Magnetic Effects of Current and Magnetism

Magnetism and Matter

Physics

Unit: - 3rd

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Chapter:- 5

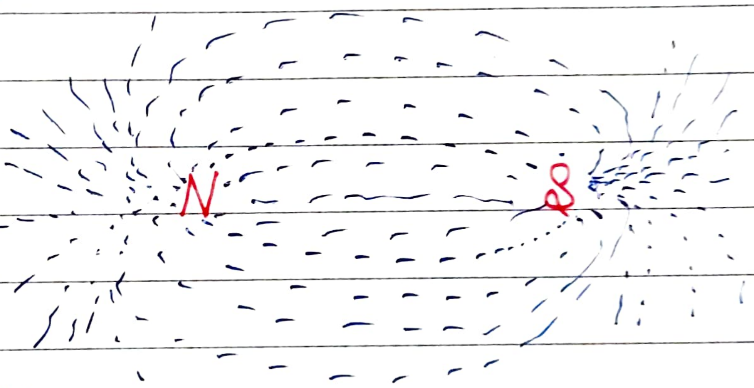
Magnets and Earth's Magnetism:

Magnetism:-

The phenominon of attraction of small bits of iron, steel, Caball, nickel etc. toward the ore is called magnetism. The iron ore showing this effect is called a natural magnet.

BAR Magnet:-

A magnet in the form of a bar with magnetic poles at each end is known as bar magnet.



Some properties of Bar magnet:

(I) It has two poles (North-pole and South pole)

(II) when a magnet is suspended freely, it alings it self with one end pointing toward north of earth and other towar South of earth.

Some Basic's of Magnetism :-

1) The earth behaves as a magnet.
2) Every magnet attracts small pieces of magnetic substances like iron, cobalt, nickel and steel towards it.
3) When a magnet is suspended freely with the help of an thread, it comes to rest along the north south direction.
4) like poles repell each other and unlike pole attract each other.
5) The force of attraction or Repulsion (F) between two magnetic poles of strengths m_1 and m_2 separated by a distance r is directly proportional to the product of pole strengths and inversely proportional to the square of the distance between their centres.

$$F \propto \frac{m_1 m_2}{r^2} \quad \text{or} \quad F = K \frac{m_1 m_2}{r^2}$$

$$F = \frac{\mu_0}{4\pi} \frac{m_1 m_2}{r^2}$$

Here $k = \frac{\mu_0}{4\pi} = 10^{-7}\,\text{WbA}^{-1}\text{m}^{-1}$

μ_0 = absolute magnetic permeability of free space.

S.I. Unit of magnetic pole Strength.

Strength of a magnetic pole is said to be one ampere-metre.

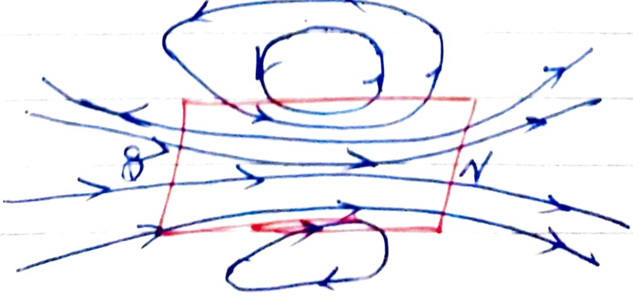
6) The magnetic poles always exist in pair. The poles of a magnet can never be separated or i.e magnetic monopoles do not exist.

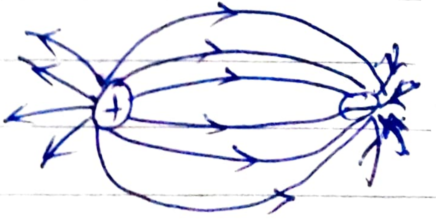
7) Inductive property :- when a piece of a magnetic material like soft iron, Cabalt, nickel etc. is placed near a bar magnet, it acqures magnetism.

8) Repulsion is the sure test of magnetism

The Magnetic field Lines :-

The Magnetic field line is an imaginary curve the tangent to which at any point give us the direction of magnetic field $\vec{B}$ at that point.





Properties of Magnetic field Lines :-

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

2) Outside the body of the magnet, the direction of magnetic field is from North pole to south pole.

3) At any give point, tangent to the magnetic field line represents the direction of net magnetic field ($\vec{B}$) at that point.

4) The magnitude of magnetic field at any point is represented by the number of magnetic field lines passing through unit area around that point.

5) No two magnetic field lines can intersect eachother.

6) Magnetic field lines have a tendency to contract longitudinally indicating attraction between unlike magnetic pole.

Magnetic Dipole : A magnetic dipole consists of two unlike poles of equal strength and separated by a small distance.

eg:- A bar magnet, a Compass needle etc.

magnetic dipole moment:- It is the product of strength of either pole (m) and the magnetic length ($2\vec{l}$) of the magnet.

It is represented by $\vec{M}$.

$$\vec{M} = m(2\vec{l})$$

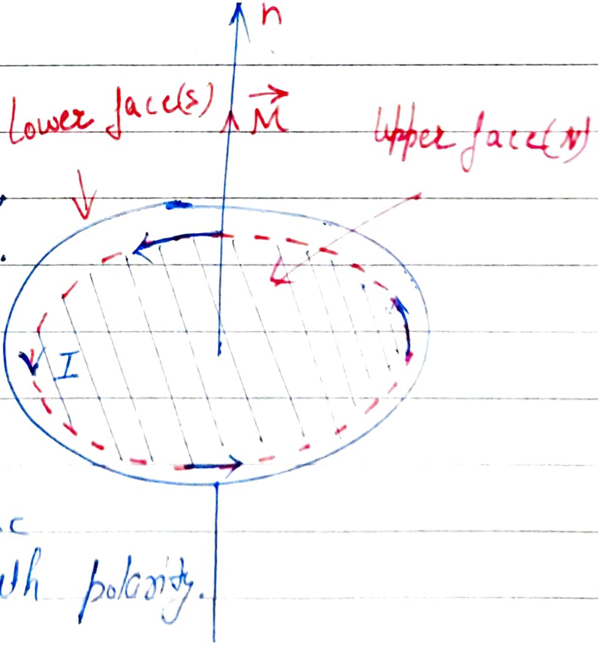
It is a vector quantity.

S.I. Unit:- Joule/Tesla or amperemetre^2

SI- unit of pole (Am).

Current loop as A Magnetic Dipole:-

Consider a plane loop of wire carrying current. At the upper face, current is anticlockwise. Therefore taken as (North polarity)
Looking at the lower face current is Clockwise Therefore taken as south polarity.



∴ The current carrying loop thus behaves as a system of two equal and opposite magnetic poles and hence is a magnetic dipole.

The magnetic dipole moment of the current loop (M) directly proportional to the

(I) Strength of current (I) through the loop.
(II) area (A) enclosed by the loop.

ie $M \propto I$ and $M \propto A$

$$M \propto IA \Rightarrow M = KIA$$

Here $K = N$ (Number turns)

$$\boxed{M = NIA}$$

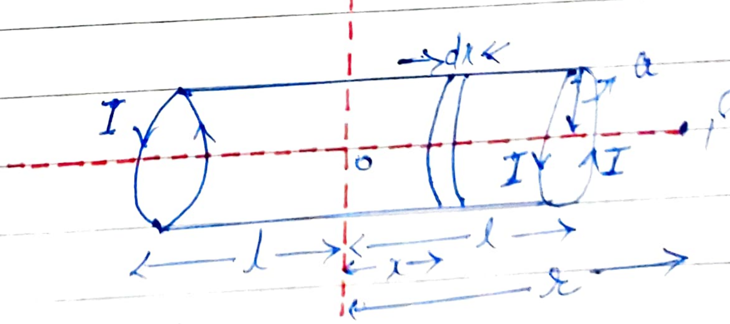
SI Unit:- Ampere m^2

In vector form

$$\boxed{\vec{M} = NIA\hat{n}}.$$

BAR MAGNET AS AN EQUIVALENT SOLENOID:-

a = Radius
2l = length of Solenoid with Centre O
n = number of turns per unit length of solenoid.
i = Strength of current passed through the solenoid.



We have to calculate magnetic field at any point (P) on the axis of solenoid.
Here $(OP = r)$
Let us conder small element of thickness (dx).

Number of turns in the element $= n\,dx$

Now according to Boit-Savart's Law

$$dB = \int \frac{\mu_0}{4\pi} \frac{I\,dl\,\sin\theta}{r^2}$$

$$= \frac{\mu_0}{4\pi} \int \frac{I\,dl\,\sin\theta}{r^2}$$

Using the Magnetic field at a point on the axis of a circular coil.

$$dB = \frac{\mu_0 i a^2 (n\,dx)}{2\left[(r-x)^2 + a^2\right]^{3/2}} \quad ①$$

If (P) Point lies at very large distance from O
ie $r \gg a$ and $r \gg x$

$$\therefore \left[(r-x)^2 + a^2\right]^{3/2} = (r^{\cancel{2}})^{3/\cancel{2}} = r^3$$

$$dB = \frac{\mu_0 i\, a^2 n dx}{2r^3} \text{ ——— } ②$$

Intigrating both side taking limit $x = -l$ to $x = +l$

$$B = \frac{\mu_0 n i a^2}{2r^3} \int_{x=-l}^{x=l} dx = \frac{\mu_0 n i a^2}{2r^3} [x]_{-l}^{l}$$

$$B = \frac{\mu_0 n i a^2}{2r^3} [l+l] = \frac{\mu_0 n i a^2 2l}{2r^3}$$

$$B = \frac{\mu_0}{4\pi} \frac{2n(2l)\, i \pi a^2}{r^3} \text{ ——— } ③$$

If M is magnetic moment of the solenoid,

M = total no. of turns x current x area of cross section

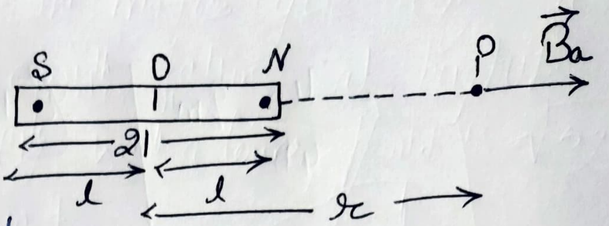
$$M = n(i)(2l) \times \pi a^2$$

$$M = 2lni \pi a^2$$

$$\boxed{B = \frac{\mu_0 2M}{4\pi r^3}}$$

This is the expression for magnetic field on the axial line of a short bar magnet.

⇒ Magnetic field Intensity due to a magnetic dipole:- on axial line:-



Let us consider a bar magnet of length ($2l$).
O = Centre of the bar magnet
q_m = Pole strength of each pole.

Magnetic field Intensity at (P) due to North Pole.

$$B_1 = \frac{\mu_0}{4\pi}\frac{q_m}{(OP)^2} \text{ along } NP$$

$$OP = (r - l)$$

$$B_1 = \frac{\mu_0}{4\pi}\frac{q_m}{(r-l)^2} \text{ along } NP.$$

Simillarly ~~at~~ due to south pole.

$$B_2 = \frac{\mu_0}{4\pi}\frac{q_m}{(r+l)^2} \text{ along } SP.$$

Now Net magnetic force at Point P

$$B_a = B_1 + B_2$$

$$= \frac{\mu_0}{4\pi}\frac{q_m}{(r-l)^2} + \frac{\mu_0}{4\pi}\frac{q_m}{(r+l)^2}$$

$$= \frac{\mu_0 q_m}{4\pi}\left[\frac{1}{(r-l)^2} + \frac{1}{(r+l)^2}\right]$$

$$= \frac{\mu_0}{4\pi} q_m \left[\frac{(r+l)^2 - (r-l)^2}{(r-l)^2 (r+l)^2} \right]$$

$$= \frac{\mu_0}{4\pi} q_m \left[\frac{\cancel{r^2} + \cancel{l^2} + 2rl - \cancel{r^2} - \cancel{l^2} + 2rl}{(r^2-l^2)^2} \right]$$

$$= \frac{\mu_0}{4\pi} q_m \left[\frac{4rl}{(r^2-l^2)^2} \right]$$

$$= \frac{\mu_0}{4\pi} \left[\frac{2Mr}{(r^2-l^2)^2} \right] \text{along } NP \Big] \qquad q_m \times 2l = M$$

$$\left[B_a = \left[\frac{\mu_0}{4\pi} \cdot \frac{2Mr}{(r^2-l^2)^2} \right] \text{along } NP \right]$$

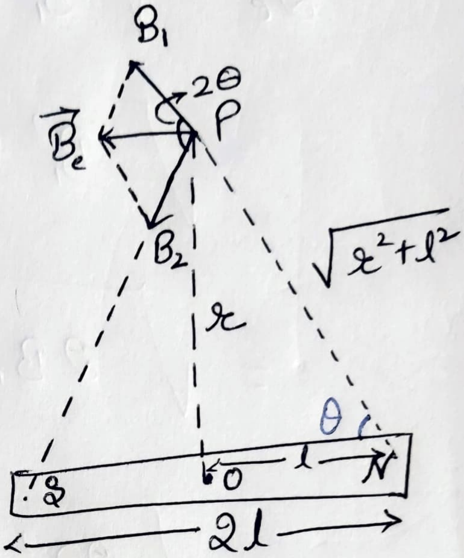
if the magnet is of very small length then

$$l^2 << r^2$$

$$B_a = \frac{\mu_0}{4\pi} \frac{2Mr}{r^{\cancel{4}3}}$$

$$\boxed{\therefore\ B_0 = \frac{\mu_0}{4\pi} \frac{2M}{r^3}}$$

Magnetic field on Equatorial line of bar Magnet :-



Let the Point (P) lie on the equiatorial line of a bar magnet at a distance (r) from the point O.

Now Magnetic intensity at (P) due to North-Pole.

$$\vec{B}_1 = \frac{\mu_0}{4\pi}\frac{q_m}{(NP)^2} \text{ along } (NP)$$

from Δ NoP

$$(NP)^2 = (ON)^2 + (OP)^2$$

$$(NP)^2 = l^2 + r^2$$

$$(NP) = \sqrt{l^2+r^2}$$

$$\vec{B}_1 = \frac{\mu_0}{4\pi}\frac{q_m}{l^2+r^2} \text{ along } NP.$$

Similarly due to S-Pole

$$\vec{B}_2 = \frac{\mu_0}{4\pi}\frac{q_m}{(r^2+l^2)} \text{ along } PS.$$

Now $\vec{B}_1$ and $\vec{B}_2$ are inclined at angle 2θ.

$$B_e = \sqrt{B_1^2 + B_2^2 + 2B_1B_2\cos 2\theta}$$

$$= \sqrt{B_1^2 + B_1^2 + 2B_1B_1\cos 2\theta} \quad [|B_1| = |B_2|]$$

$$= \sqrt{2B_1^2 + 2B_1^2\cos 2\theta}$$

$$= \sqrt{2B_1^2(1+\cos 2\theta)} \quad [1+\cos 2\theta = 2\cos^2\theta]$$

$$= \sqrt{2B_1^2 \, 2\cos^2\theta}$$

$$= 2B_1\cos\theta$$

$$B_e = 2\frac{\mu_0}{4\pi}\frac{q_m}{(r^2+l^2)}\cos\theta$$

Now $\cos\theta = \dfrac{l}{\sqrt{l^2+r^2}}$

$$B_e = 2\frac{\mu_0}{4\pi}\frac{q_m}{r^2+l^2}\left(\frac{l}{\sqrt{l^2+r^2}}\right)$$

$$B_e = \frac{2\mu_0 q_m l}{4\pi(r^2+l^2)^{3/2}}$$

$q_m \times 2l = m$

$$\boxed{B_c = \frac{\mu_0}{4\pi}\frac{m}{(r^2+l^2)^{3/2}}}$$

In Case, magnet is of very Small length

$l^2 << r^2$

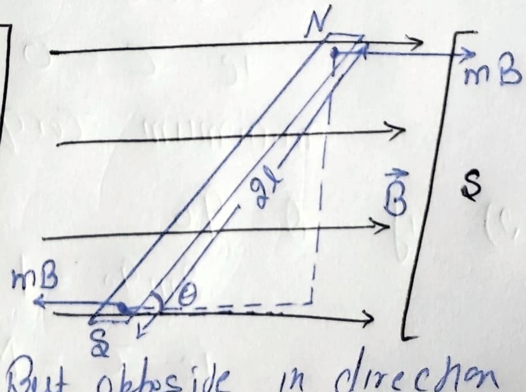
$$B_e = \frac{\mu_0}{4\pi}\frac{m}{(r^{\cancel{2}})^{3/\cancel{2}}}$$

$$\boxed{B_e = \frac{\mu_0}{4\pi}\frac{m}{r^3}}$$

⇒ Torque on a bar magnet in a Magnetic Field :-

in uniform magnetic field

Let us consider a bar magnet in uniform magnetic field
$\vec{B}$ makes an angle θ.
$2l$ = length of Bar magnet.
Force on N-pole = mB, along ($\vec{B}$) N
Force on S-pole = mB, opposite ($\vec{B}$)



This force equal in magnitude But opposite in direction makes an couple. Which tends to rotate the magnet Clockwise so as to alin it along $\vec{B}$.

Draw NA perpendicular to $\vec{B}$ ie $\vec{SA} \parallel B$.

∴ Torque acting on the bar magnet

= force × ⊥ distance

= $mB \times NA$ —— ①

from Δ SAN

$\sin\theta = \frac{NA}{SN} \Rightarrow NA = SN \sin\theta$

$NA = 2l \sin\theta$

using NA in ①

$\tau = mB \times (2l \sin\theta)$

$\tau = MB \sin\theta$ $\quad [\because M = m \times 2l]$

$$\boxed{\tau = \vec{M} \times \vec{B}}$$

Special cases :-

1) if $\theta = 0$ and 180

$\sin\theta = 0$

ie $\tau = 0$

minimum Torque in the magnet.

2) if $\theta = 90$

$\sin 90 = 1$

ie $\tau = MB$

maximum Torque in the bar magnet.

Potential energy of a Magnetic Dipole in a Magnetic field:-

Potential energy of a magnetic dipole in a magnetic field is the energy possessed by the dipole due to its particular position in the field.

When a magnetic dipole of moment $\vec{M}$ is held at an angle θ with the direction of a uniform magnetic field $\vec{B}$.

$$\tau = MB\sin\theta \quad \text{———} \quad ①$$

Now small amount of work done in rotating the dipole through a small angle θ in the magnetic field

$$dw = \tau\, d\theta = MB\sin\theta\, d\theta$$

Total work done in Rotating the dipole through a small angle from $\theta = \theta_1$ to $\theta = \theta_2$

$$W = \int_{\theta_1}^{\theta_2} MB\sin\theta\, d\theta$$

$$= MB\int_{\theta_1}^{\theta_2} \sin\theta\, d\theta = MB\left[-\cos\theta\right]_{\theta_1}^{\theta_2}$$

$$= -MB\left[\cos\theta_2 - \cos\theta_1\right]$$

__/__/__

∴ Potential energy of the dipole is

$$U = W = -MB(\cos\theta_2 - \cos\theta_1) \quad \text{—— (II)}$$

when $\theta_1 = 90$, and $\theta_2 = \theta$

$$U = W = -MB[\cos\theta - \cos 90)$$

$$= -MB\cos\theta$$

$$\boxed{W = -MB\cos\theta} \quad \text{—— (III)}$$

If vector notation

$$\boxed{U = -\vec{M}\cdot\vec{B}}$$

Particular cases :-

1) when $\theta = 90°$

$$U = -MB\cos\theta = -MB\cos 90 = -MB(0) = 0$$

when the dipole is ⊥ to magnetic field its potential energy is zero.

2) when $\theta = 0°$

$$U = -MB\cos(0) = -MB$$

when the magnetic dipole is aligned along the magnetic field. It is in stable equilibrium having minimum P.E.

3. when $\theta = 180°$

$$U = -MB\cos 180°$$
$$U = -MB(-1)$$
$$\boxed{U = MB}$$

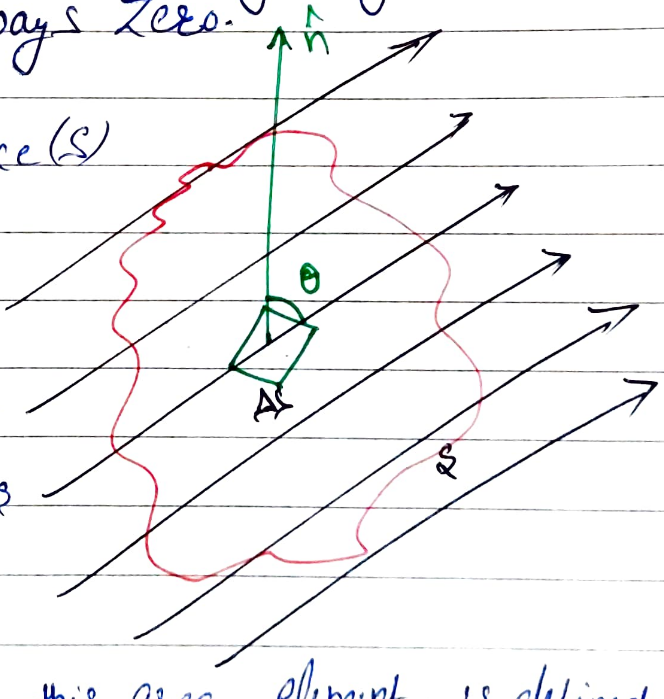
This is the position of unstable equilibrium.

MAGNETISM AND GAUSS's law :-

According to Gauss's law for magnetism, the net magnetic flux (ϕ_B) through any closed surface is always zero.

Suppose a closed surface (S) is held in a uniform magnetic field $\vec{B}$.

Consider a small vector area element $\Delta\vec{S}$ of this surface.



Magnetic flux through this area element is defined as $\Delta\phi_B = \vec{B}\cdot\Delta\vec{S}$

Now total magnetic flux through the surface is

$$\phi_B = \sum_{all}\Delta\phi_B = \sum\vec{B}\cdot\Delta\vec{S} = 0 \quad ①$$

Now for small area elements

$$\boxed{\phi_B = \oint_S \vec{B}\cdot d\vec{s} = 0} \quad \text{——} \ ②$$

This is the magnetic flux.

Earth's Magnetic field :-

Sir willian Gilbert was the first to suggest in the year 1600, ie earth it self is a huge magnet. His statement was based on the following evidince.

1) A magnet suspended from a thread and free to rotate in a horizontal plane comes to Rest along the north-south direction. The north pole of this magnet must be toward geographic south so as to attract south pole of the suspended magnet and vice-versa.

2) when a soft iron piece is buried under the surface of earth in the north-south direction, it is found to acqure the properties of a magnet after some time.

3) when we draw field lines of a magnet, we come across neutral points. At these points magnetic field due to the magnet is neutralized or can celled exactly by magnetic field of earth.

If earth had no magnetism of its own, we would never observe neutral Points.

Cause of Earth's Magnetism :-

1) Earth's magnetism may be due to the Rotation of earth about its axis. This because every substance is made up of charged particles (protons and electrons).
∴ a substance Rotating about an axis is equivalent to circulating current which are responsible for the magnetisation.

2) As earth Rotates, strong electric currents are set up due to movement of ions.

3) The earth's Core is extremely hot and molten. Circulating ions of iron and nickel in the highly conducting liquid region of the earth's Core might be forming current loops and producing earth's magnetic field.

Hypothesis is supporting by the following facts.

(1) Moon has no molten Core and hence no magnetic field.

2) Venus has a slower Rate of Rotation and hince a weaker magnetic field.

3). Jupiter has the fastest Rotation Rate. ∴ it has a fairly strong magnetic field.

Magnetic Elements :-

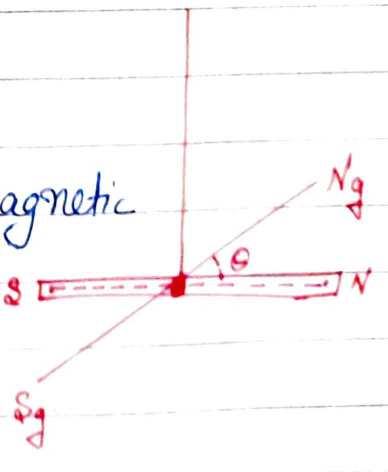
Magnetic elements of earth at a place are the quanities which describe completely in magnitude as well as direction, the magnetic field of earth at that place.

Three Magnetic elements of earth :-

i) Magnetic declination (θ)
ii) Magnetic inclination or Magnetic dip (δ)
iii) Horizontal Component (H).

i) Magnetic declination (θ)

The small angle between magnetic axis and geographic axis at a place is defined as the magnetic declination at the place. It is represented by θ.

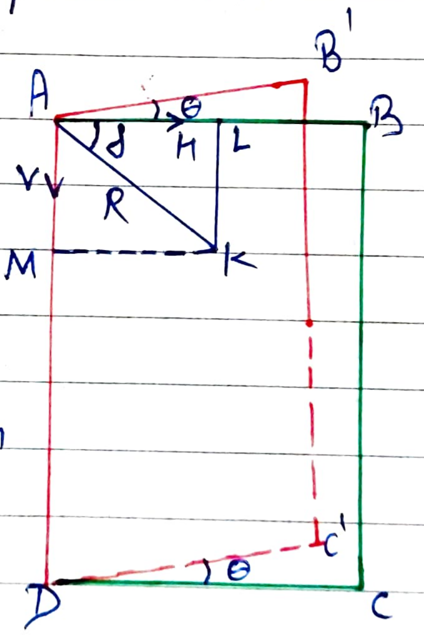


★ vertical plane passing through (N-S) line of freely Suspended magnet is called magnetic meridian.

★ The vertical plane passing through the geographic north south direction is called geographic meridion.

I) Magnetic declination :- magnetic declination at a place is the angle between magnetic meridian and geographic meridian at that place.

Here CDAB Represents the magnetic meridian and AB'C'D Represents the geographic meridian and the angle between magnetic meridian and geographic meridian is known as magnetic declination (θ)



II) Magnetic dip or Magnetic Inclination:-

Magnetic dip or magnetic Inclination at a place is defined as the angle which the direction of total strength of earth's magnetic field makes with a horizontal line in magnetic meridian.

iii) Horizontal Component :- It is the Component of total intensity of earth's magnetic field in the horizontal direction in magnetic meridian. It is denoted by (H).

Here (AK) represents the total intensity of earth's magnetic field, ∠BAK = δ

The resultant intensity (R) along AK is resolved into two rectangular Components:

Horizontal Component along AB is

$$AL = H = R\cos\delta \quad \text{——} \quad ①$$

Vertical Component along AD is

$$AM = V = R\sin\delta. \quad \text{——} \quad (II)$$

Squaring and adding equation ① and (II)

$$H^2 + V^2 = R^2\cos^2\delta + R^2\sin^2 d$$

$$H^2 + V^2 = R^2(\cos^2 \delta + \sin^2 \delta)$$

$$H^2 + V^2 = R^2$$

$$\left[R = \sqrt{H^2 + V^2}\right] \quad \text{——} \quad (III)$$

Dividing equation (ii) by (i)

$$\frac{R\sin\delta}{\cancel{R}\cos\delta} = \frac{V}{H}$$

$$\boxed{\tan\delta = \frac{V}{H}}$$

The value of Horizontal Component $H = R\cos\delta$ is different at different places.

at magnetic pole $\delta = 90$

$$H = R\cos 90$$

$$\boxed{H = \text{Zero}}$$

at the magnetic equator $\delta = 0$

$$H = R\cos(0) = R$$

$$\boxed{H = R}.$$

Numerical:- The vertical component of earth's magnetic field at a place is $\sqrt{3}$ time the horizontal component. What is the value of angle of dip at this place?

Solution:- Here $V = \sqrt{3}$, $\delta = ?$

$$\tan \delta = \frac{V}{H}$$

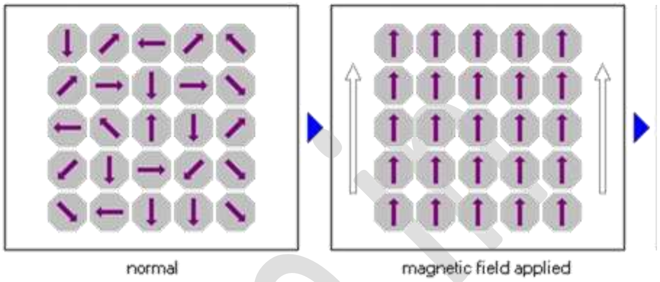
$$\tan \delta = \frac{\sqrt{3}\,\cancel{H}}{\cancel{H}}$$

$$\tan \delta = \sqrt{3}$$

$$\delta = \tan^{-1}(\sqrt{3}) \Rightarrow \boxed{\delta = 60^\circ}$$

(i) Magnetic properties of materials-Para-, dia- and ferro -magnetic substances with examples

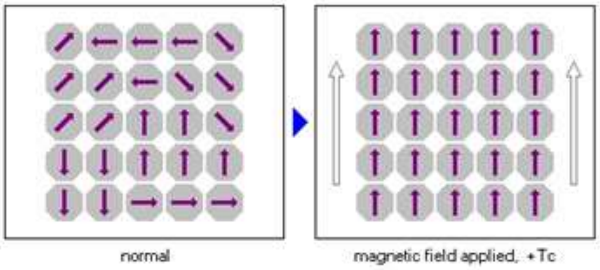
1. Paramagnetic Materials:



PARAMAGNETIC MATERIALS

- **Definition:** Paramagnetic materials are characterized by the presence of unpaired electrons, which results in a weak attraction to an external magnetic field.
- **Behavior:**
  - In the absence of an external magnetic field, the magnetic moments of individual atoms or ions are randomly oriented.
  - When exposed to a magnetic field, these moments tend to align parallel to the field, but the alignment is weak.
- **Examples:**
  - **Aluminum (Al):** While aluminum is paramagnetic, the effect is weak due to the small number of unpaired electrons.
  - **Platinum (Pt):** Paramagnetic behavior is exhibited due to the presence of unpaired electrons.
- **Properties:**
  - Magnetic susceptibility is positive but small.
  - The material acquires a temporary magnetic moment in the direction of the applied field.

2. Diamagnetic Materials:



FERROMAGNETIC MATERIALS

- **Definition:** Diamagnetic materials have all their electrons paired, leading to a weak repulsion when exposed to an external magnetic field.
- **Behavior:**
  - Diamagnetic materials develop a magnetic moment in the opposite direction of the applied field.
  - This negative magnetic moment is weak and typically overwhelmed by other stronger magnetic effects.

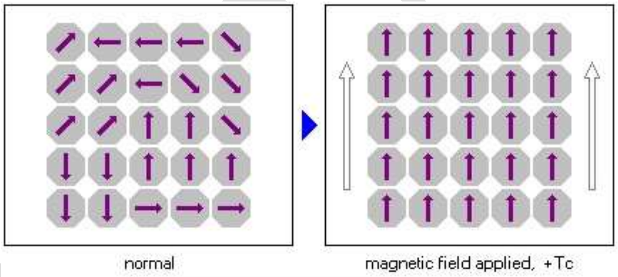
- **Examples:**
  - **Bismuth (Bi):** Strongly diamagnetic due to the pairing of all electrons.

  - **Copper (Cu):** Exhibits weak diamagnetic behavior.

- **Properties:**
  - Magnetic susceptibility is negative.
  - The repulsive force is weak, and these materials are often considered non-magnetic.

3. Ferromagnetic Materials:

- **Definition:** Ferromagnetic materials are characterized by the presence of magnetic domains in which groups of atoms align their magnetic moments in the same direction.
- **Behavior:**
  - In the absence of an external magnetic field, these materials exhibit spontaneous magnetization.
  - When subjected to a magnetic field, the magnetic moments align more uniformly, resulting in a strong overall magnetization.



FERROMAGNETIC MATERIALS

- **Examples:**
  - **Iron (Fe):** A classic example with strong ferromagnetic properties.
  - **Cobalt (Co):** Exhibits a high Curie temperature, making it suitable for high-temperature applications.
- **Properties:**
  - High magnetic susceptibility.
  - Retain a significant magnetic moment even after the external field is removed.
  - Easily magnetized and demagnetized.

4. Ferrimagnetic Materials:

- **Definition:** Ferrimagnetic materials have opposing magnetic moments in different sublattices, resulting in a net magnetization.

- **Behavior:**
  - Consists of two sublattices with magnetic moments pointing in opposite directions.
  - The unequal magnitudes of these moments lead to a net magnetization.

- **Examples:**
  - **Magnetite (Fe_3O_4):** Contains both Fe^{2+} and Fe^{3+} ions, resulting in ferrimagnetic behavior.

  - **Yttrium Iron Garnet ($Y_3Fe_5O_{12}$):** Exhibits ferrimagnetism at certain temperatures.

- **Properties:**
  - Display characteristics of both ferromagnetic and antiferromagnetic materials.
  - Net magnetic moment arises due to the imbalance of magnetic moments in different sublattices.

(ii) Magnetization of Materials:

- **Definition:**
  - Magnetization is the process of inducing a magnetic moment in a material, aligning its magnetic domains.

- **Process:**
  - Application of an external magnetic field aligns the magnetic moments within the material.
  - This alignment leads to the creation or enhancement of magnetic domains.

- **Factors Affecting Magnetization:**
  - **Material Composition:** Different materials have varying responses to magnetization.
  - **Applied Magnetic Field:** The strength and direction of the external magnetic field influence magnetization.

(iii) Effect of Temperature on Magnetic Properties:

- **Curie Temperature:**
  - **Definition:** The Curie temperature (T_c) is the temperature at which certain materials undergo a phase transition, changing their magnetic properties.

- **Paramagnetic and Ferromagnetic Materials:**
  - **Paramagnetic:** Magnetic susceptibility decreases with increasing temperature.
  - **Ferromagnetic:** Above the Curie temperature, ferromagnetic materials become paramagnetic, losing their spontaneous magnetization.

- **Antiferromagnetic Materials:**
  - Above the Néel temperature, antiferromagnetic materials may lose their antiferromagnetic order and become paramagnetic.

- **Applications:**
  - Understanding temperature effects is crucial for designing materials for specific applications, such as magnetic storage and sensors.
  - High-temperature stability is essential for maintaining magnetic properties in diverse environments.

Property	**Paramagnetic Materials**	**Diamagnetic Materials**	**Ferromagnetic Materials**
Definition	Weakly attracted by an external field	Repelled by an external field	Exhibit strong magnetization and retention
Behavior	Weak alignment of magnetic moments	Opposite alignment to the field	Spontaneous magnetization, strong alignment
Examples	Aluminum (Al), Platinum (Pt), Chromium (Cr)	Bismuth (Bi), Copper (Cu), Graphite (C)	Iron (Fe), Cobalt (Co), Nickel (Ni)
Magnetic Susceptibility	Positive but small	Negative	High
Magnetic Moment Orientation	Parallel to the applied field (weakly)	Opposite to the applied field	Parallel to the applied field
Retained Magnetic Moment	Temporary	Weak, repulsive force	Retains a significant moment
Magnetization Process	Develops a temporary moment in the field	Develops a weak, opposite moment	Spontaneous magnetization in uniform field
Temperature Effects	Susceptibility decreases with temperature	Generally unaffected	Loss of spontaneous magnetization above Curie Temperature

Magnetism and Matter
Formulas

1) Force between two Magnetic Poles :-

$$F = \frac{\mu_0}{4\pi}\,\frac{{}_1m_2}{r^2}$$

2) Magnetic Dipole moment :-

$$\vec{M} = m(2\vec{l})$$

S.I :- Ampere-metre^2

3) Current loop as a Magnetic dipole :-

$$\vec{M} = NIA\hat{n}$$

4) BAR Magnet as an equivalent Solenoid :-

$$B = \frac{\mu_0 2M}{4\pi r^3}$$

5) Magnetic field Intensity due to a magnetic dipole :-

1) On axial line :-

$$B_0 = \frac{\mu_0}{4\pi} \frac{2M}{r^3}$$

2) On Equatorial line :-

$$B_e = \frac{\mu_0}{4\pi} \frac{M}{r^3}$$

6) Torque on a bar magnet in a Magnetic field:-

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

$$\tau = MB\sin\theta$$