MAGNETISM AND ELECTROMAGNETIC THEORY

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MAGNETISM

- **Magnetic Field and Magnetic flux density**
- **Gauss's law for magnetic Flux**
- **Ampere's Circuital Law**
- **Faraday's Law of Electromagnetic Induction**
- **Magnetic Susceptibility**
- **Magnetic Permeability**

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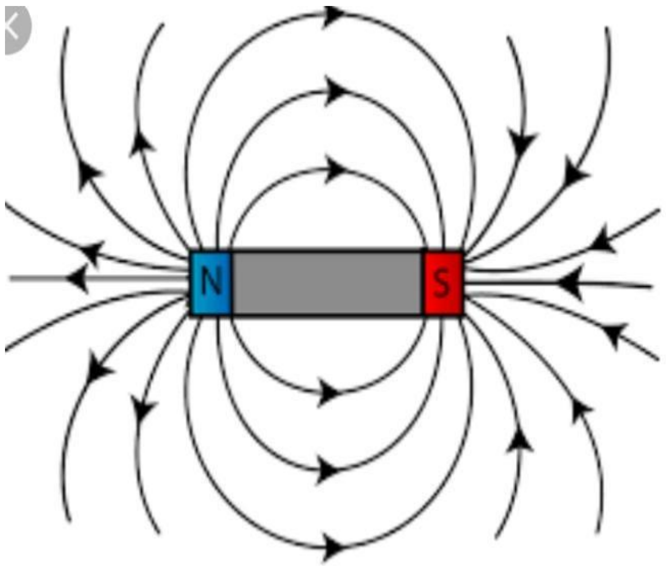
MAGNETIC FIELD

- It is the area around a magnet in which there is magnetic force.
- Defined as the magnetic force experienced by a unit positive charge in motion
- It is a vector quantity
- Represented either by ‘B’ or ‘H’



MAGNETIC FLUX DENSITY (B)

- **The total Number of magnetic field lines passing perpendicularly through unit area.**
- **Expressed Weber/sq.meter Or Tesla**

$$B = \frac{\phi}{A}$$

$$\boxed{\phi = BA}$$

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GAUSS'S LAW FOR MAGNETIC FLUX

$$\oint \vec{B} \cdot d\vec{A} = 0$$

- **Magnetic fields do not start or end at any point**
- **The number of lines entering a surface equals the number of lines leaving the surface.**

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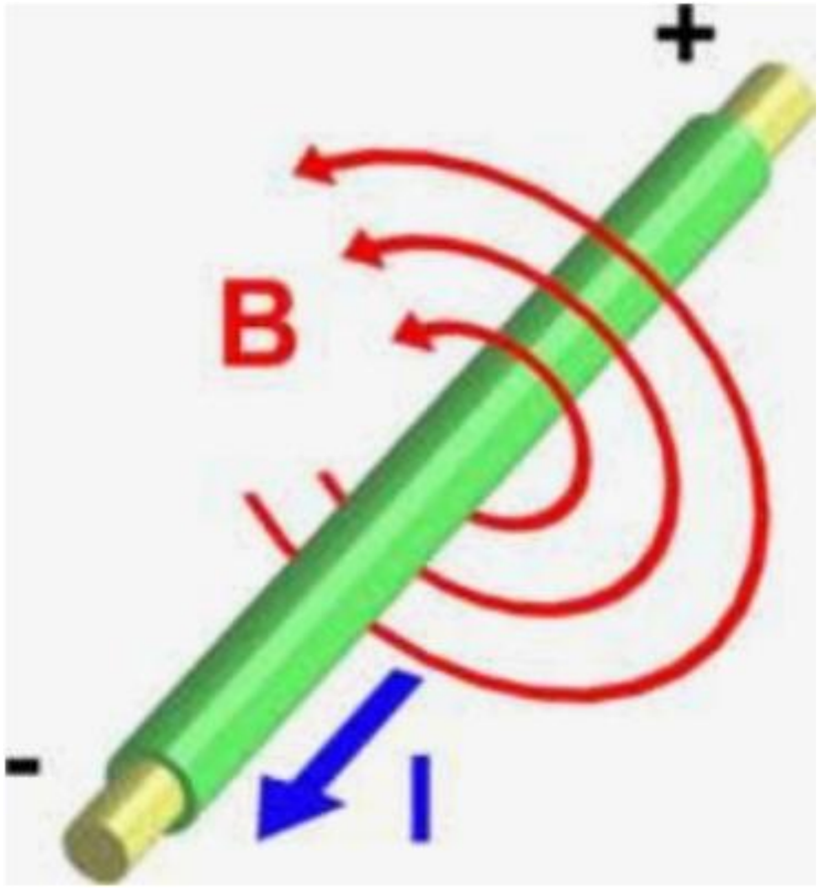
AMPERE'S CIRCUITAL LAW



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AMPERE'S CIRCUITAL LAW

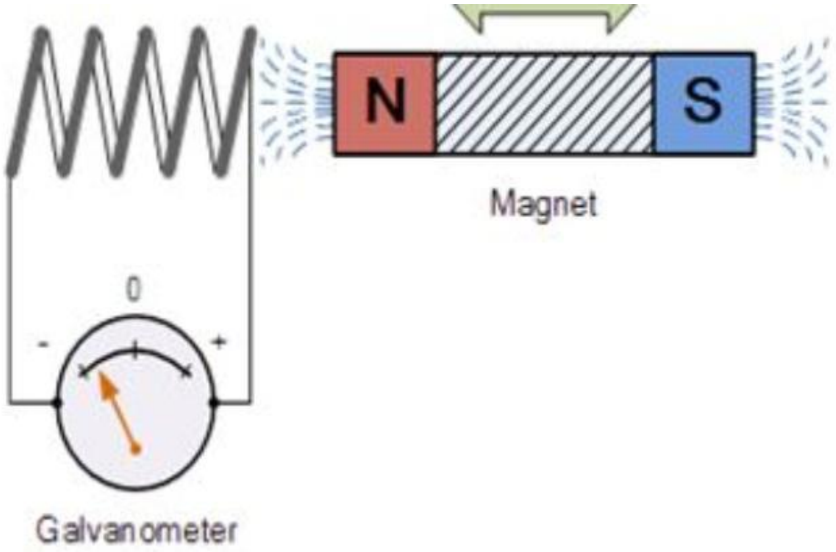
- Relationship between the current and the magnetic field created by it.
- The magnetic flux density B for a closed path is equal to

$$\boxed{\oint_C \underline{B} \cdot d\underline{l} = \mu_0 I_{encl}}$$

FARADAY'S LAW OF ELECTROMAGNETIC INDUCTION

- Whenever the magnetic flux linked with a circuit changes an emf is induced.
- The magnitude of induced emf is equal to the rate of change of magnetic flux .

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



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INTENSITY OF MAGNETISATION (M)

- Measure of the magnetisation of a magnetised specimen.
- Defined as the magnetic moment per unit volume of the material.

$$I = \frac{\text{Magnetic Moment}}{\text{Volume}}$$

$$= \frac{M}{V}$$

MAGNETIC SUSCEPTIBILITY

- Indicates degree of magnetization of a material.
- Ratio of magnetization M to the applied magnetizing field intensity H.
- Dimensionless quantity.

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

MAGNETIC PERMEABILITY

- Defined as the property of the material to allow the magnetic lines of force to pass through it.
- Ratio of the flux density B to the field intensity H.

$$\mu = \frac{B}{H} \qquad \mu_r = \frac{\mu}{\mu_0}$$

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	DIAMAGNET	PARAMAGNET	FERROMAGNET
DEFINITION	It is a material in which there is no permanent magnetic moment	It has permanent magnetic moment	It has more permanent magnetic moment
Behaviour	Repulsion of magnetic line of force from the centre of the material	Attraction of magnetic line of force towards the centre of the material	Heavy attraction of magnetic line of force towards the centre of the material
Magnetised direction	Opposite to the external magnetic field	Same Direction as the external magnetic field	Same Direction as the external magnetic field
Permeability	Very less	High	Very high
Relative Permeability	<1	>1	>>1
Magnetic Susceptibility	Negative	Low positive	High positive

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DIAMAGNETISM

- Tendency to love from stronger to weaker magnetic field
- Repelled by the applied magnetic field.
- Orient perpendicular to the field
- Atomic shells are filled and have no unpaired electron

When magnetic field is applied

- It will distort orbital motion
- e's having orbital moment in the same direction of applied M.F slow down.and those in the opposite direction speed up.
- Net magnetic moment is produced which opposes the applied field.

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PARAMAGNETISM

- Tendency to move from weak to strong MF
- Unpaired electrons are there.
- Induced field will be in the direction of applied field;but weak
- Free electron magnetism
- They do not retain any magnetism in the absence of an external MF.

CURIE'S LAW

$$\chi = \frac{C}{T}$$

FERROMAGNETISM

- Domain concept
- Magnetism persists even after the removal of MF
- Strongly attracted by external field
- Loss their magnetic properties if they are heated to high temperatures.

CURIE-WEISS LAW

$$\varepsilon = \frac{C}{T - T_c}$$

WEISS THEORY

- The magnetic moment of atoms associated with ferro magnetic substance are of spin origin
- Ferromagnetic specimen contains a number of small regions(domain)
- **Weiss** predicted that, in ferromagnetic materials **Spontaneous magnetization** is observed, which is due to a **strong internal field** arising from an **exchange interaction** between the magnetic moments in the neighborhood **domains**

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Exchange Interaction Theory

- In ferro magnetic materials like Fe,Ni,Co the 3d orbitals are partially filled.
- There are 4 unpaired electrons in Fe.
- In complete 3d orbital electron interact strongly with neighbour.Result is zero magnetic moment to orbital motion.But magnetic moment due to spin motion exists.
- If the electrons interact very strongly then their spins will be aligned in the same direction.But It is short range interaction.
- Each in changes the magnetic moment of its neighbouring ion.

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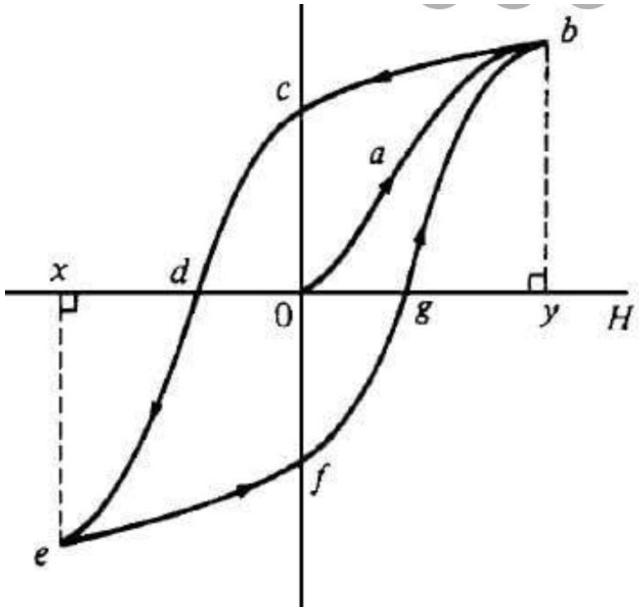
HYSTERESIS CURVE



- Remanent flux density-Br
- Coercive Field- Hc
- Flux density changes lags behind the changes in MF. This effect is hysteresis.

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ELECTROMAGNETIC THEORY

Del Operator

$$\boxed{\nabla = \frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}}$$

del operator = differential operator

- Gradient of a Scalar function
- Divergence of a vector
- Curl of a vector
- Line Integral
- Surface Integral
- Volume Integral
- Gauss Theorm
- Stokes Theorm

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Equation of continuity

- The total current flowing out of some volume must be equal to the rate of decrease of charge with in the volume, since the charge is conserved.
- This conservation of charge concept in mathematical terms

$$\nabla \cdot \mathbf{J} = -\frac{\partial \rho_v}{\partial t}$$

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MAXWELL'S EQUATIONS

1. $\nabla \cdot \mathbf{D} = \rho_V$
2. $\nabla \cdot \mathbf{B} = 0$
3. $\nabla \times \mathbf{E} = -\dfrac{\partial \mathbf{B}}{\partial t}$
4. $\nabla \times \mathbf{H} = \dfrac{\partial \mathbf{D}}{\partial t} + \mathbf{J}$

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{j} + \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t}$$

Significance of $\frac{\partial D}{\partial t}$

- The term physically indicates that not only a current produces a magnetic field but a changing electric field also produces a magnetic field.
- It is the presence of this term which leads to the production of em waves

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Conduction current

- Due to the movement of electric charges in a conductor when an E.F is applied.

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Displacement current

- It is the current produced due to the rate of change of electric flux.

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Difference between conduction current and displacement current

- Conduction current is produced due to rate of change of charges.But the displacement current is produced due to rate of change of Electric Field.
- Conduction current is zero in perfect vacuum but displacement current has a finite value in vacuum.
- Conduction current leads the EF where as Displacement current leads the Electric Field where as the Displacement current leads the electric field by pi/2 radians.

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ELECTROMAGNETIC WAVES

- A varying Electric field produces a varying magnetic field and varying magnetic field produces a varying Electric field. Thus E and B are closely related.
- When the time varying Electric field give rise to time varying Magnetic field, this varying magnetic field again produces varying electric field. And this process continues.
- Thus E and B are coupled and propagate in space as Electromagnetic wave.and travels with velocity of light.
- EM waves are transverse in nature.