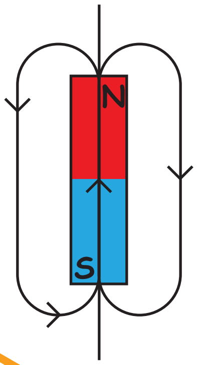
MAGNETISM AND MATTER

MBC

THE MAGNETIC FIELD LINES



1. The magnetic field lines of a magnet form continous closed loops
2. The tangent to the field lines at a given point represents the direction of the net magnetic field B at that point
3. The larger no.of field lines $\longrightarrow$ stronger $\vec{B}$
4. Do not intersect

CUTTING OF BAR MAGNET

LENGTHWISE / TRANSVERE

$\longleftarrow l \longrightarrow$

$l/2$ $\quad$ $l/2$

Pole strength $\longrightarrow$ same

length $\longrightarrow$ reduce to half

$M_{new} = \frac{ml}{2}$

HORIZONTAL

$\longleftarrow l \longrightarrow$

Pole strength $\longrightarrow$ reduce to half

length $\longrightarrow$ same

$M_{new} = \frac{ml}{2}$

FACTS

A) Magnetic monopoles does not exist
B) A solenoid and bar magnet produce similar magnetic fields

POTENTIAL AT ANY GENERAL POINT

$V = \frac{1}{4\pi\varepsilon_0}\frac{P\cos\theta}{r^2}$ $\qquad$ $V_m = \frac{\mu_0}{4\pi}\frac{M\cos\theta}{r^2}$

TORQUE

1) $F_{net}=0$ $\qquad$ 1) $(F_m)_{net}=0$

2) $\vec{\tau}=\vec{p}\times\vec{E}=pE\sin\theta$ $\qquad$ 2) $\vec{\tau}=\vec{M}\times\vec{B}=MB\sin\theta$

WORK DONE IN ROTATING A DIPOLE

1. $W=PE(\cos\theta_1-\cos\theta_2)$ $\qquad$ 1. $W_B=MB(\cos\theta_1-\cos\theta_2)$

Maximum work done is from $\theta_1=0^\circ$ to $\theta_2=180^\circ$

POTENTIAL ENERGY

$U=-\vec{P}.\vec{E}$ $\qquad$ $U_B=-\vec{M}.\vec{B}$

$\theta_1=0^\circ$ Stable position; $\theta=180^\circ$ Unstable position

APPARENT ANGLE OF DIP

Inclination of magnetic needle in plane other than magnetic meridian

$\tan\delta' = \frac{\tan\delta}{\cos\theta}$

δ' Apparent angle of dip
δ true angle of dip
θ Angle between MM and the plane other than MM

RELATION BETWEEN TWO FALSE ANGLE OF DIPS (δ_1&δ_2) IN MUTUALLY PERPENDICULAR PLANES AND TRUE ANGLE OF DIP (δ)

$\cot^2\delta_1+\cot^2\delta_2=\cot^2\delta$

MAGNETIC DIPOLE MOMENT ($\vec{M}$)

$\vec{M}=m\vec{l}$

m $\rightarrow$ pole strength

l $\rightarrow$ Straight line distance b/w poles

Direction from southpole to N pole

Unit of M $\rightarrow$ Am^2

Unit of m $\rightarrow$ Am

THE ELECTROSTATIC ANALOG

(Help from electrostatics to magnetism)

SHORT ELECTRIC DIPOLE $\qquad$ **SHORT MAGNETIC DIPOLE**

'q' $\vec{p}$, d $\qquad$ 'm' l

$\vec{p}=q\vec{d}$ $\qquad$ $\vec{M}=m\vec{l}$

COULOMB'S LAW

$F=\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$ $\qquad$ $F_m=\frac{\mu_0}{4\pi}\frac{m_1m_2}{r^2}$

AXIAL & EQUITORIAL LINE OF DIPOLE

$E_{axial}=\frac{1}{4\pi\varepsilon_0}\frac{2P}{r^3}$ $\qquad$ $B_{axial}=\frac{1}{4\pi\varepsilon_0}\frac{2M}{r^3}$

$E_{eq}=\frac{1}{4\pi\varepsilon_0}\frac{P}{r^3}$ $\qquad$ $B_{eq}=\frac{\mu_0}{4\pi}\frac{M}{r^3}$

$\vec{E}_{axial}=-2\vec{E}_{eq}$ $\qquad$ $\vec{B}_{axial}=-2\vec{B}_{eq}$

MAGNETISM AND GAUSS' LAW

"The net magnetic flux through any closed surface is zero"

$\oint \vec{B}.\vec{ds}=0$

NOTE: "The simplest magnetic element is a magnetic dipole or a current loop."Magnetic monopoles do not exist.

FACTS

1. Declination is greater at poles and smaller near equator
2. Angle of dip is maximum at poles and minimum at equator

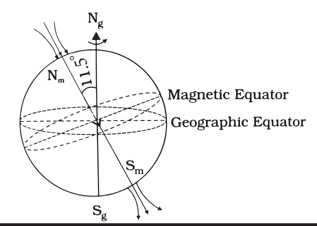
BAR MAGNET TO DIFFERENT SHAPES

$M_{new}=\frac{M\sin(\frac{\theta}{2})}{(\frac{\theta}{2})}$ $\qquad$ $l'=\frac{l\sin(\frac{\theta}{2})}{(\frac{\theta}{2})}$

RESULTANT DIPOLE MOMENT

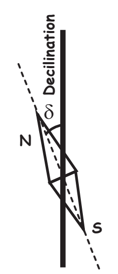
$M_{net}=\sqrt{M_1^2+M_2^2+2M_1M_2\cos\theta}$

THE EARTH'S MAGNETISM



MAGNETIC ELEMENTS OF EARTH

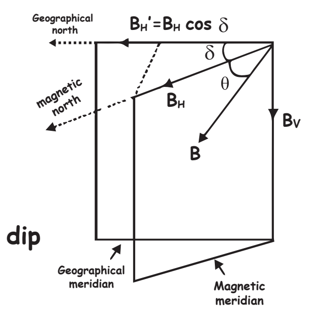
- Magnetic declination $-\delta$
- Inclination or Dip $-\theta$
- Horizontal component $-B_H$



Angle between geographic meridian & magnetic meridian (MM)

True angle of dip

$\tan\theta=\frac{B_V}{B_H}$



COMPASS NEEDLE AND DIP NEEDLE

1. A compass needle at the North pole can point along any direction.
2. A dip needle at the north pole points down and at South pole points straight up.

TIME PERIOD

of a magnetic dipole in uniform magnetic field

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

I - Moment of Inertia of the body
M - Magnetic dipole moment
B - Magnetic field

Frequency $\nu=\frac{1}{2\pi}\sqrt{\frac{MB}{I}}$

To find B, $B=\frac{4\pi^2 I}{MT^2}$

Magnetism

MAGNETIC PROPERTIES

1) Magnetic Permeability

Absolute Permeability of air or free space $\mu_0 = 4\pi \times 10^{-7} \dfrac{\text{Tesla metre}}{\text{Ampere}} \left[\dfrac{Tm}{A}\right]$

Relative Permeability of medium $\mu_r = \dfrac{\mu_{medium}}{\mu_0}$

2) Intensity of magnetizing field ($\vec{H}$)

$\vec{H} = \dfrac{B_{ext}}{\mu_0}$ vector quantity

SI unit $\rightarrow \dfrac{A}{M}$ CGS unit $\rightarrow$ Oersted

3) Magnetisation ($\vec{M}$)

$\vec{M} = \dfrac{\vec{M}_{net}}{V} \rightarrow \left[\dfrac{\text{Induced dipole moment}}{\text{volume}}\right]$ also, $\vec{M} = \dfrac{\vec{B}_{ind}}{\mu_0}$

vector quantity

SI unit $\rightarrow \dfrac{A}{m}$ $[M] \rightarrow [L^{-1}A]$

4) Magnetic Susceptibility (χ_m)

$\chi_m = \dfrac{M}{H}$ Also $\chi = \dfrac{B_{ind}}{B_{ext}}$

scalar quantity

no unit

no dimension

5) Relation between relative permeability and susceptibility

$\mu_r = (1+\chi_m)$ Also $\mu = \mu_0\mu_r = \mu_0(1+\chi_m)$

6) Relation between B, M and H

$B = \mu_m H$ $M = \chi H$

MAGNETIC MATERIALS

1. Diamagnetic

a. Weakly repelled by a magnet

b. Eg: Cu, Ag, Au, NaCl, H_2O etc.

c. Superconductors - Perfect conductivity

perfect diamagnetism

$\chi = -1, \mu_r = 0$

d. Perfect diamagnetism in superconductors is called as MEISSNER EFFECT

e. Important $\boxed{\begin{array}{l} -1 \le \chi < 0 \\ 0 \le \mu_r < 1 \\ \mu < \mu_0 \end{array}}$

f. Individual atoms do not possess permanent magnetic dipole moment

g. No effect of temperature on magnetisation

2. Paramagnetic substances

a. Weakly attracted by a magnet

b. Eg : Al, Mn, Pt, Na, $CuCl_2$, O_2, Crown glass

c. Individual atom possesses permanent dipole moment

d. Curie's law

Magnetisation of a paramagnetic material is inversely proportional to the absolute temperature

$$\left.\begin{array}{l} M = C\dfrac{B_0}{T} \\ \chi = C\dfrac{\mu_0}{T} \end{array}\right\} \text{Curie's law}$$

e. Important

$\boxed{\begin{array}{l} 0 < \chi < \varepsilon \\ 1 < \mu_r < 1+\varepsilon \ (\varepsilon \rightarrow \text{Small positive number}) \\ \mu > \mu_0 \end{array}}$

f. Graph

3. Ferromagnetic substances

a. Strongly attracted by a magnet

b. Eg : Fe, Co, Ni, Cd, Fe_3O_4

c. Individual atoms possess permanent magnetic moment and magnetic moments of neighbouring atoms tend to align due to a force called exchange coupling

d. Due to exchange coupling, atoms form domains inside which magnetic moments are aligned in the same direction

e. Important $\boxed{\begin{array}{l} \chi >>> 1 \\ \mu_r >> 1 \\ \mu >> \mu_0 \end{array}}$

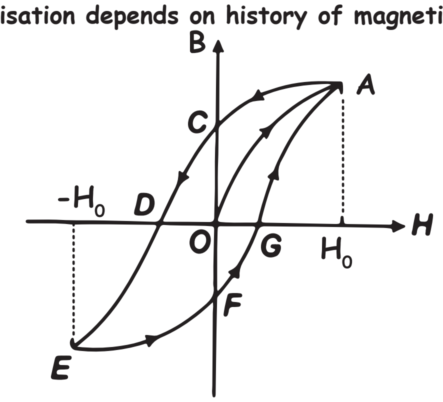
f. At high temperature, a ferromagnetic substance becomes paramagnetic

Curie's temperature

$\chi = \dfrac{C}{T-T_C} \ (T > T_C)$

HYSTERESIS CURVE / B-H CURVE

Magnetisation depends on history of magnetisation



Important terms

Retentivity - OC - Residual magnetism

Coercivity -OD-Demagnetising process

1. High coercivity - Hard substance - Steel
2. Low coercivity - Soft substance - Soft iron

Important result

B-H curve signifies the energy loss/heat loss in the process and is proportional to the area of the loop.

Area of hysteresis loop → Smaller for soft iron; Higher for steel

Permanent magnets

should have

1. High retentivity
2. High coercivity
3. High permeability

Steel is used for making permanent magnets

Steel	soft iron
Smaller retentivity High coercivity	Higher retentivity than steel Smaller coercivity than steel

ELECTROMAGNETS

Materials should have

high permeability

low retentivity

Soft iron is used

Used in electric bells, Loudspeakers, telephone diaphragms, heavy cranes to lift machinery