The phenomenon in which electric current is generated by varying magnetic fields is called Electromagnetic Induction (EMI).

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Magnetic Flux

Magnetic flux through an area A is given by ϕ

$$\phi = \int \vec{B}.d\vec{A}$$

SI unit of ϕ is weber (Wb) or Tesla meter^2 (T m^2).

If $\vec{B}$ is uniform

$$\phi = \vec{B} \cdot \vec{A}$$

$$\phi = |\vec{B}| \times |\vec{A}| \cos\theta$$

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Faraday's Law of Induction

$$\mathcal{E} = \left|\frac{d\phi}{dt}\right|$$

↓

EMF Induced

If N turns, $\mathcal{E} = N\left|\frac{d\phi}{dt}\right|$

$$<\mathcal{E}> = \left|\frac{\Delta\phi}{\Delta t}\right|$$

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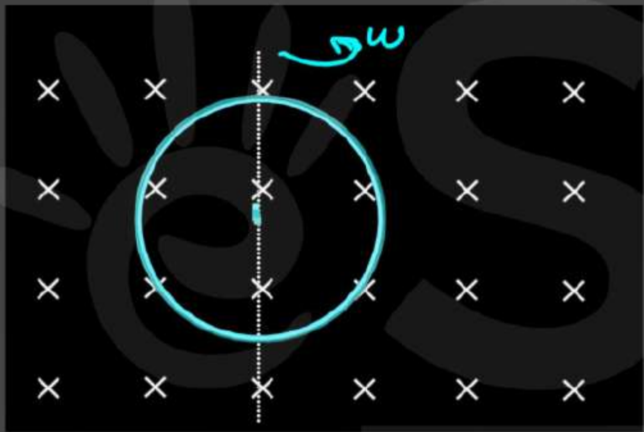
Q) Find instantaneous EMF if ring is rotated about it's vertical diameter with angular speed ω rad/sec.



$\phi = BA\cos\omega t$

Sol.

$|\varepsilon| = BA\omega\sin\omega t$

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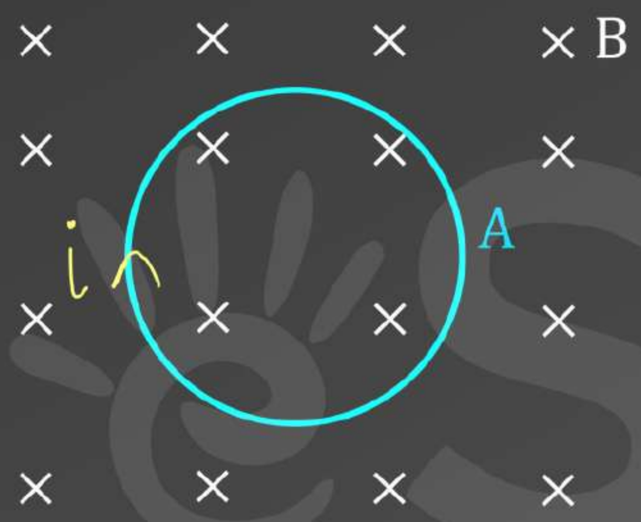

Charge flown in time t, $Q = \frac{\Delta\phi}{R}$ → Resistance

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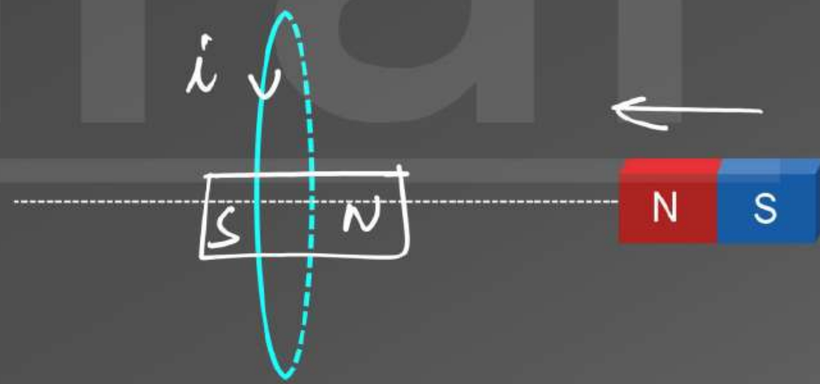
Lenz's Law

Induced emf opposes its cause of generation.

Lenz's law is based on law of conservation of energy.

$$\varepsilon = -\frac{d\phi}{dt}$$



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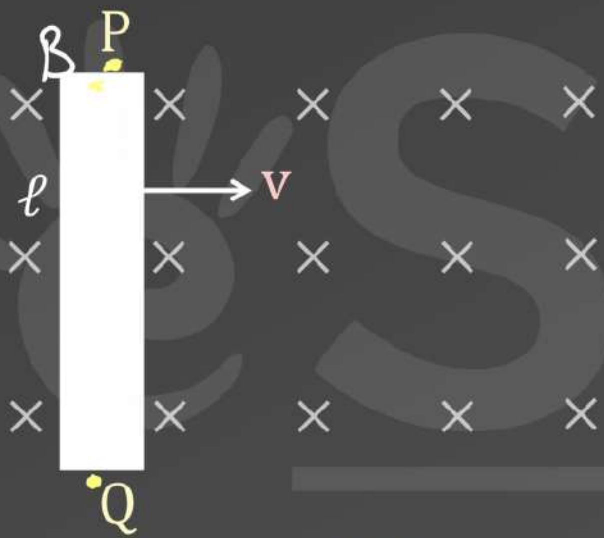
Motional EMF



$$v_P - v_Q = B\ell v$$

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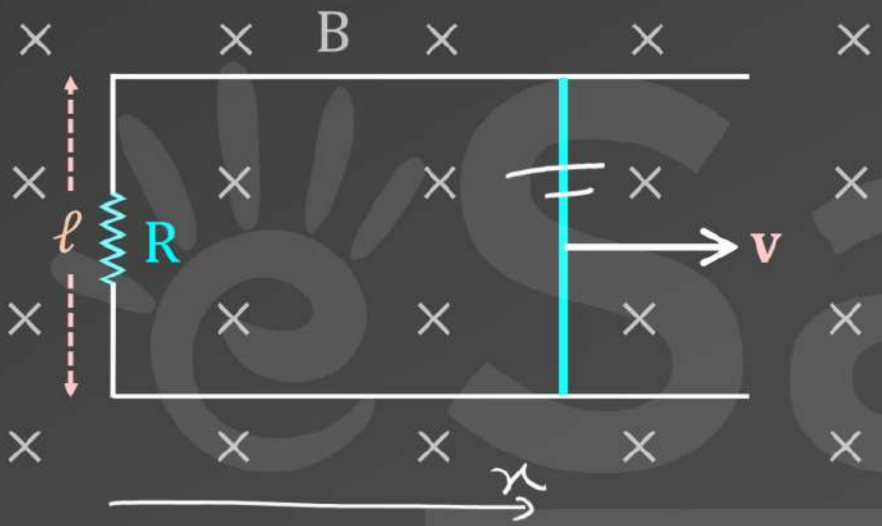
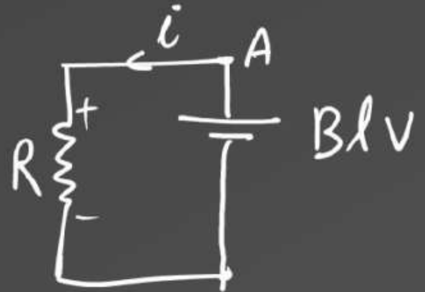
Q) Find the induced current in the circuit.



$$\frac{Bl v}{R} = i$$

Sol.



$$i = \frac{B\ell v}{R}$$

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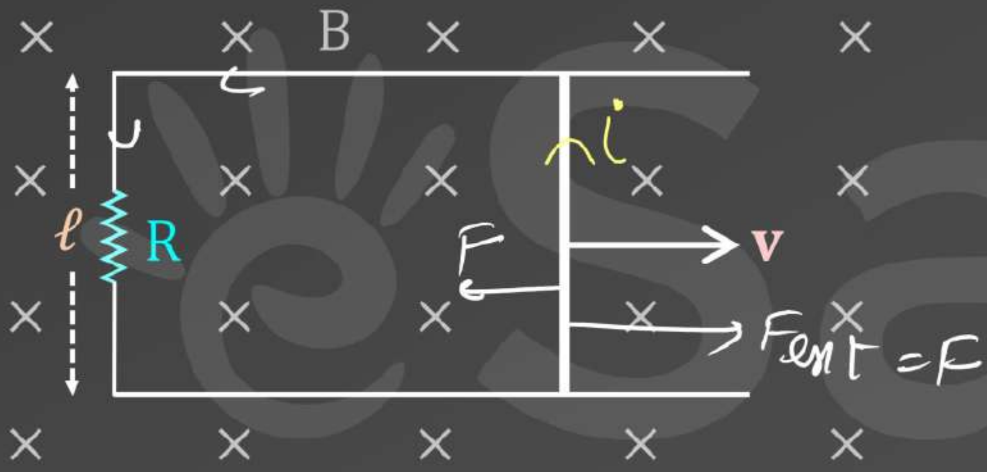
Force and Power Analysis



$$F = F_{ext} = \frac{B^2 \ell^2 v}{R}$$

$$P_{ext} = F_{ext} v \frac{B^2 \ell^2 v^2}{R} = P_{loss}$$

$i^2 R$

$i = \frac{B\ell v}{R}$

$i \ell B$

$\frac{B\ell v}{R} \ell B$

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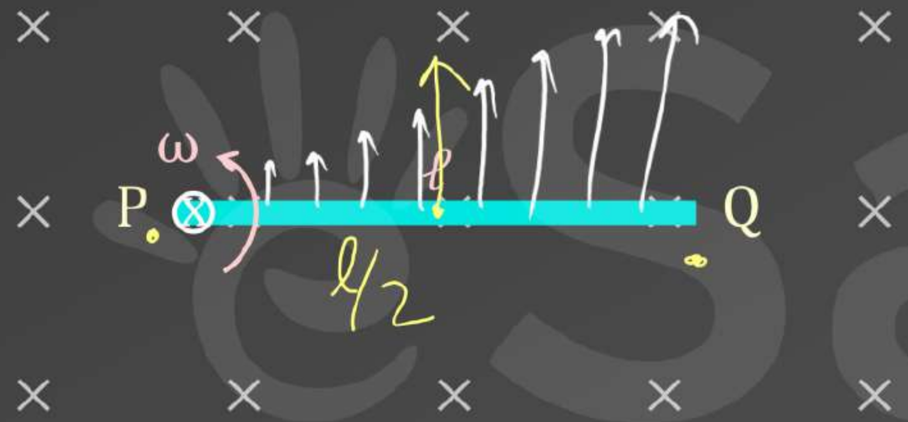
EMF due to Rotation of Wire



$B\ell v$ $\quad$ $B\ell\dfrac{\omega\ell}{2}$

$$\mathcal{E} = V_p - V_d = \frac{B\omega\ell^2}{2}$$

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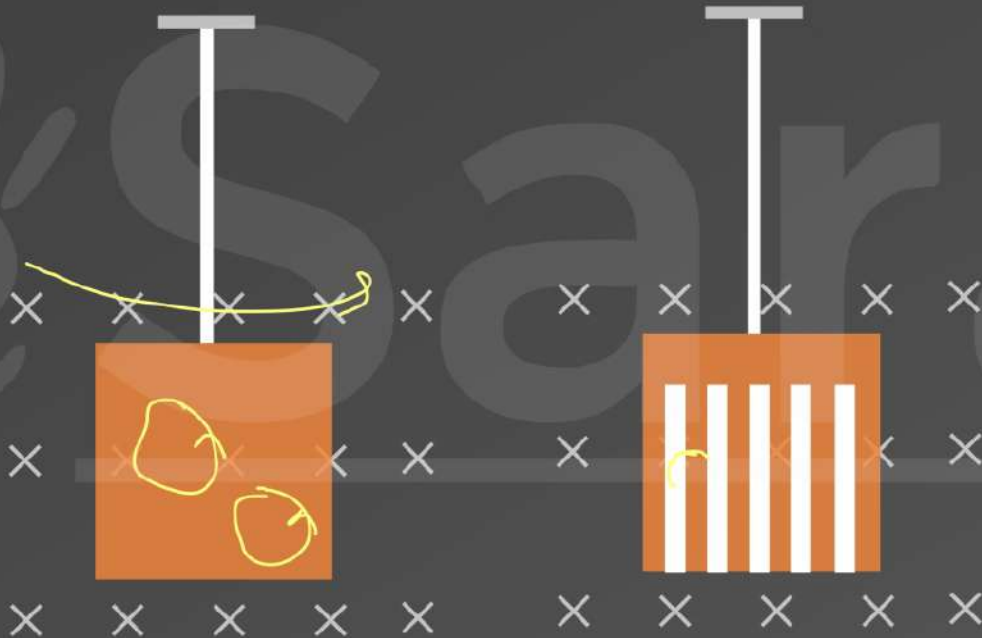
Eddy Currents



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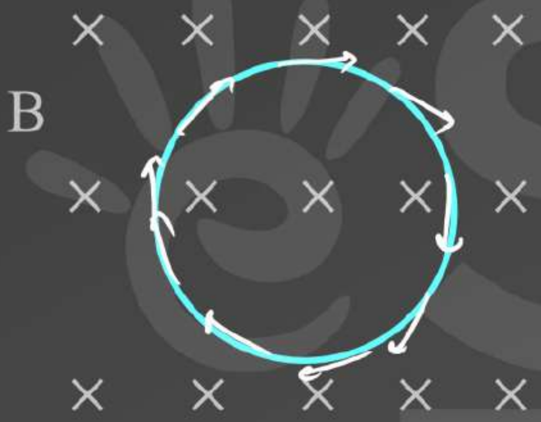
Induced Electric Field



$$\oint \vec{E} \cdot \overrightarrow{d\ell} = \frac{-d\phi_B}{dt}$$

- Produced by the changing magnetic field
- Non-electrostatic and non-conservative in nature
- Cannot define a potential for it
- Form closed loops. No source and sink

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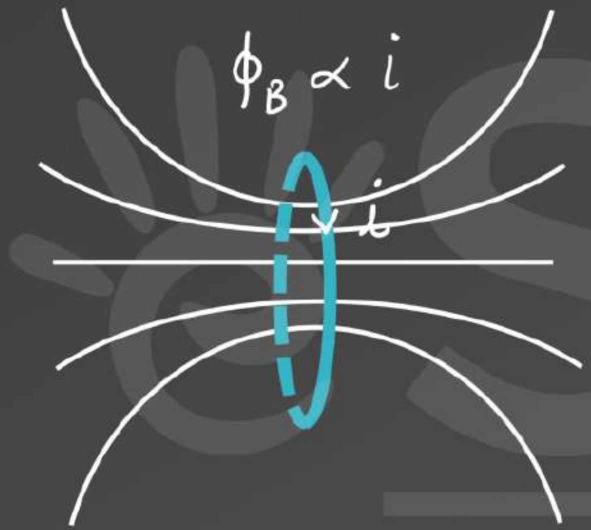
Self Inductance



Flux through a coil having current 'i' due to its own current is ϕ then

$$\phi = L\, i$$

↳ L → Self Inductance of Coil

L depends on

- Geometrical construction of coil
- Intrinsic material properties

SI unit of L is henry (H)

$$1 \text{ henry} = \frac{1 \text{ Weber}}{1 \text{ Ampere}}$$

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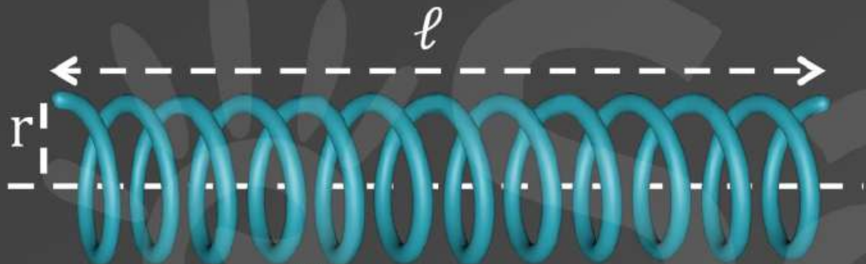
Q) Solenoid of length ℓ is given. n is the no. of turns per unit length, A is area of cross section, and its radius is r. Find its inductance.



$A = \pi r^2$

Sol. $L = \mu_0 n^2 A\ell$

$= \mu_0 n^2 \pi r^2 \ell$

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Symbolic Representation of Inductor

$$\phi = Li$$

$$\mathcal{E} = -\frac{L\,di}{dt}$$

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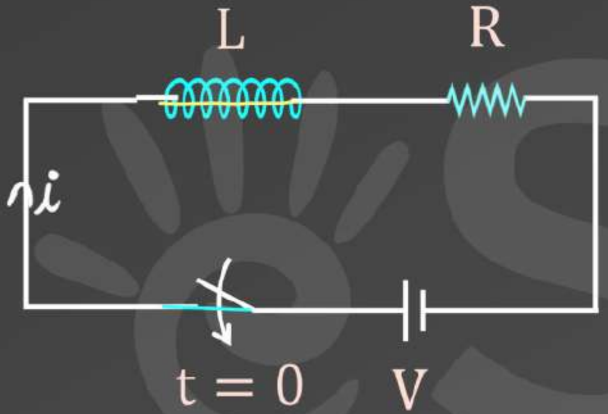
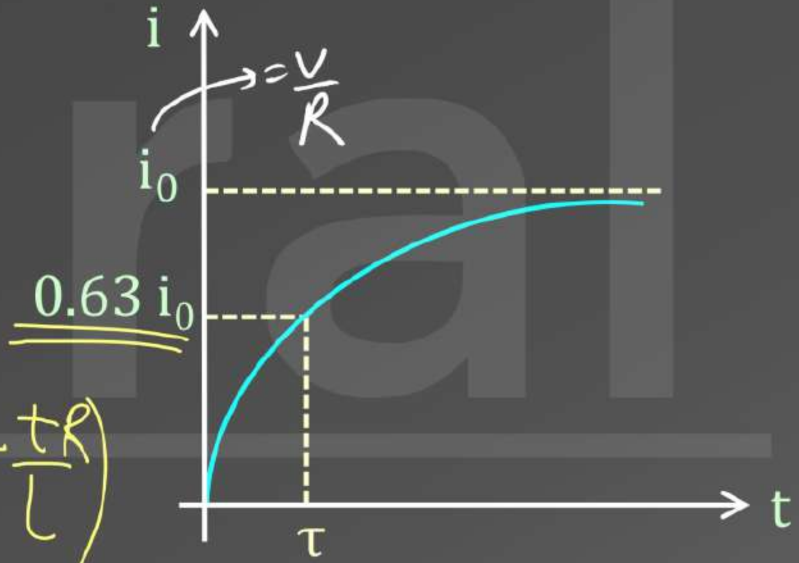
Growth of Current in LR Circuit

90%



1τ ⇒ 63%



$$i = \frac{V}{R}\left(1 - e^{-\frac{tR}{L}}\right) = \frac{V}{R}\left(1 - e^{-\frac{tR}{L}}\right)$$

$$1 \text{ Time constant } '\tau' = \frac{L}{R}$$

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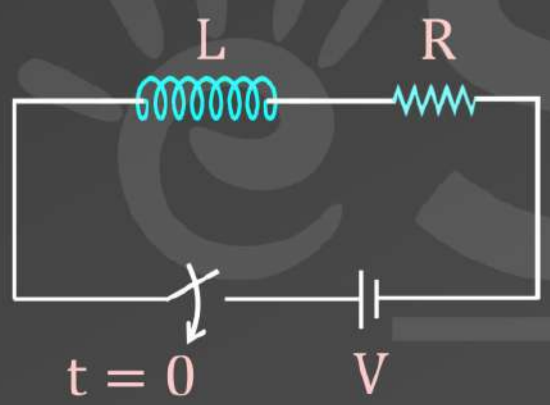
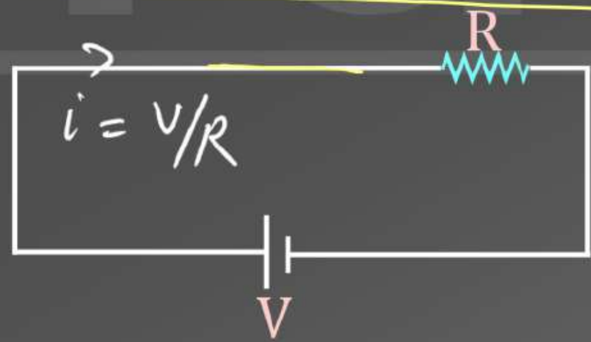
Circuit Analysis



At $t = 0$, Open the inductor

At $t = \infty$, Short the inductor



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Energy Stored in Inductor

Trick

$m \rightarrow V;\ KE = \frac{1}{2} m V^2$

$$\text{Energy} = \frac{1}{2} L i^2$$

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Magnetic Energy Density

Magnetic Energy Density $= \dfrac{B^2}{2\,\mu_0}$

↓

Energy Per Unit Volume

$\frac{1}{2}\epsilon_0 E^2$

$\frac{1}{2}\frac{1}{\mu_0}B^2$

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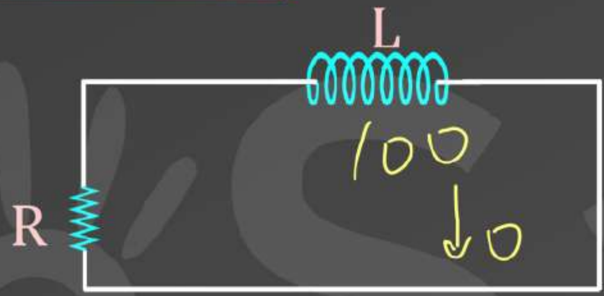
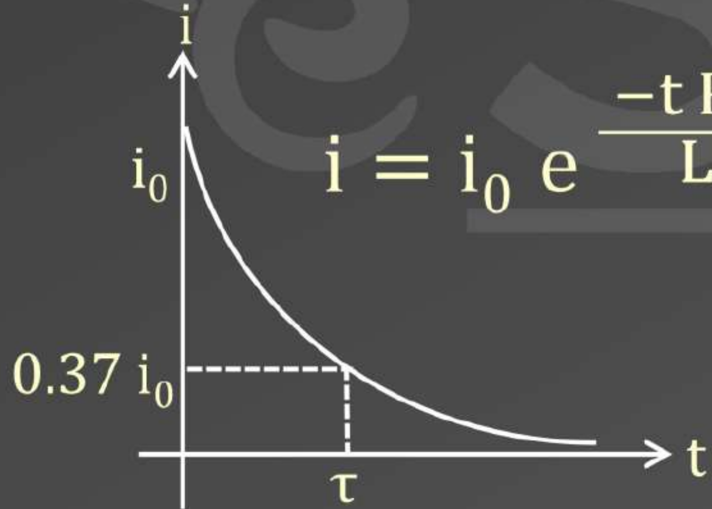
Decay of Current



$$i = i_0\, e^{\frac{-tR}{L}}$$



After 1τ, current decays by 63%.

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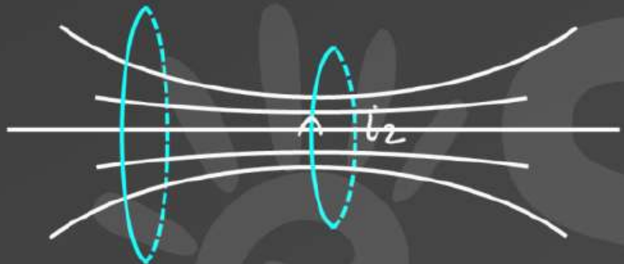
Mutual Inductance

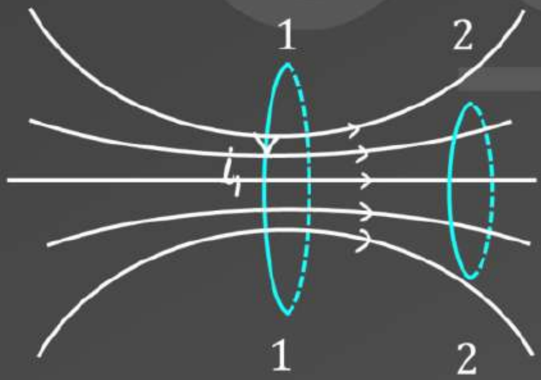


Theorem of Reciprocity

$$M_{21} = M_{12}$$

$$\phi_{21} = M_{21}\, i_1$$

M_{21} → Mutual Ind of ② wrt ①



$$\phi_{12} \propto i_2$$

$$\phi_{12} = M_{12}\, i_2$$

M_{12} → Mut Ind of ① wrt ②

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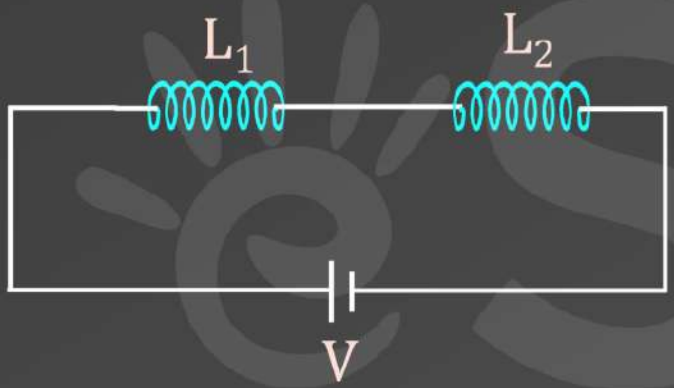
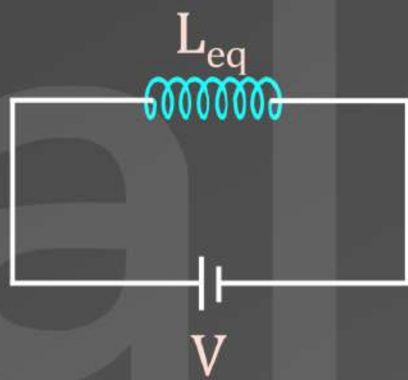
Inductors in Series



$$L_{eq} = L_1 + L_2$$



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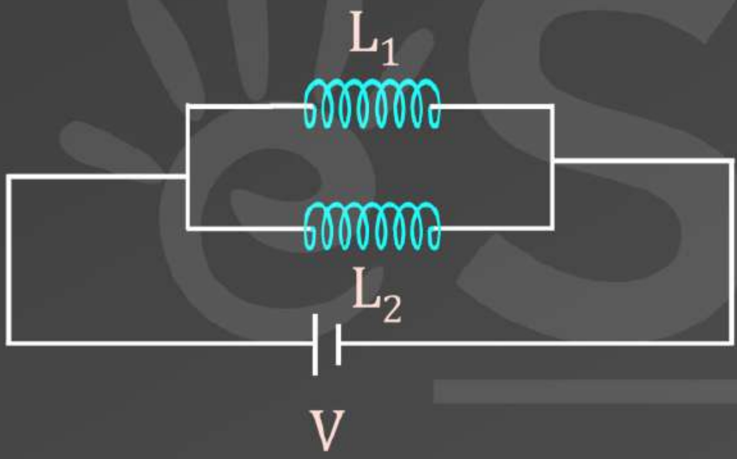
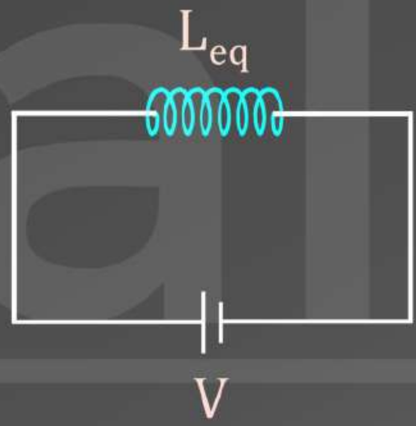
Inductors in Parallel



$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2}$$



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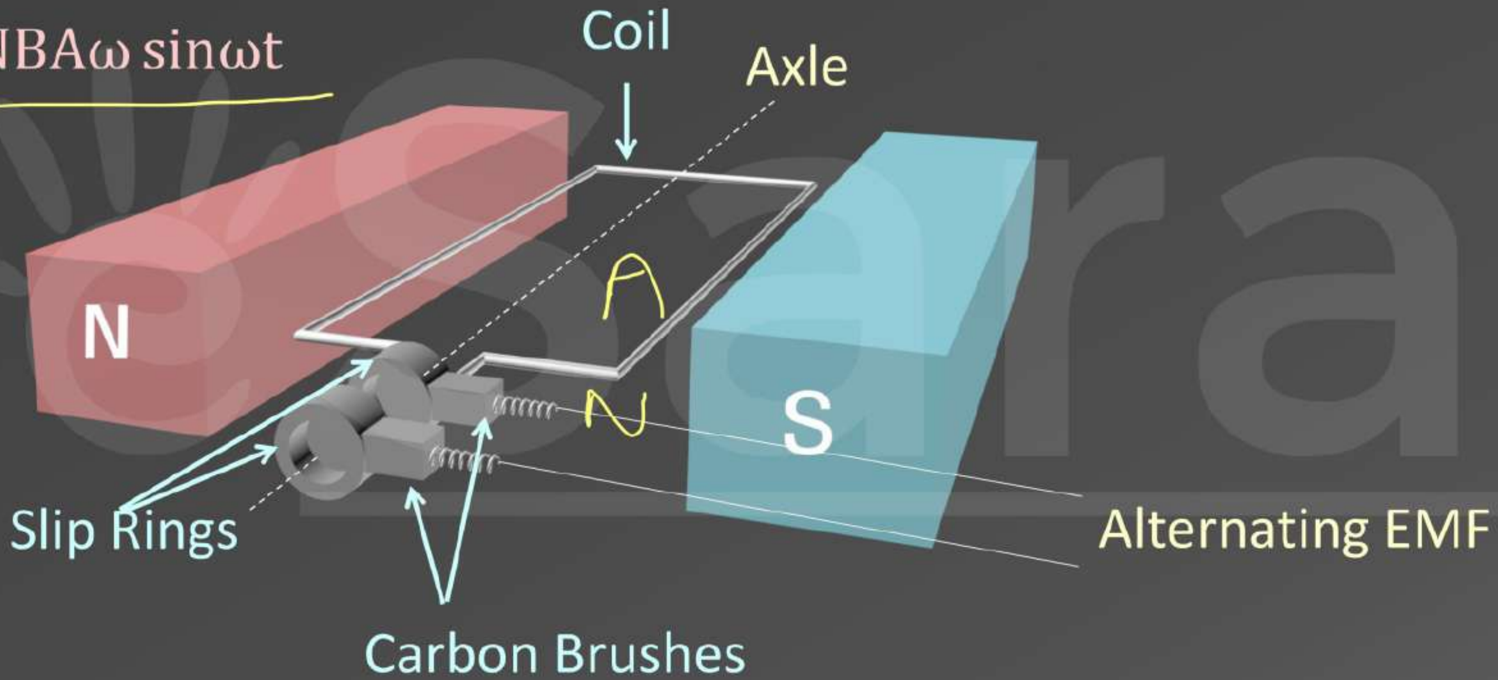
AC Generator

$\mathcal{E} = NBA\omega \sin\omega t$



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Lets Meditate !!

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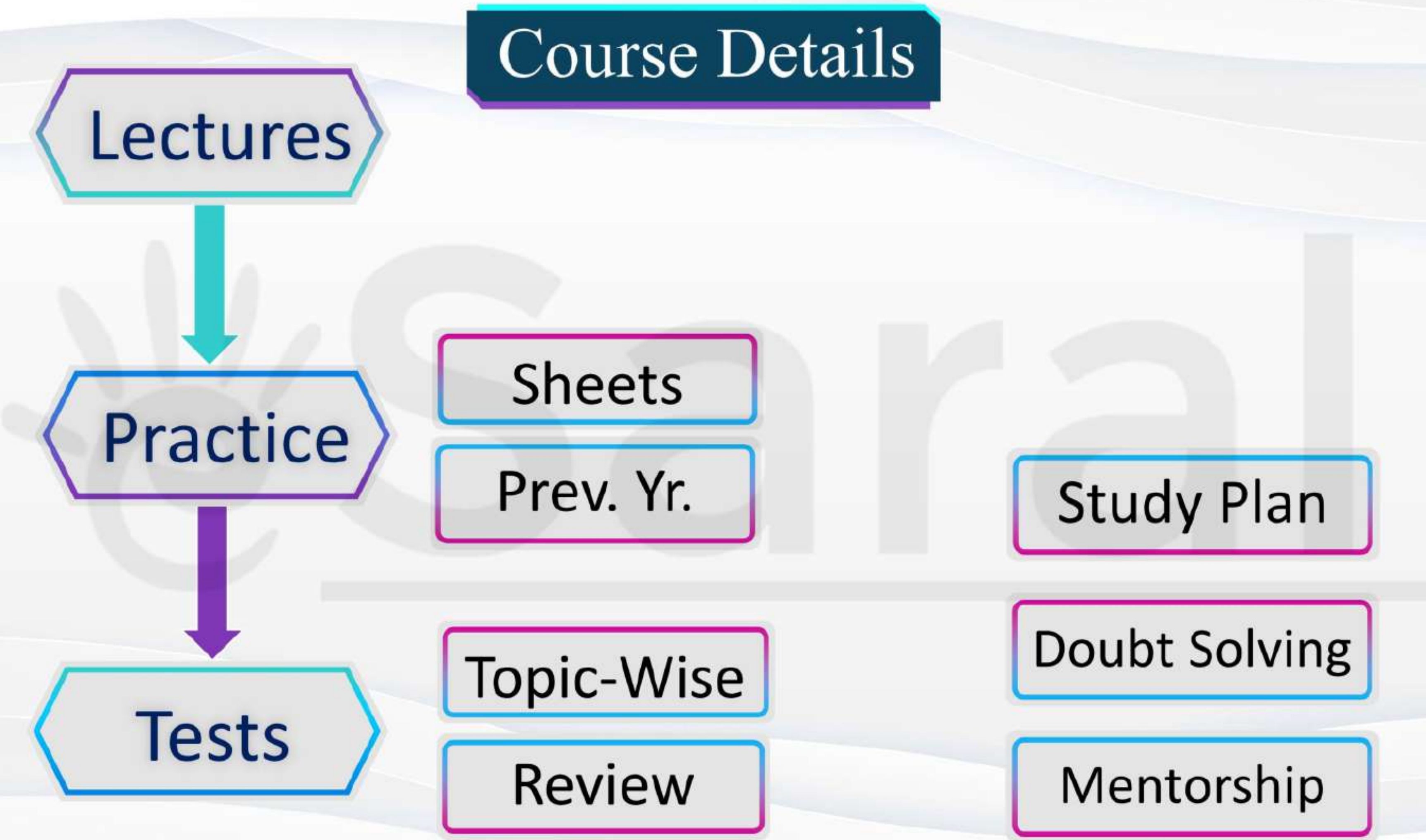

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Alternating Current
Superfast Revision

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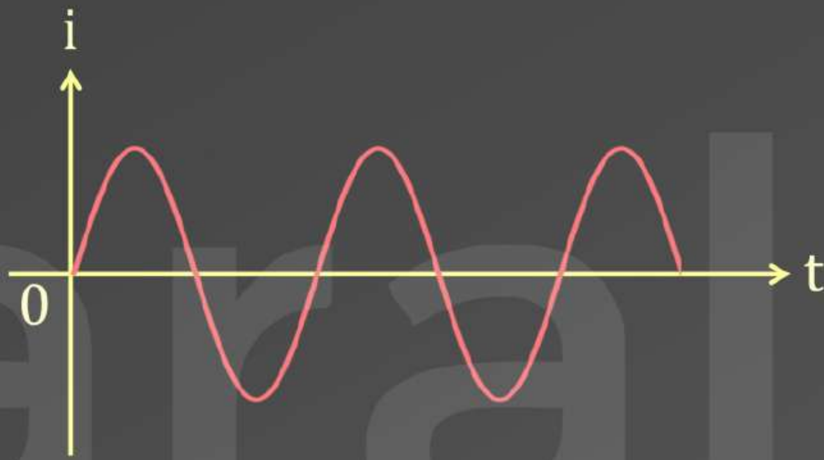
Alternating Current

If the direction of current changes alternately, it is called Alternating Current.

$V = V_0 \sin(\omega t)$



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R

Pure Resistive Circuit

$V = V_0 \sin(\omega t)$

$$i = \frac{V}{R} = \frac{V_0 \sin(\omega t)}{R}$$

$$i = i_0 \sin(\omega t)$$

$$i_0 = \frac{V_0}{R} \qquad i_{rms} = \frac{V_{rms}}{R}$$

$$i_{rms} = \frac{i_0}{\sqrt{2}} \qquad V_{rms} = \frac{V_0}{\sqrt{2}}$$

In pure resistive circuit V and i are in same phase.

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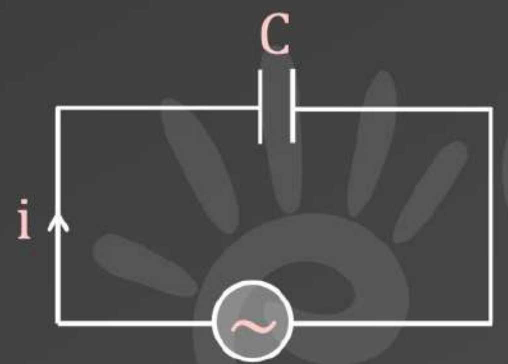
Pure Capacitive Circuit



$V = V_0 \sin(\omega t)$

$i = i_0 \sin\left(\omega t + \frac{\pi}{2}\right)$

$i_{rms} = \frac{V_{rms}}{X_C}$

Golden TRICK

$i_0 = \frac{V_0}{R}$

$i_0 = \frac{V_0}{X_C}$ $\quad X_C = \frac{1}{\omega C}$ $\rightarrow \Omega$

(Capacitive reactance)

In pure Capacitive circuit Current leads Voltage by phase $\frac{\pi}{2}$

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Pure Inductive Circuit

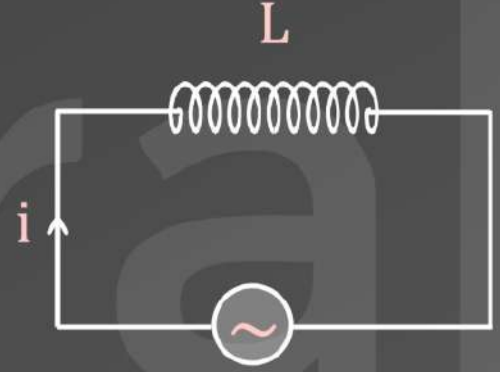
$$i = i_0 \sin\left(\omega t - \frac{\pi}{2}\right)$$

$$i_0 = \frac{V_0}{X_L} \qquad i_{rms} = \frac{V_{rms}}{X_L}$$

$X_L = \omega L$

$X_L = \omega L$ (inductive reactance)

{where X_L unit is Ω}



$V = V_0 \sin(\omega t)$

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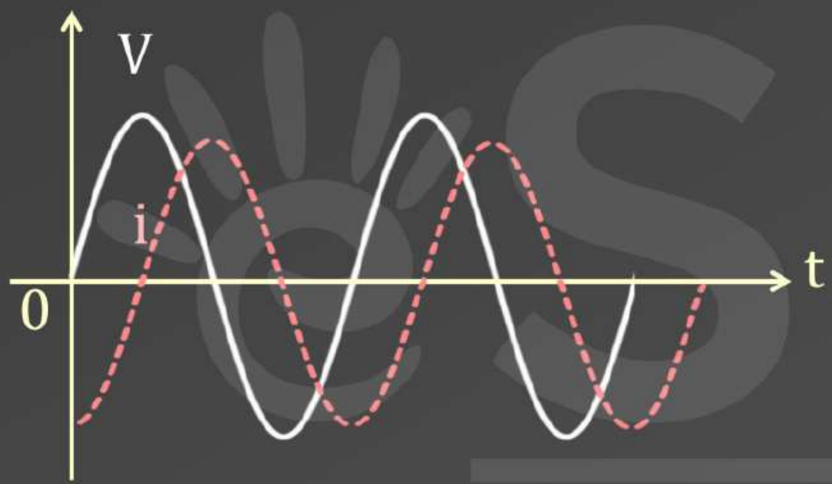
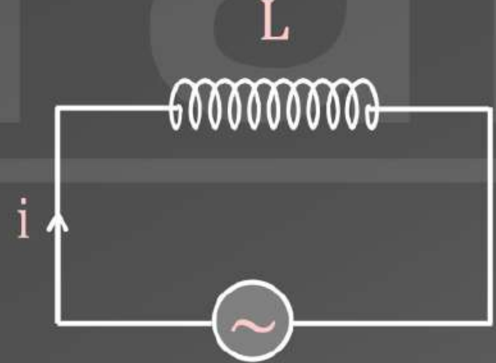
Pure Inductive Circuit



Keypoint

$V = V_0 \sin(\omega t)$ $\quad i = i_0 \sin\left(\omega t - \frac{\pi}{2}\right)$

In pure Inductive circuit Voltage leads Current by phase $\frac{\pi}{2}$



$V = V_0 \sin(\omega t)$

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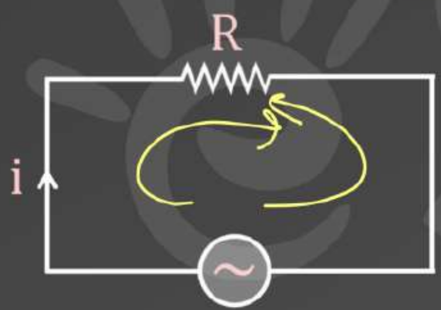
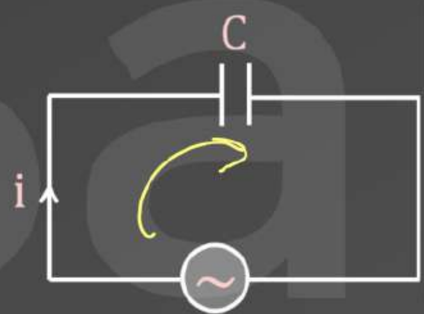
Power Analysis

$< P_R > = i_{rms}^2 R$



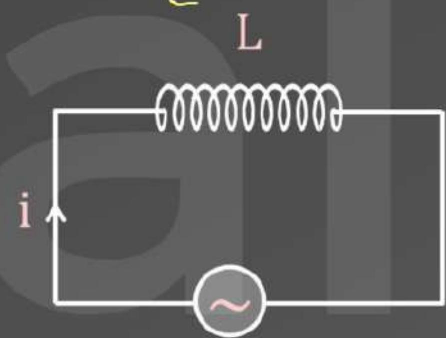
$V = V_0 \sin(\omega t)$

$< P_C > = 0$



$V = V_0 \sin(\omega t)$

$< P_L > = 0$



$V = V_0 \sin(\omega t)$

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Impedance

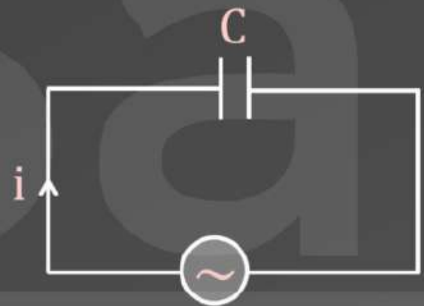
$Z = R$

$i_0 = \dfrac{V_0}{R}$

$V = V_0 \sin(\omega t)$

$Z = X_C = \dfrac{1}{\omega C}$

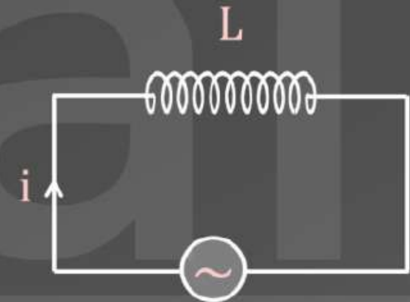
$i_0 = \dfrac{V_0}{X_C}$



$V = V_0 \sin(\omega t)$

$Z = X_L = \omega L$

$i_0 = \dfrac{V_0}{X_L}$



$V = V_0 \sin(\omega t)$

$i_{rms} = \dfrac{V_{rms}}{Z}$ $i_0 = \dfrac{V_0}{Z}$ $\longrightarrow$ Impedance $\rightarrow$ Unit is Ω

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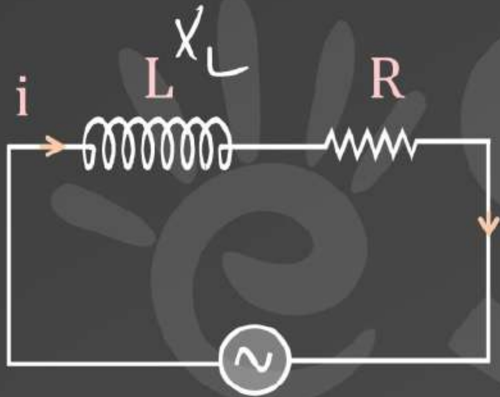
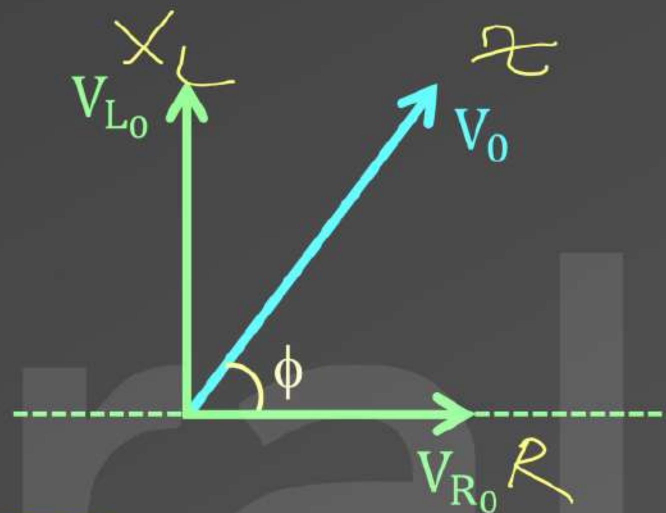
L–R Circuit



$i = i_0 \sin(\omega t)$

$V = V_0 \sin(\omega t + \phi)$



$$i_0 = \frac{V_0}{Z}$$

$$i_{rms} = \frac{V_{rms}}{Z}$$

$$Z = \sqrt{X_L^2 + R^2}$$

$$\tan\phi = \frac{X_L}{R}$$

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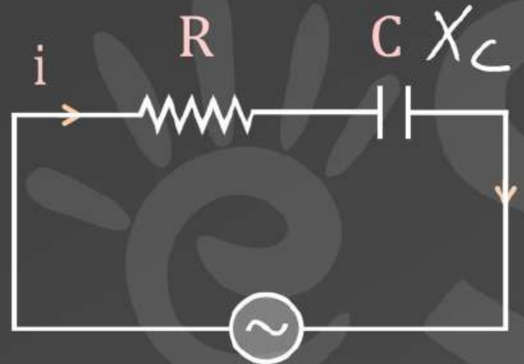
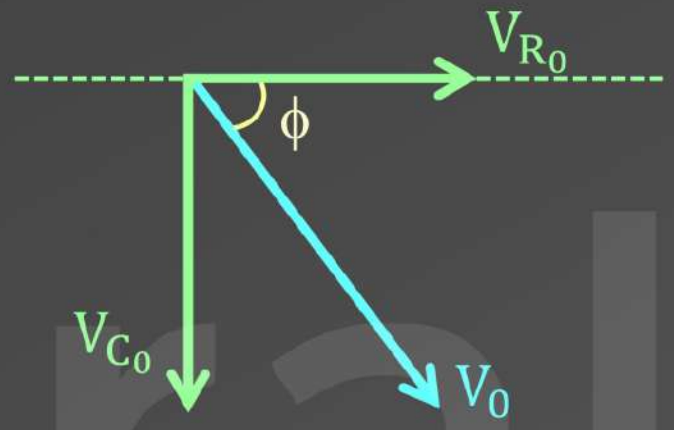
R – C Circuit



$i = i_0 \sin(\omega t)$

$V = V_0 \sin(\omega t - \phi)$



$$i_0 = \frac{V_0}{Z} \qquad i_{rms} = \frac{V_{rms}}{Z}$$

$$Z = \sqrt{X_C^2 + R^2} \qquad \tan\phi = \frac{X_C}{R}$$

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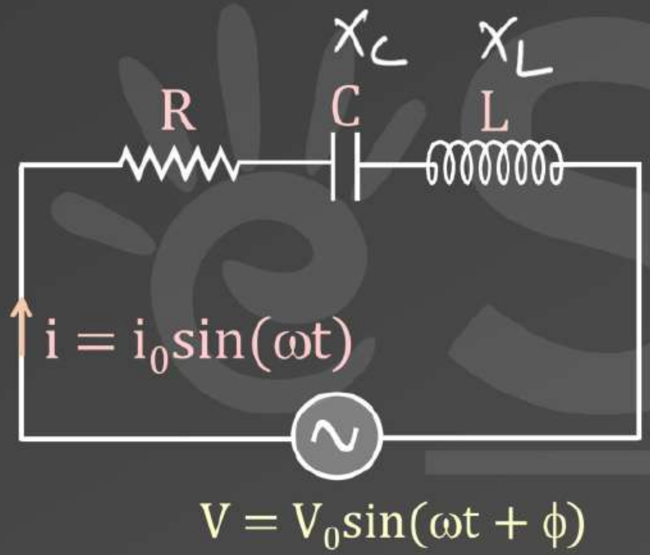
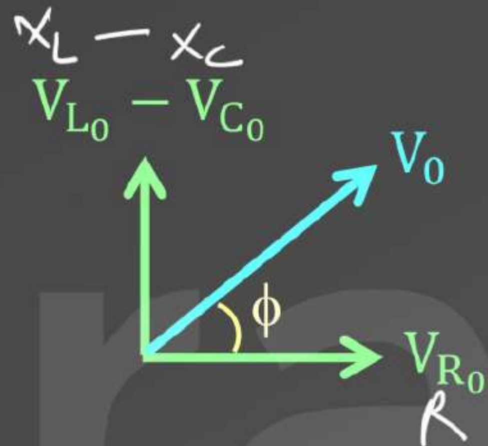
L–C–R Circuit





$$i_0 = \frac{V_0}{Z} \qquad i_{rms} = \frac{V_{rms}}{Z}$$

$$Z = \sqrt{(X_L - X_C)^2 + R^2} \qquad \tan\phi = \frac{X_L - X_C}{R}$$

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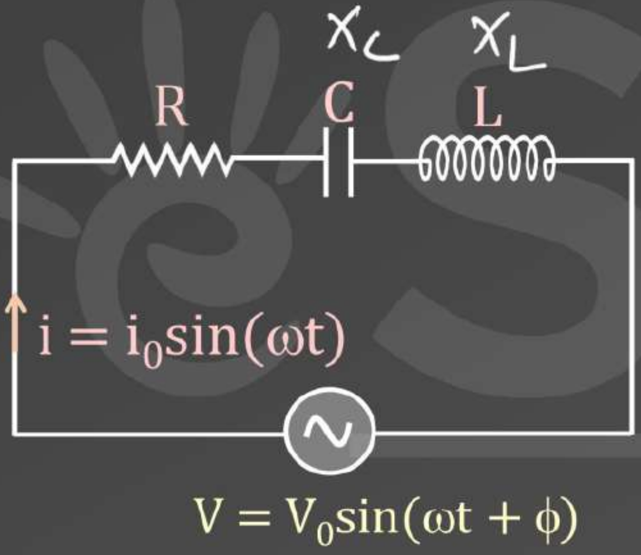
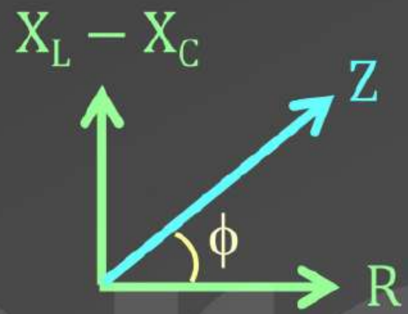
L—C—R Circuit





$\omega L > \frac{1}{\omega c}$

If $X_L > X_C$ circuit is predominantly Inductive (V leads i)

If $X_L < X_C$ circuit is predominantly Capacitive (i leads V)

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$$Z = \sqrt{(X_L - X_C)^2 + R^2}$$

Element	Z
R	R
C	X_C
L	X_L
RC	$\sqrt{X_c^2 + R^2}$
LR	$\sqrt{X_L^2 + R^2}$
LCR	$\sqrt{(X_L - X_C)^2 + R^2}$

$$i_0 = \frac{V_0}{Z}$$

$$i_{rms} = \frac{V_{rms}}{Z}$$

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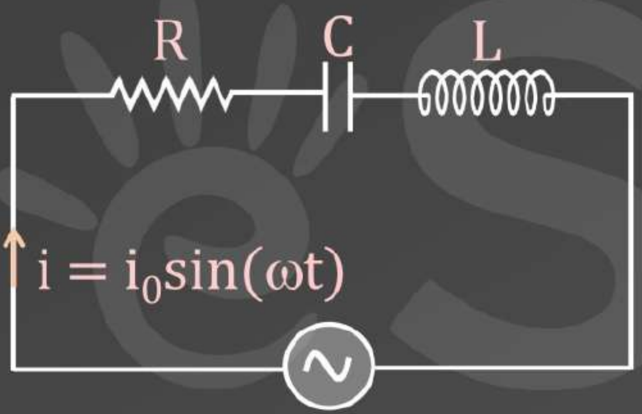
Power Delivered by Source



$i = i_0 \sin(\omega t)$

$V = V_0 \sin(\omega t + \phi)$

Power Factor

$$< P_s > = i_{rms} V_{rms} \cos\phi$$

$$\cos\phi = \frac{R}{Z}$$

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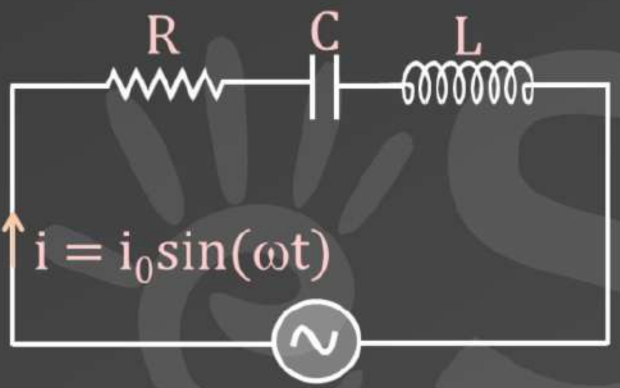
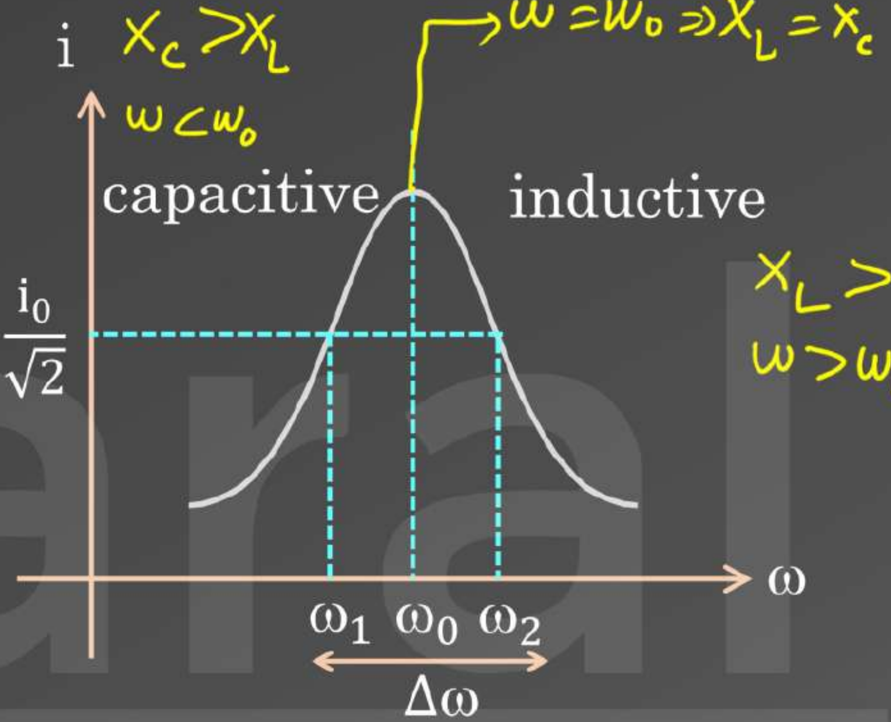
Resonance in LCR Circuit



$\omega_0 L = \frac{1}{\omega_0 C}$

$\frac{P_{max}}{2} = \frac{i_0}{\sqrt{2}}$



At Resonance

1) i_0 will be maximum 2) $X_L = X_C$

3) Z=R 4) $\cos\phi = 1$ 5) $\omega_0 = \frac{1}{\sqrt{LC}}$

Resonant Frequency

$f_0 = \frac{1}{2\pi\sqrt{LC}}$

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Quality Factor

Quality factor Q : Q-factor of AC circuit basically gives an idea about stored energy & lost energy.

$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 CR}$$

$\omega_0 = \frac{1}{\sqrt{LC}}$

$\omega_0^2 = \frac{1}{LC}$

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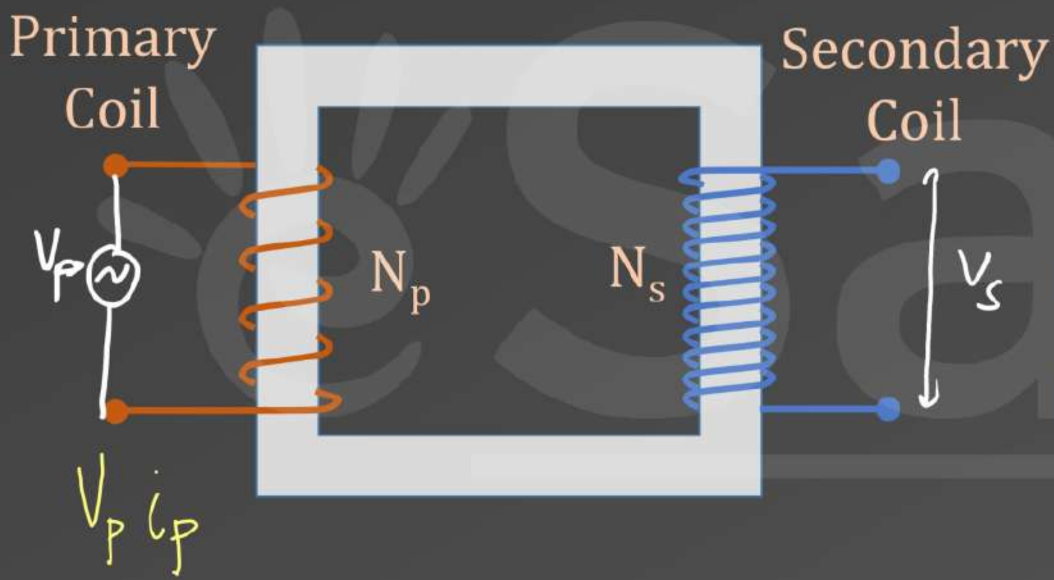
Transformers



$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

If $N_S > N_P$: Step-up Transformer

If $N_S < N_P$: Step-down Transformer

$$V_p i_p = V_s i_s$$

$$P_p = P_s$$

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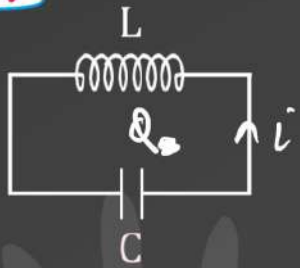
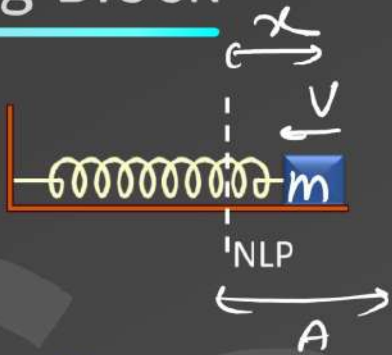
LC & Spring Block





Q	x
i	v
$\frac{1}{C}$	k
L	m

Electrical energy $\frac{Q^2}{2C}$

Potential energy $\frac{1}{2}kx^2$

Magnetic energy $\frac{1}{2}Li^2$

Kinetic energy $\frac{1}{2}mv^2$

$$\frac{Q_0^2}{2C} = \frac{1}{2}L\,i_0^2 = \frac{Q^2}{2C} + \frac{1}{2}L\,i^2$$

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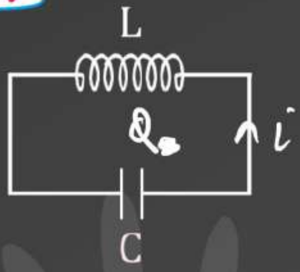

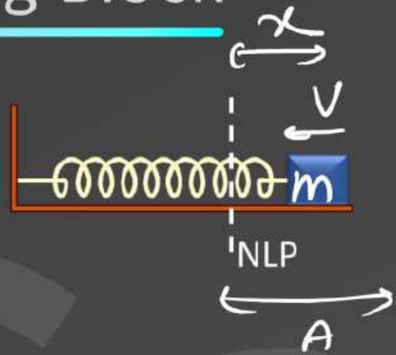

$$\omega = \frac{1}{\sqrt{LC}} \; ; \; T = 2\pi\sqrt{LC}$$

$$\omega = \sqrt{\frac{k}{m}} \; ; \; T = 2\pi\sqrt{\frac{m}{k}}$$

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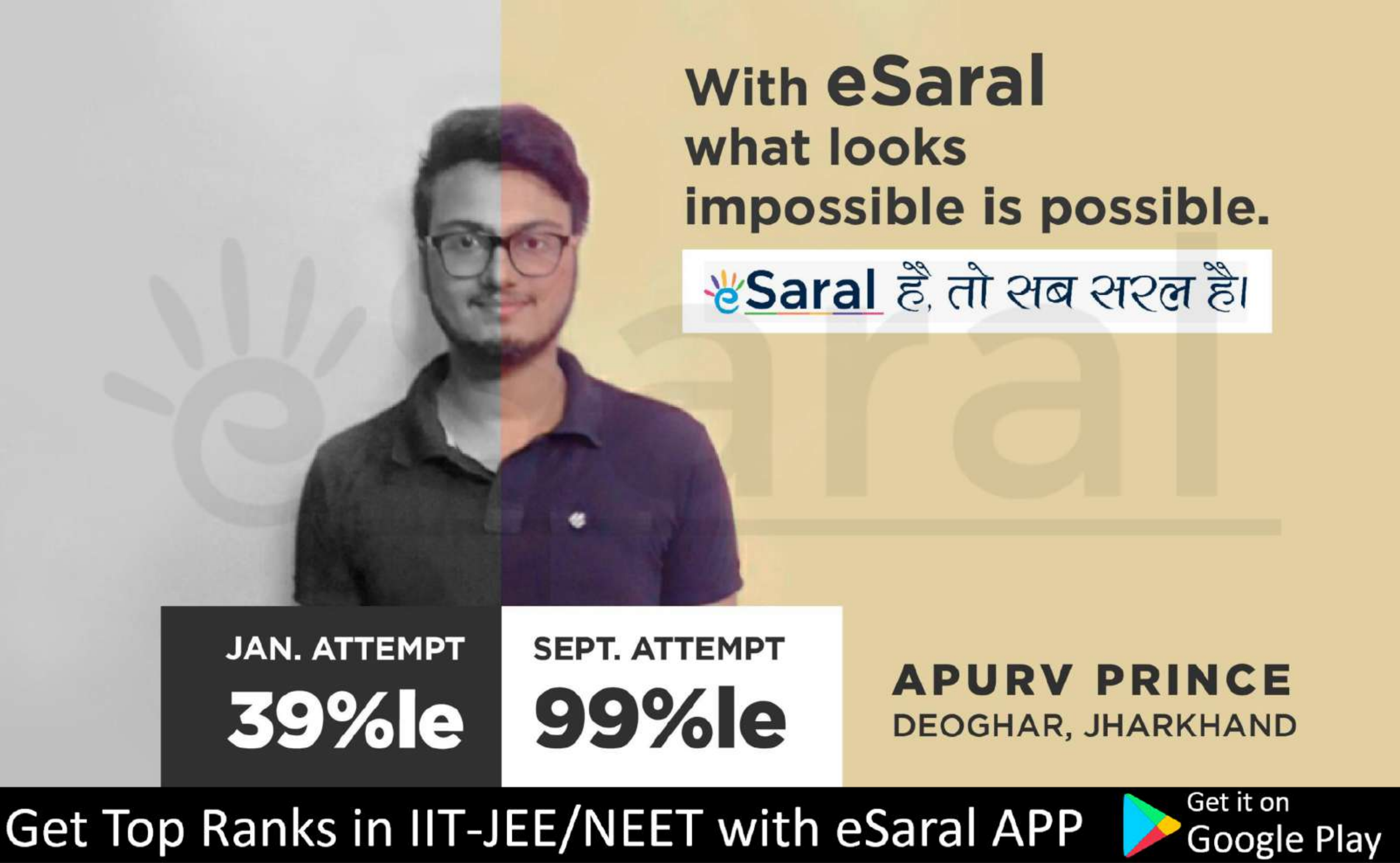
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