NDA-CDS 1 2025

GS LIVE

PHYSICS

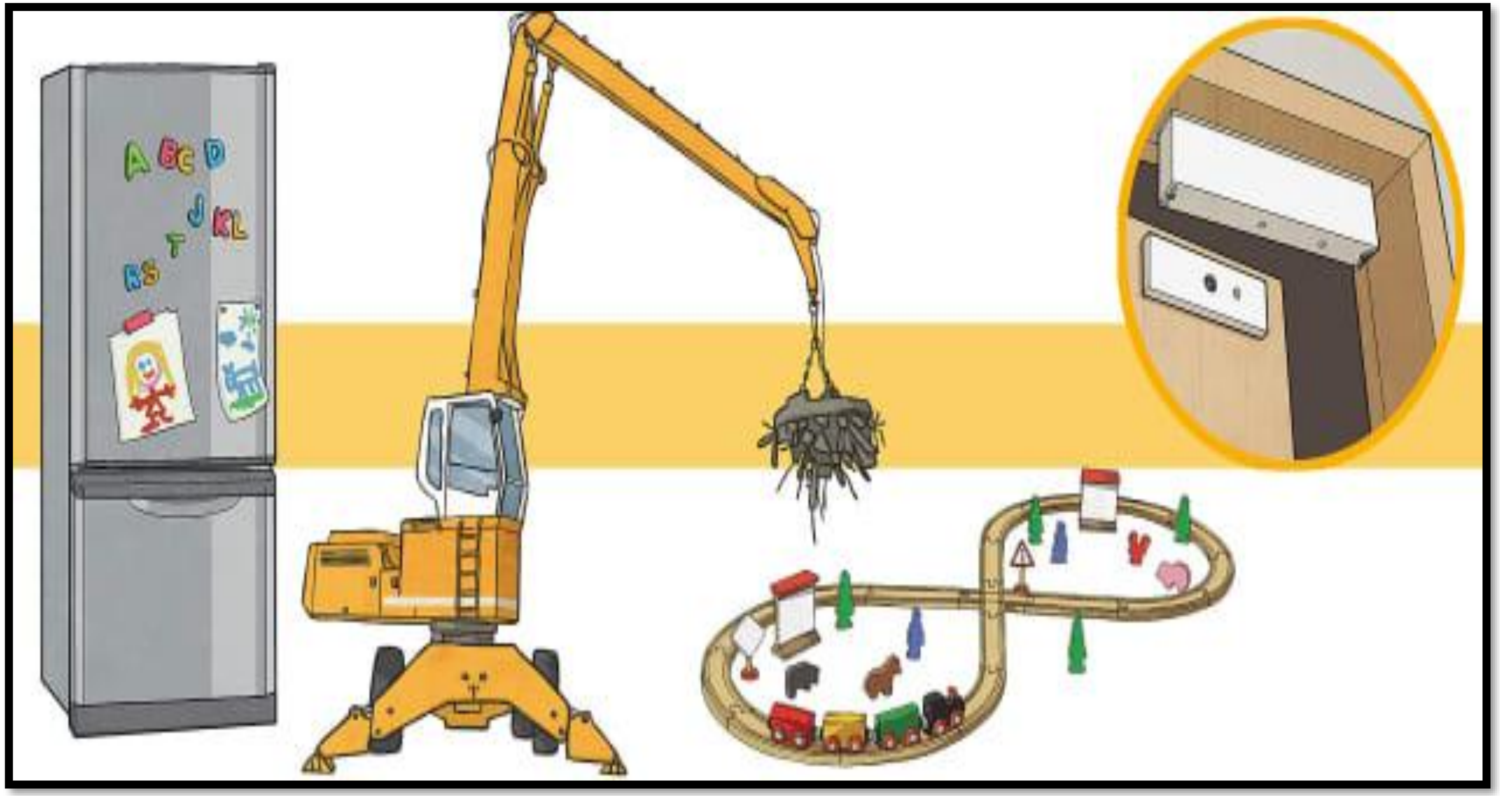
MAGNETIC EFFECTS OF ELECTRIC CURRENT

CLASS 1

NAVJYOTI SIR

SSBCrack EXAMS

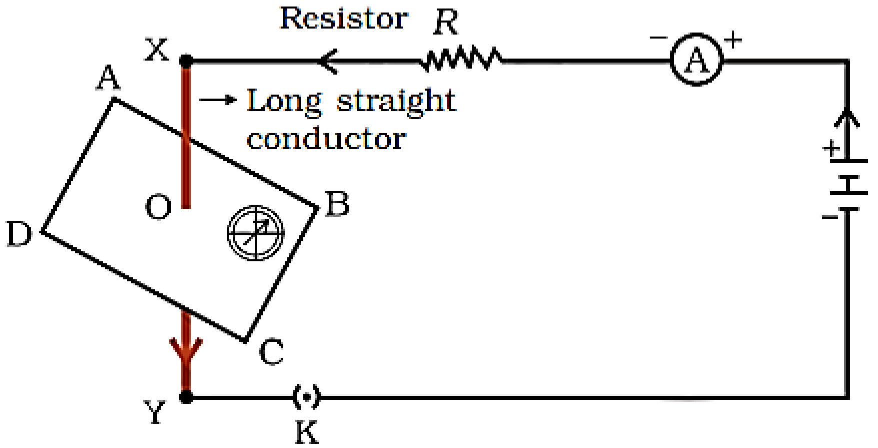
MAGNETISM



WHAT WILL WE STUDY ?

- Magnets and Magnetism
- Magnetic Field Lines
- B due to straight current carrying wire
- B due to current through a circular loop
- Solenoid
- Force on a conductor in a Magnetic Field
- Electromagnetic Induction
- Transformer and Generator

MAGNETS AND MAGNETISM



Compass needle is deflected on passing an electric current through a metallic conductor

- **A magnetic field is produced due to current carrying conductor which deflects magnetic compass.**

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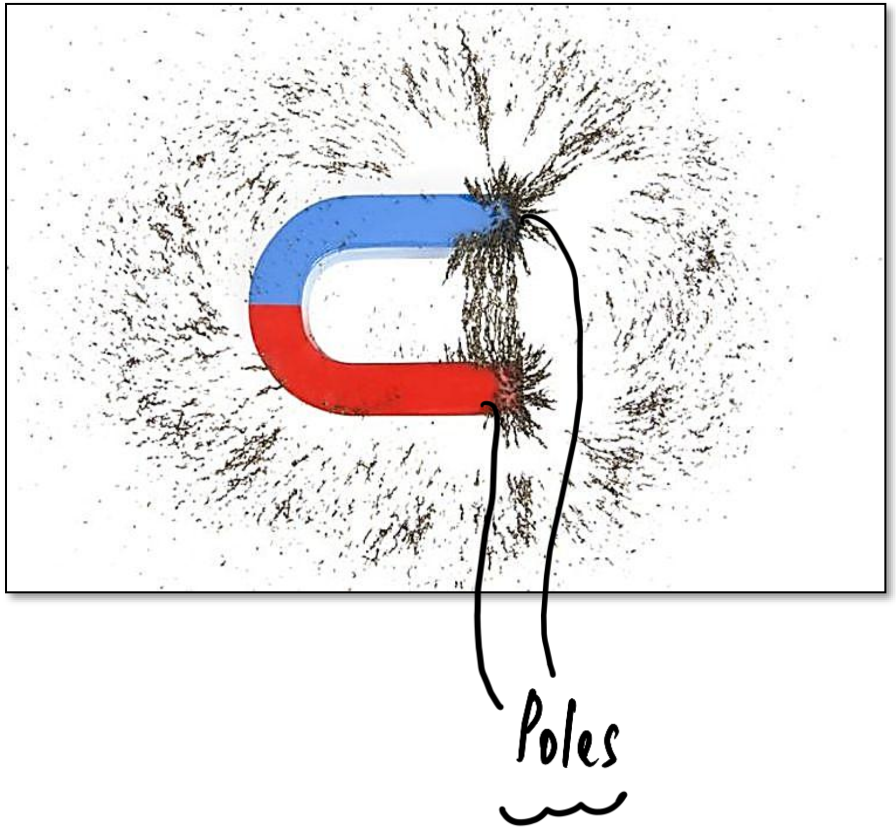
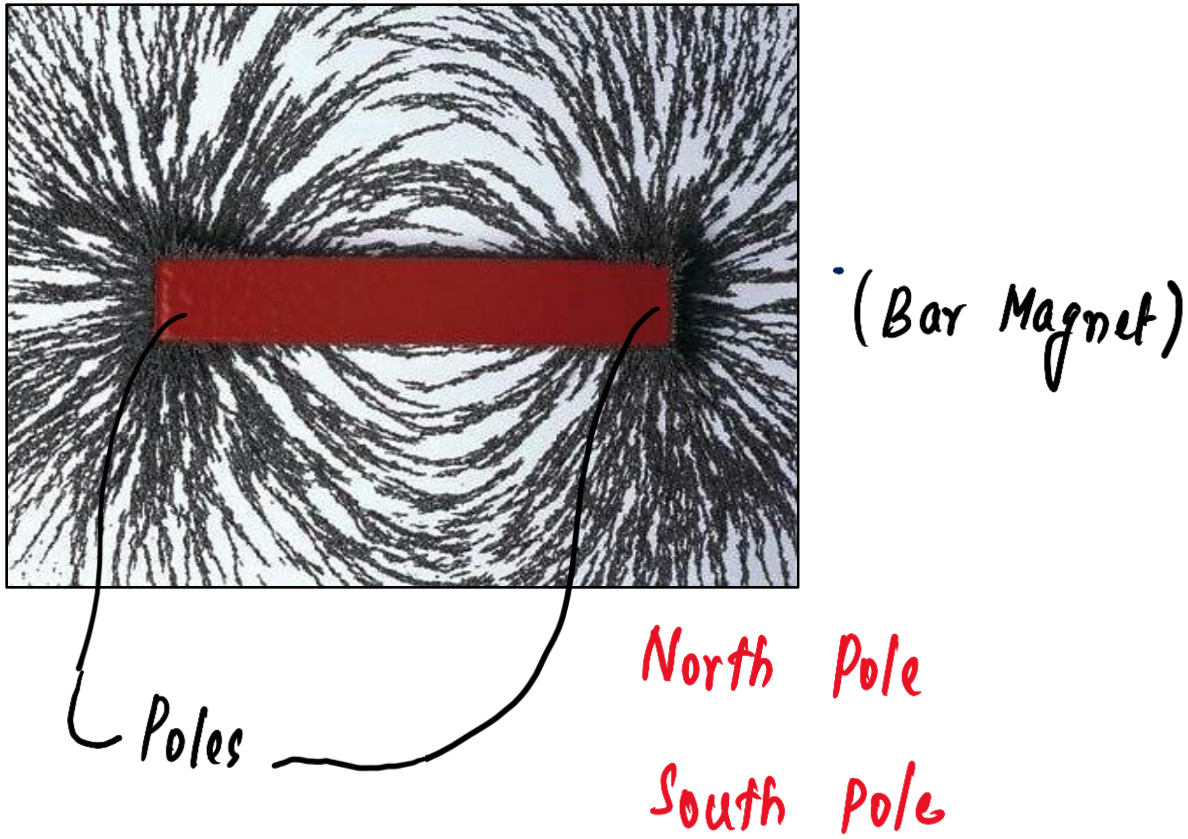
MAGNETIC FIELD (B)

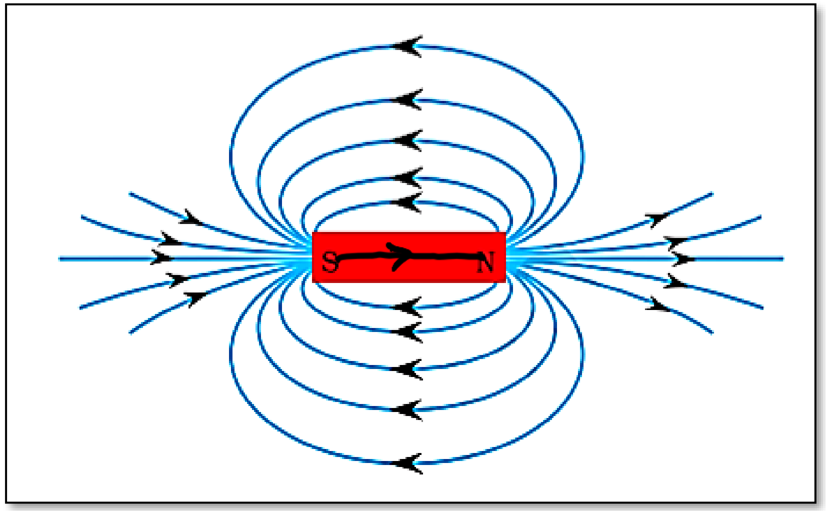
- The space in the surrounding of a magnet or any current carrying conductor in which its magnetic influence can be experienced.





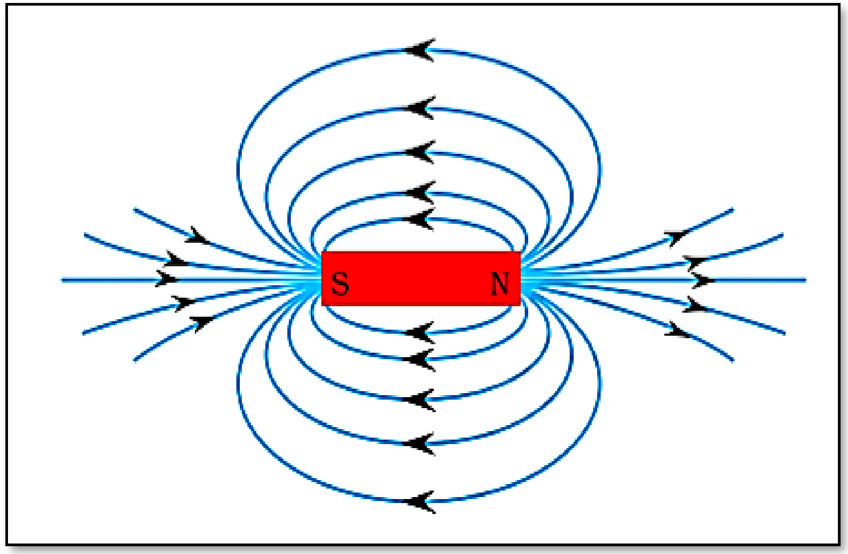
FIELD LINES

- Magnetic field is a quantity that has both direction and magnitude.
- The direction of the magnetic field is taken to be the direction in which a north pole of the compass needle moves inside it.
- Therefore it is taken by convention that the field lines emerge from north pole and merge at the south pole.
- Inside the magnet, the direction of field lines is from its south pole to its north pole. Thus the magnetic field lines are closed curves.

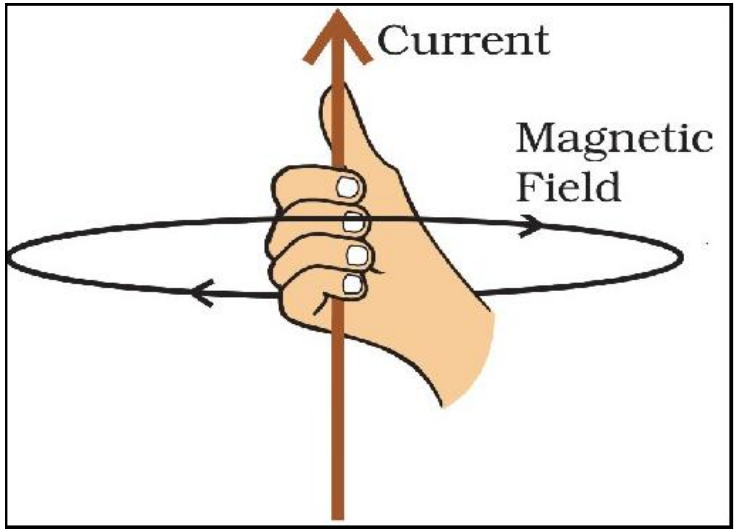


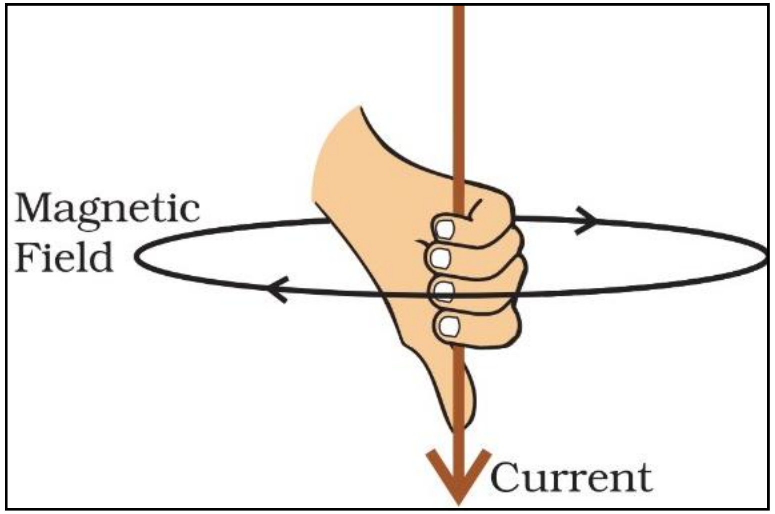
FIELD LINES

- The relative strength of the magnetic field is shown by the degree of closeness of the field lines.
- No two field-lines are found to cross each other. If they did, it would mean that at the point of intersection, the compass needle would point towards two directions, which is not possible.



RIGHT HAND THUMB RULE

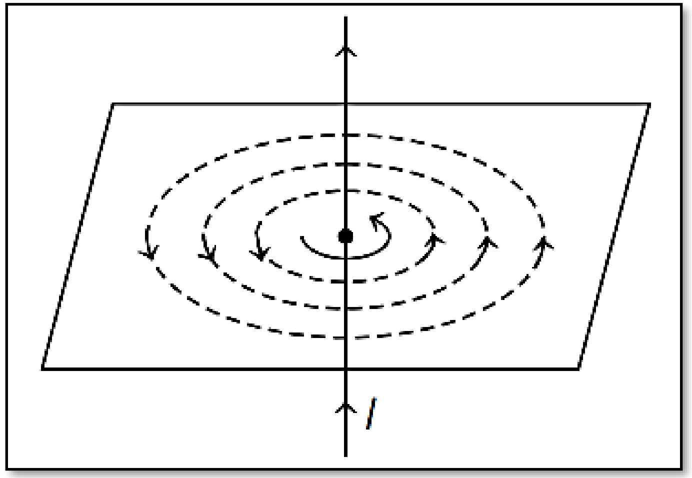




A convenient way of finding the direction of magnetic field associated with a current-carrying conductor.

B DUE TO STRAIGHT CURRENT CARRYING WIRE

The magnetic field lines due to a straight current carrying conductor are concentric circles having centre at conductor and in a plane perpendicular to the conductor.



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

$I \rightarrow$ current

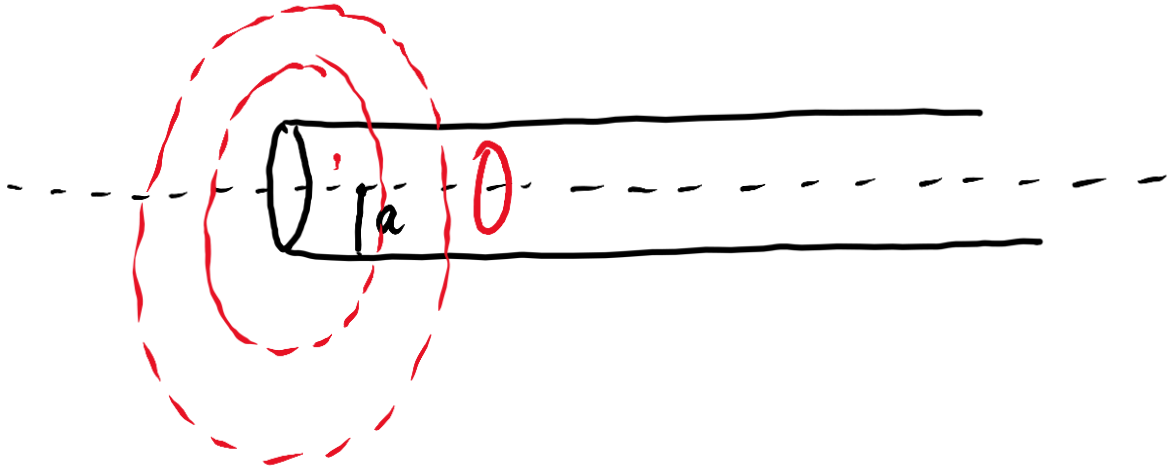
$r \rightarrow$ distance from conductor

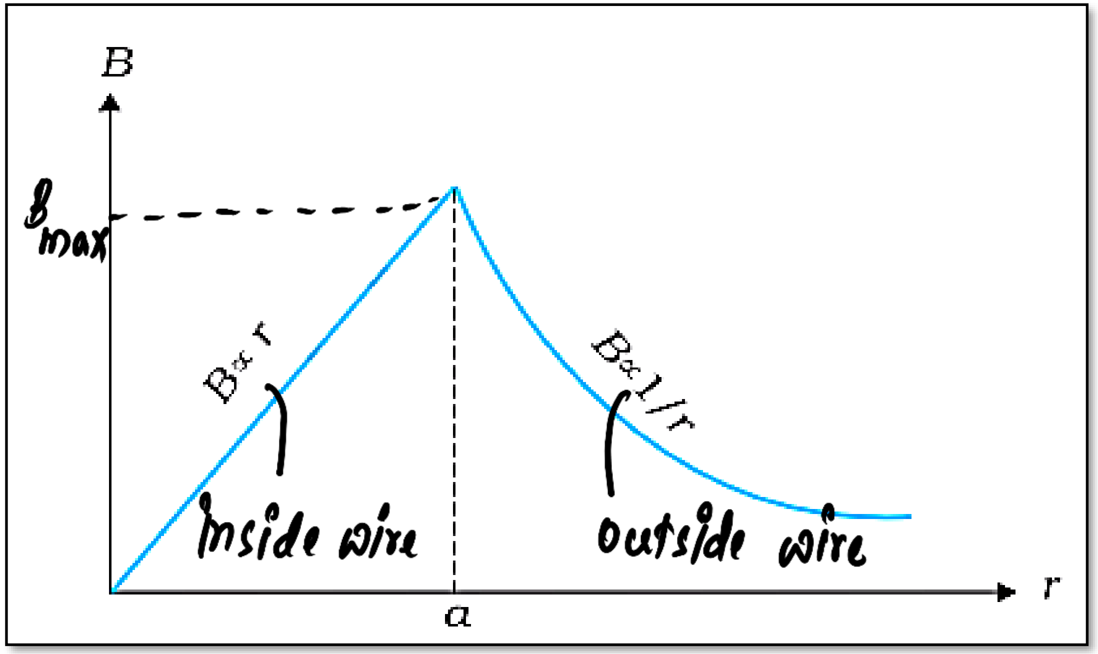
μ_0 — constant (permeability of free space)

$B \propto I$

$B \propto \frac{1}{r}$

B DUE TO STRAIGHT CURRENT CARRYING WIRE

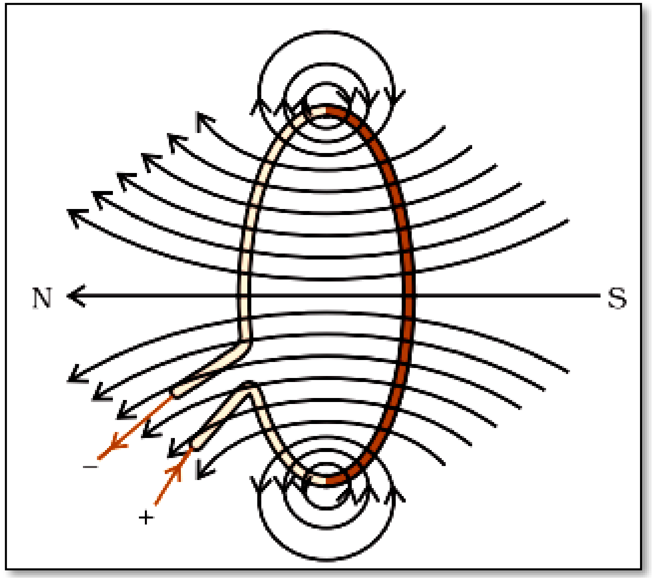




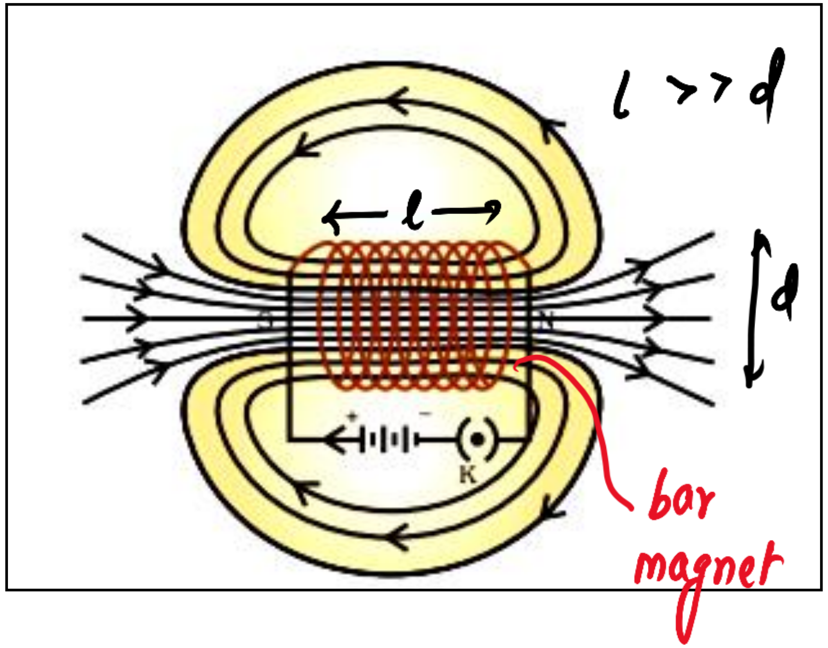
B_{max} is achieved at the surface or boundary.

B DUE TO CURRENT THROUGH A CIRCULAR LOOP

- At every point of a current-carrying circular loop, the concentric circles representing the magnetic field around it would become larger and larger as we move away from the wire.
- By the time we reach at the centre of the circular loop, the arcs of these big circles would appear as straight lines.
- By applying the right hand rule, it is easy to check that every section of the wire contributes to the magnetic field lines in the same direction within the loop.



B DUE TO CURRENT IN A SOLENOID



Field lines of the magnetic field through and around a current carrying solenoid.

- A coil of many circular turns of insulated copper wire wrapped closely in the shape of a cylinder is called a solenoid.

- One end of the solenoid behaves as a magnetic north pole, while the other behaves as the south pole.

The field lines inside the solenoid are in the form of parallel straight lines. This indicates that the magnetic field is the same at all points inside the solenoid. That is, the field is uniform inside the solenoid.

N (anti-clockwise)

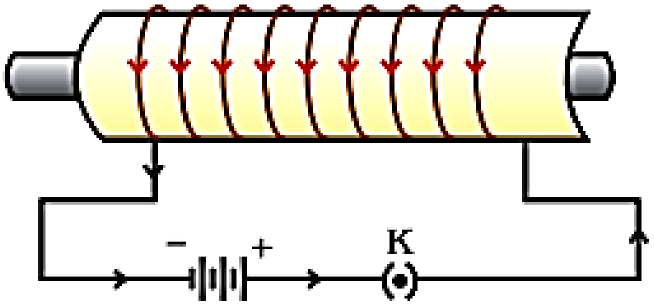
S (clockwise)

$B = \mu_0 n I$

I – current

n – number of turns per unit length

B DUE TO CURRENT IN A SOLENOID



A current-carrying solenoid coil is used to magnetise steel rod inside it – an electromagnet.

A strong magnetic field produced inside a solenoid can be used to magnetise a piece of magnetic material, like soft iron, when placed inside the coil. The magnet so formed is called an electromagnet.

FORCE ON MOVING CHARGE IN A MAGNETIC FIELD

$$\mathbf{F} = q\,(\mathbf{v} \times \mathbf{B}) = qvB\sin\theta$$ (θ — angle between $\vec{v}$ and $\vec{B}$)

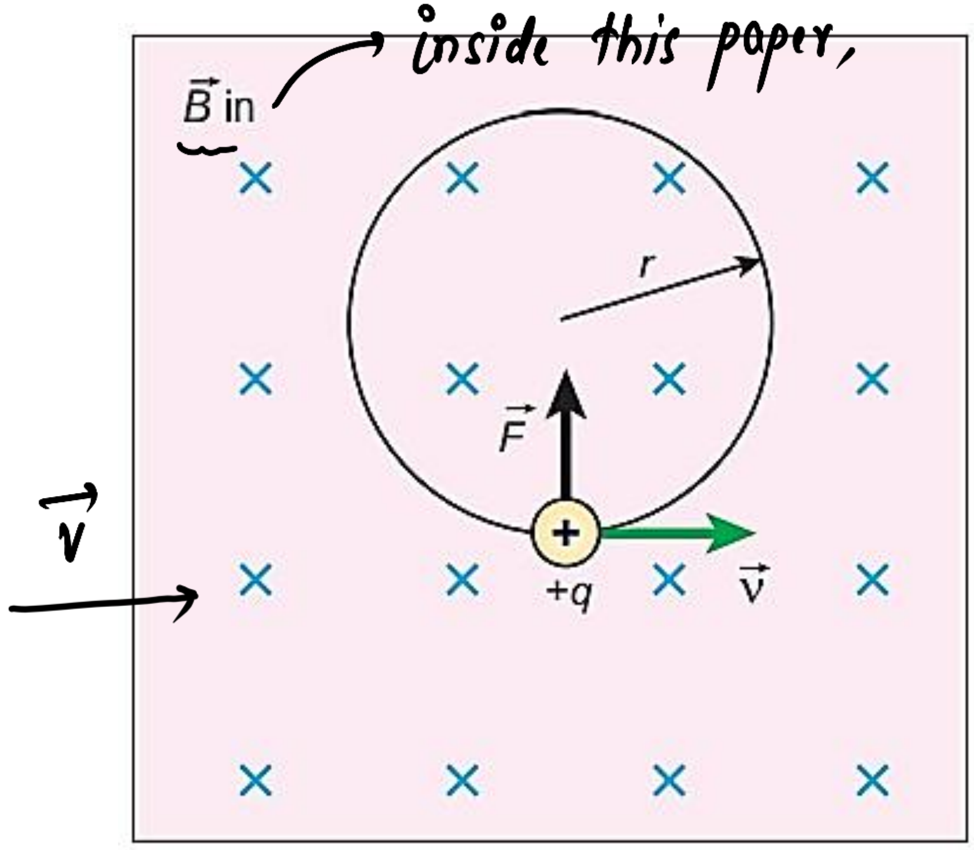
- Electromagnetic and gravitational forces act on neutral and large bodies.

- The force acting in the presence of electric and magnetic field simultaneously ,

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

MOTION OF MOVING CHARGE IN A MAGNETIC FIELD

- **When a charged particle enters in a magnetic field perpendicularly, then it moves on a circular path.**



If a charged particle is moving in the direction of magnetic field, then it experiences no force.

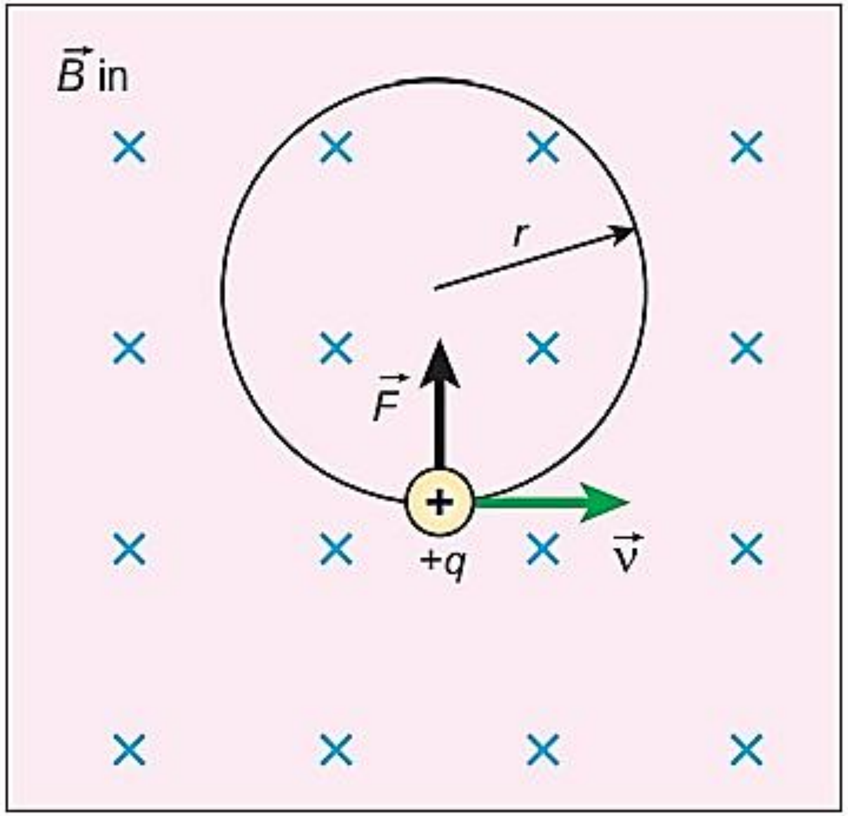
$\theta = 0°$

$\sin\theta = 0°$

$F = qvB\sin\theta = 0$

The velocity of proton moving in a magnetic field changes continuously.

MOTION OF MOVING CHARGE IN A MAGNETIC FIELD



Magnetic force = centripetal force

$$qvB\sin 90^\circ = \frac{mv^2}{r}$$

$$qvB = \frac{mv^2}{r}$$

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

Time to complete one circle or round,

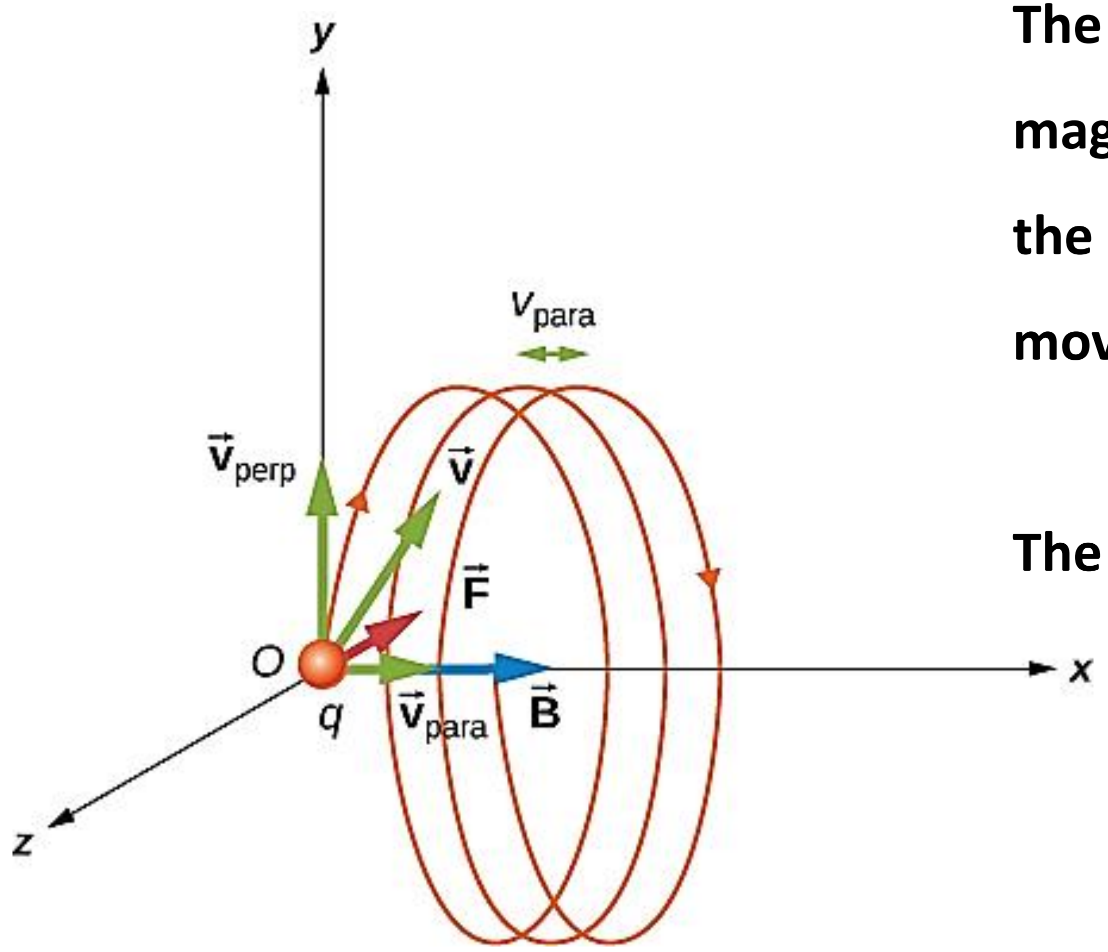
$$T = \frac{2\pi r}{v} = \frac{2\pi\left(\frac{mv}{qB}\right)}{v}$$

$$\left(T = \frac{2\pi m}{qB}\right)$$

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

$$\text{frequency} = \frac{1}{\text{Time period}} = \frac{qB}{2\pi m}$$

MOTION OF MOVING CHARGE IN A MAGNETIC FIELD – B NOT PERPENDICULAR



The velocity component perpendicular to the magnetic field creates circular motion, whereas the component of the velocity parallel to the field moves the particle along a straight line.

The resulting motion is helical.

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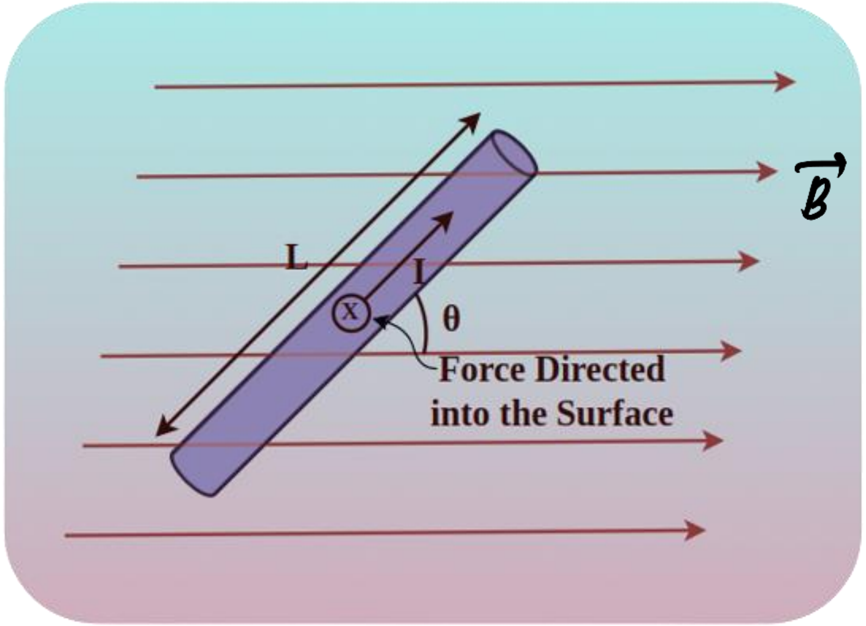
FORCE ON CURRENT – CARRYING CONDUCTOR

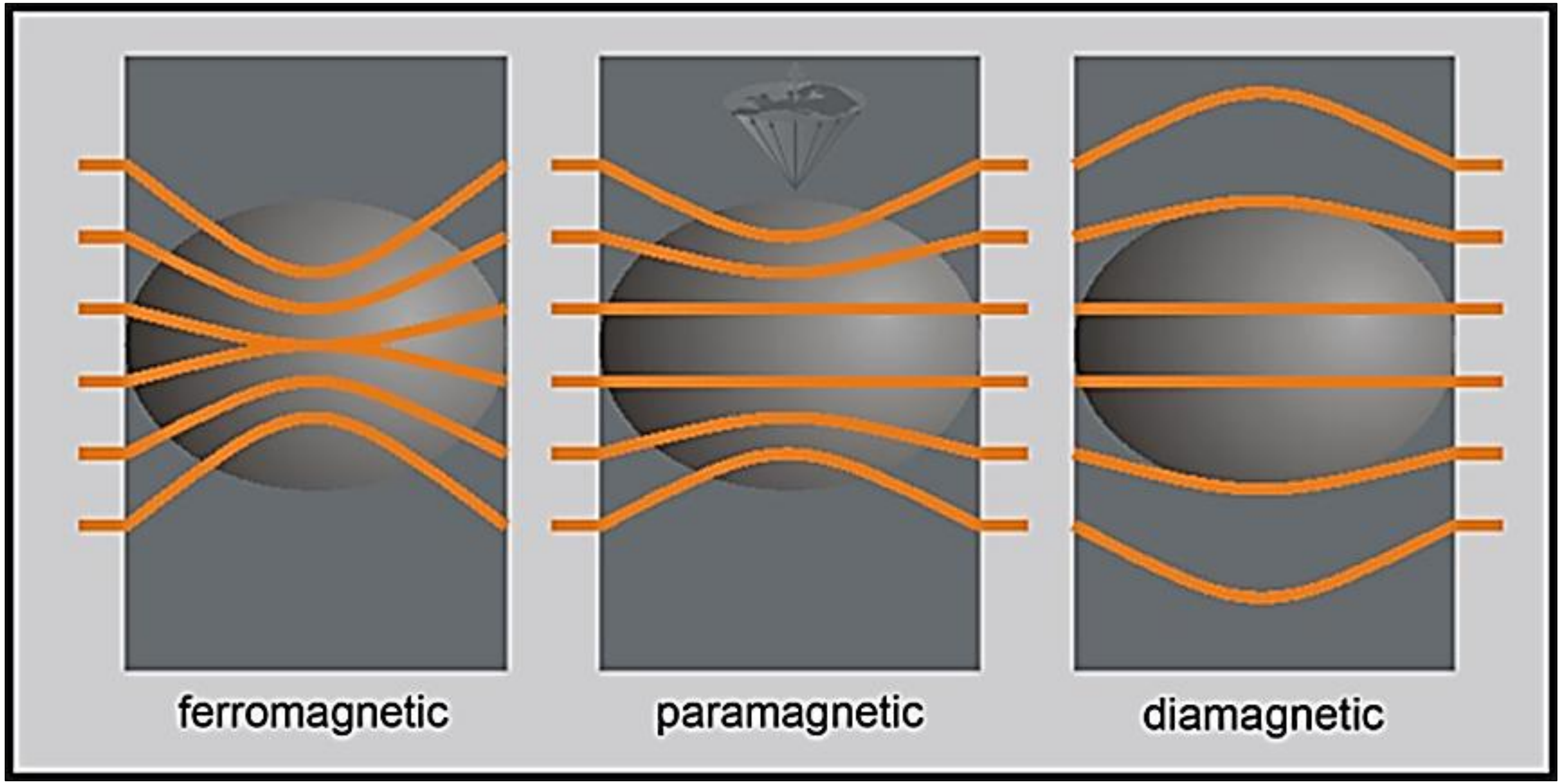
IN A MAGNETIC FIELD

$$\mathbf{F} = I\,(\mathbf{l} \times \mathbf{B})$$ $= IlB\sin\theta$.

Shorter rotation ($\vec{l}$ to be taken that way)



CLASSSIFICATION OF MAGNETIC SUBSTANCES



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CLASSSIFICATION OF MAGNETIC SUBSTANCES

Diamagnetic substances : These substances when placed in an external magnetic field, then acquire feeble magnetism opposite to the direction of the magnetic field. e.g. Bi, Zn, Au, NaCl, H_2O, etc.

(weakly magnitised)

Paramagnetic substances : These sub stances when placed in an external magnetic field, then acquire feeble magnetism in the direction of the magnetic field. e.g. Al, Na, Pt, Mn, $CuCl_2$, O_2 , etc.

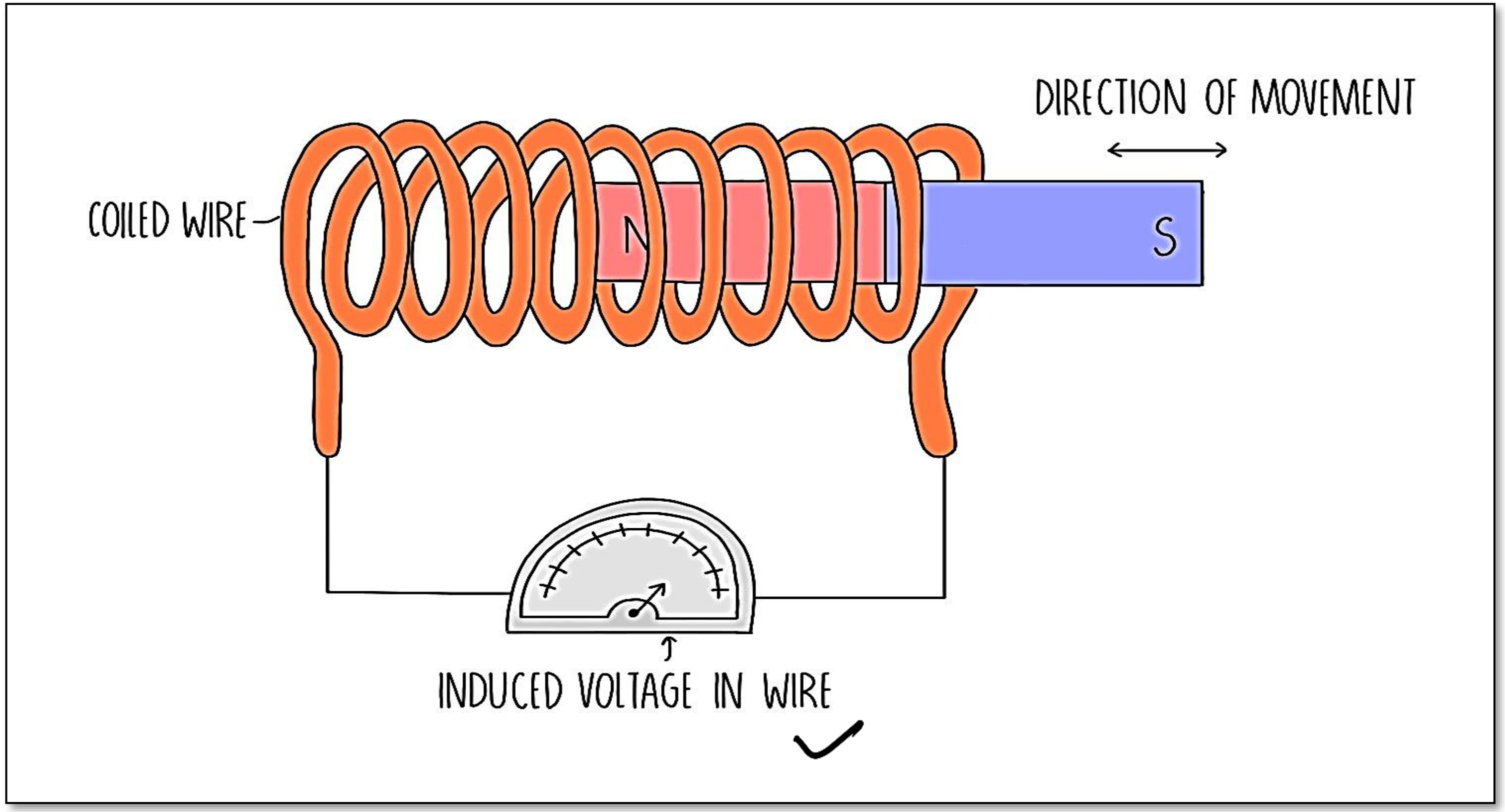
(little bit magnitised)

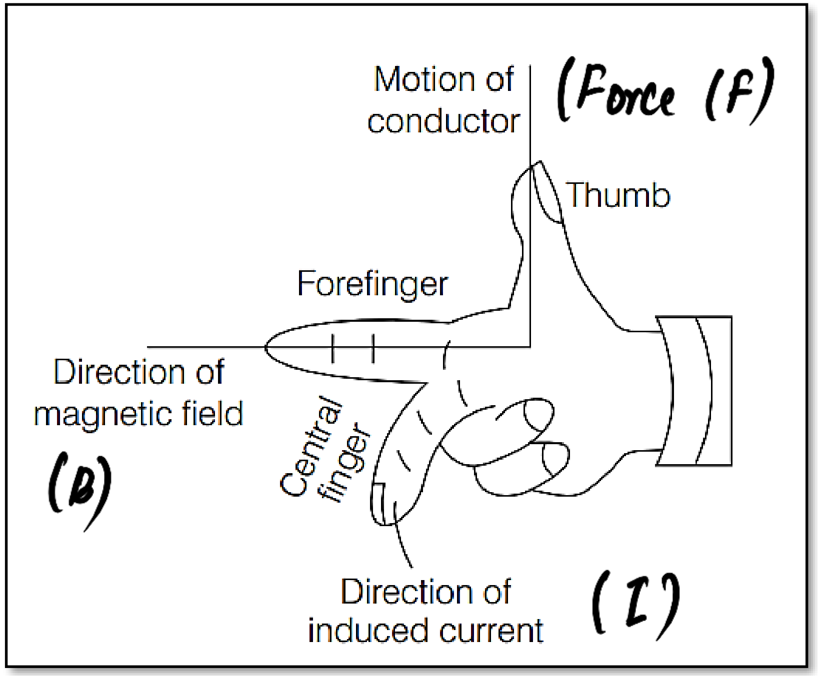
Ferromagnetic substances : These substances when placed in an external magnetic field are strongly magnetised in the direction of the field. e.g. Fe, Ni, Co, Fe_2O_3 etc.

Iron, Nickel, Cobalt, Ferric Oxide (Lodestone) (natural magnet)

ELECTROMAGNETIC INDUCTION

Whenever the magnetic flux linked with an electric circuit changes, an emf is induced in the circuit. This phenomenon is called electromagnetic induction.





Fleming's right hand rule,

TYPES OF ELECTROMAGNETIC INDUCTION

Self-Induction : When the current flowing through a coil changes, then induced current gets producesd in the same coil, it is called self-induction.

change in B → change in ϕ (magnetic flux) → (e) emf and current is induced.

$(\phi = B \cdot area)$

Coefficient of self-inductance of a coil is

$$L = \frac{N\phi}{i}$$

or $$L = -\frac{e}{\Delta i/\Delta t}$$

Coefficient of self-inductance of a solenoid

$$L = \frac{\mu_0 N^2 A}{l}$$

$$\left(e = -\frac{d\phi}{dt}\right)$$

TYPES OF ELECTROMAGNETIC INDUCTION

Mutual -Induction : When two coils are placed near each other, then if there is a change in current in one coil, then emf is induced in the another coil. ✓

Coefficient of mutual inductance is given by

$$M = \frac{N_2 \phi_2}{i_1} \quad \text{or} \quad M = \frac{-e_2}{\Delta i_1 / \Delta t}$$

Mutual inductance between two plane coils is

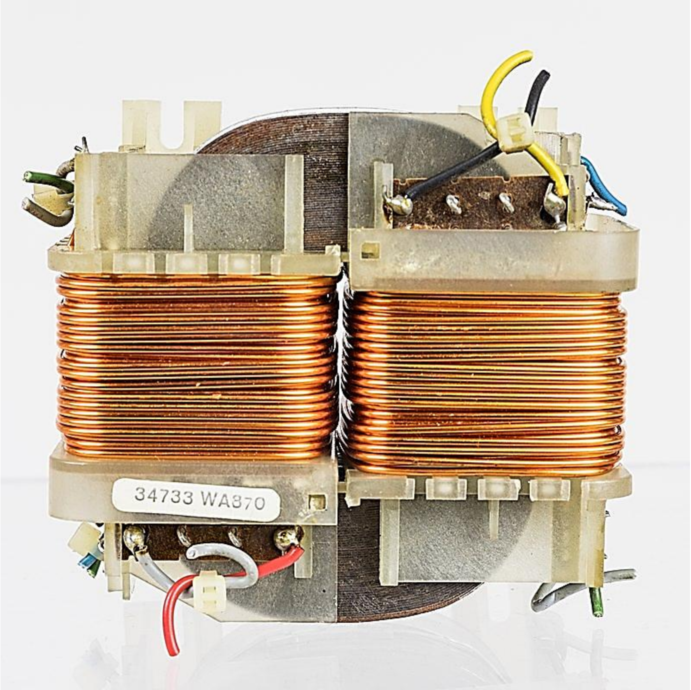
$$M = \frac{\mu_0 N_1 N_2 \pi R_2^2}{2R_1}$$

Inductance unit → Henry (H) (SI Unit)

volt/ampere/second,

TRANSFORMER

It is a static electrical device used to step-up a low voltage to a high voltage or to step down a high voltage into a low voltage and is used on AC circuits. Transformer works on the principle of electromagnetic induction.



STEP – UP TRANSFORMER

A step-up transformer steps the primary voltage up to a higher value. If the numbers of turns of secondary coil is more than the number of turns of primary coil, then it is called step-up transformers.

STEP – DOWN TRANSFORMER

A step-down transformer steps the primary voltage down a lower value. If the number of turns of the secondary coil is less than that of the primary coil, it is called a step down transformer.

For transformer $\frac{I_S}{I_P} = \frac{V_P}{V_s} = \frac{N_P}{N_S} = k$ → ratios are equal.

where, I_p and I_S = current in primary and secondary coil.

V_P and V_S = potential in primary and secondary coil.

N_P and N_S = Number of turns in primary and secondary.

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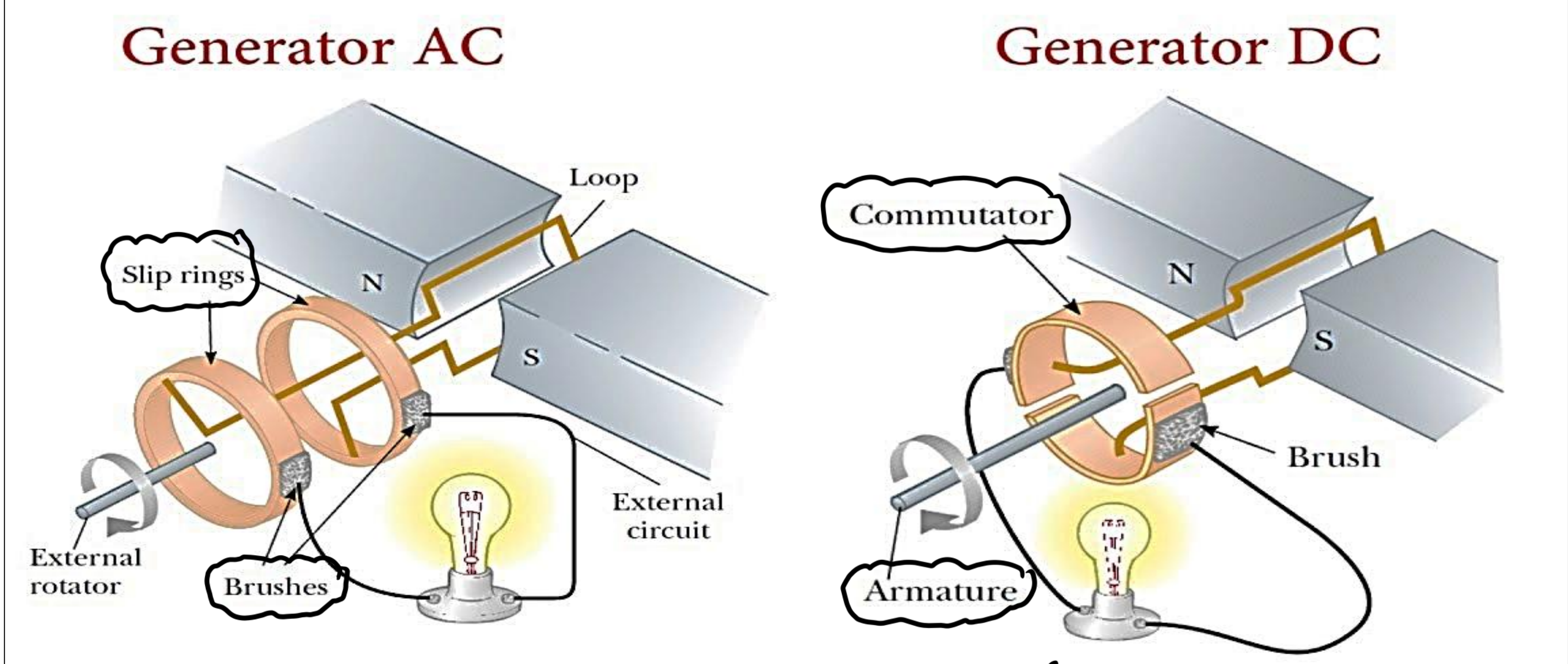
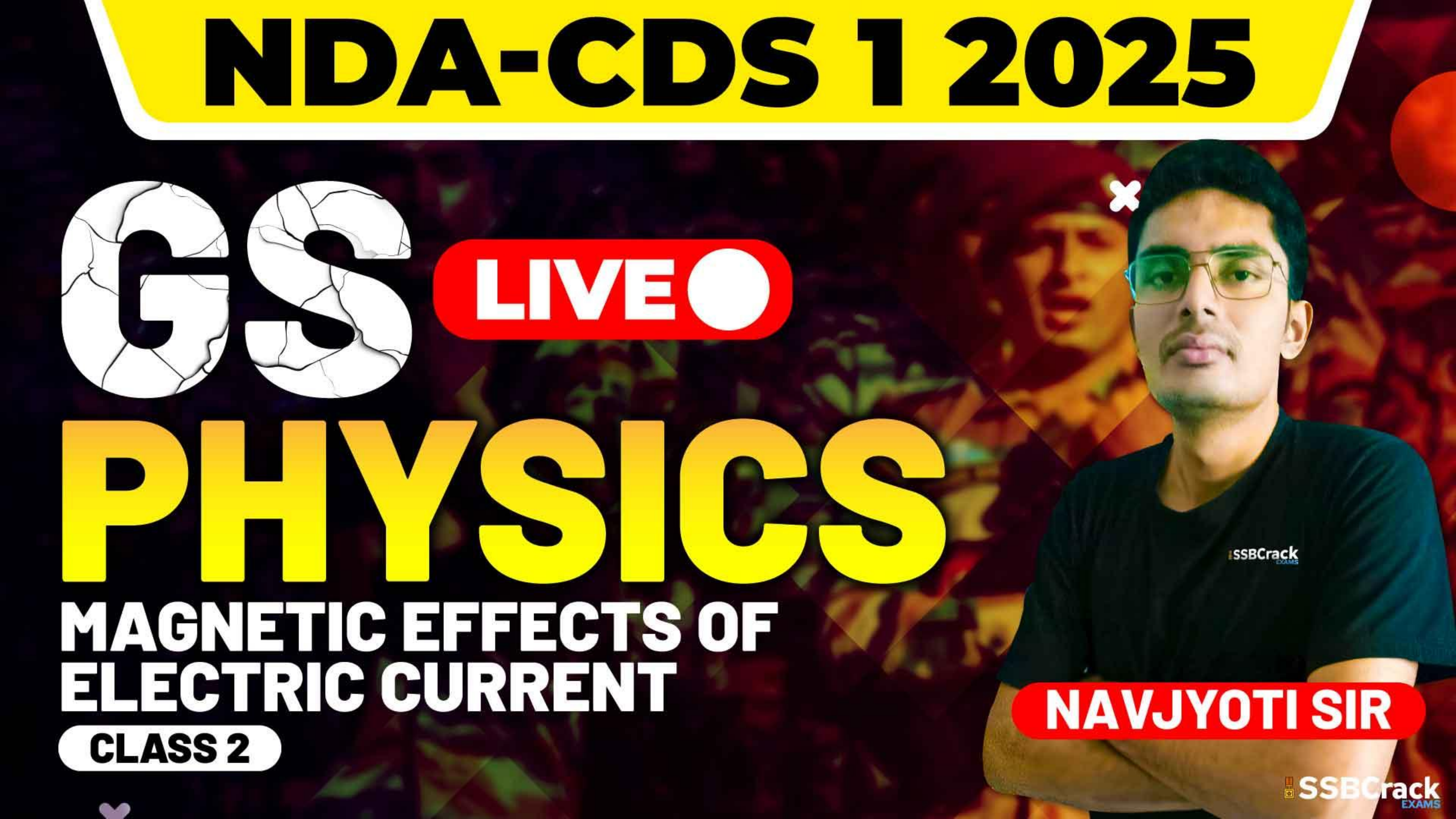
AC AND DC GENERATOR



Principle : Electromagnetic Induction

SUMMARY

- Magnets and Magnetism
- Magnetic Field Lines
- B due to straight current carrying wire
- B due to current through a circular loop
- Solenoid
- Force on a conductor in a Magnetic Field
- Electromagnetic Induction
- Transformer and Generator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