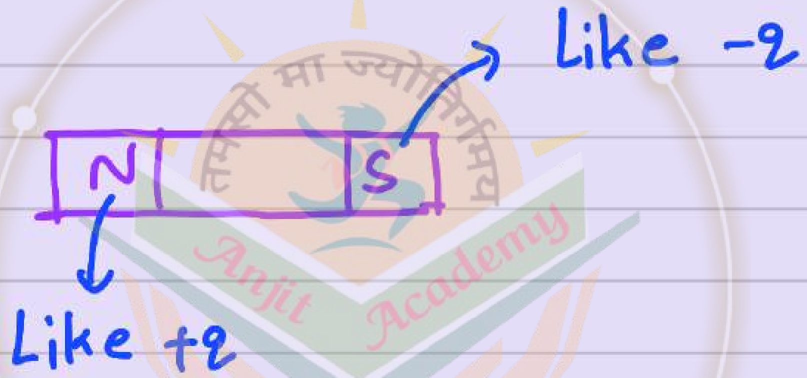
Chapter - 5

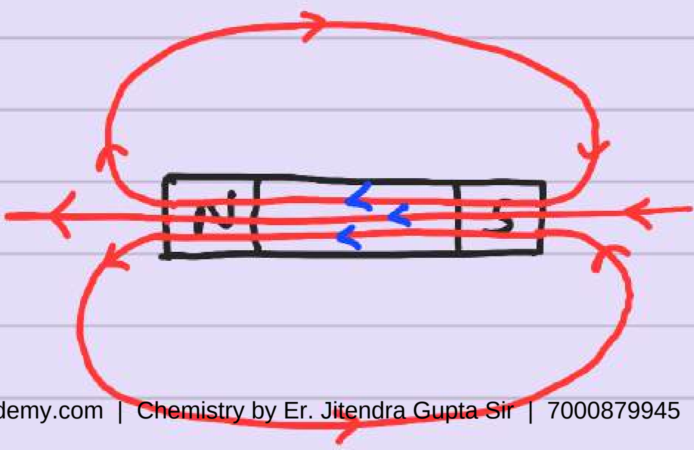
MAGNETISM & MATTER

Bar Magnet :-



Magnetic field Lines:

Imaginary Lines drawn in Space along which a North pole would move.



1) Magnetic field lines form closed loops.

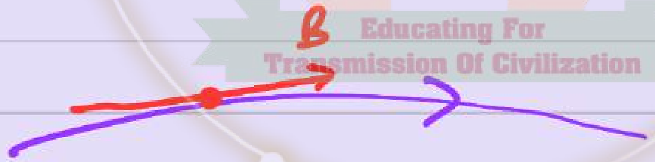
2) outside → Lines are from

$N \rightarrow S$

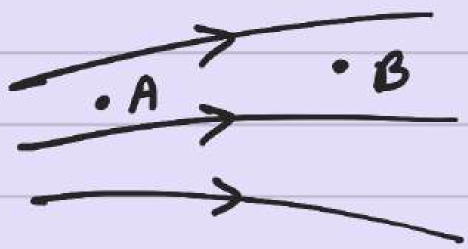
inside → Lines are from

$S \rightarrow N$

3) The tangent at any point on field lines, gives direction of net $\vec{B}$ at that point.

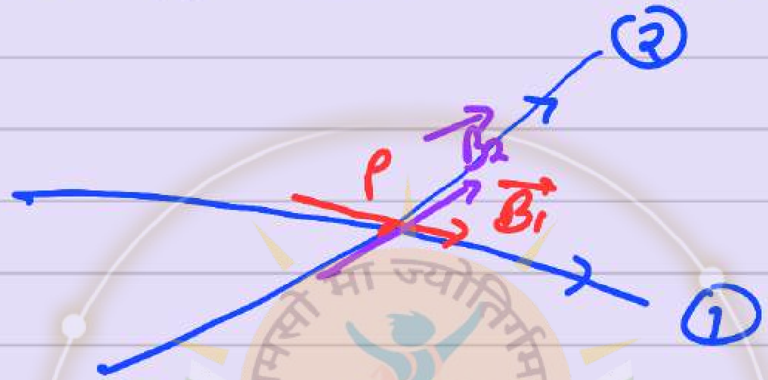


4) Closer the field (denser), stronger is $\vec{B}$

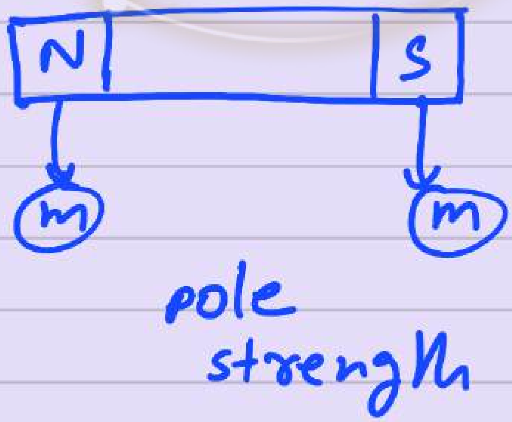


$(B)_A > (B)_B$

⑤ Two Magnetic field Lines can Never intersect each other as if they do so, There will be two tangents at point of intersection & hence two directions of $\vec{B}$ which is Not Possible.

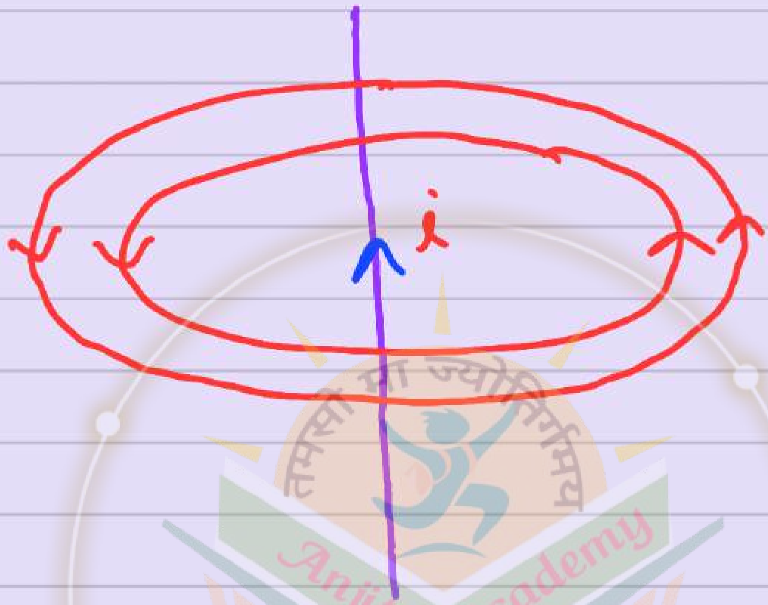


⑥ Magnetic field Lines $\propto$ Pole strength

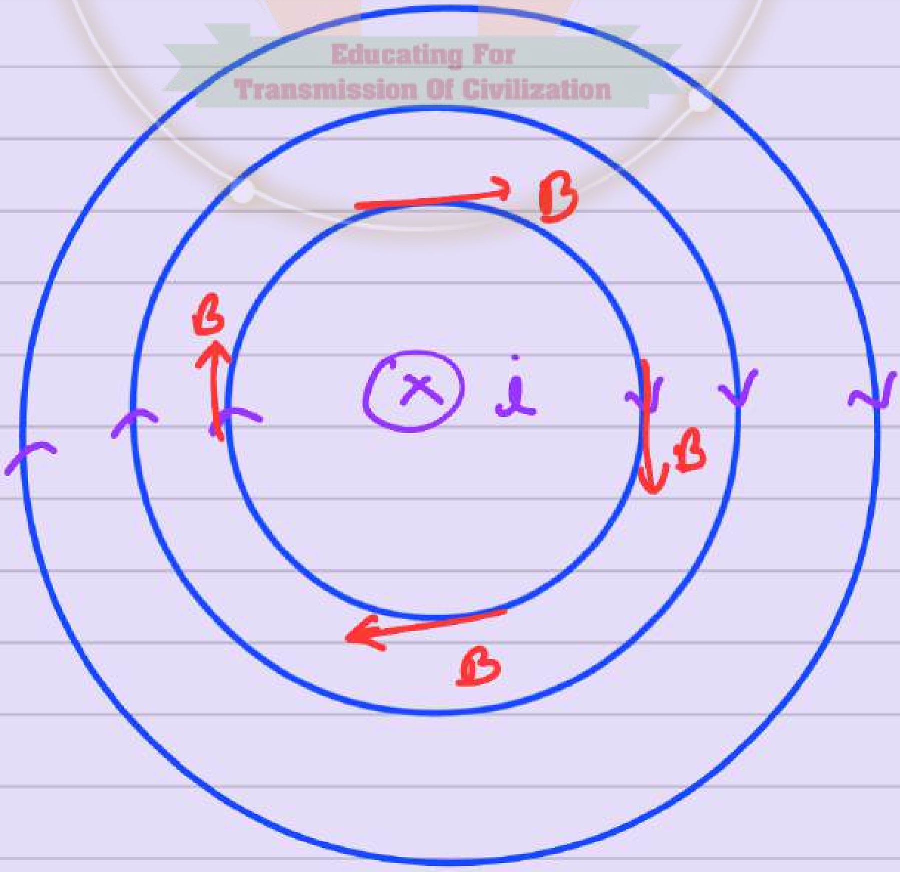


Some Standard Diagrams of magnetic field Lines.

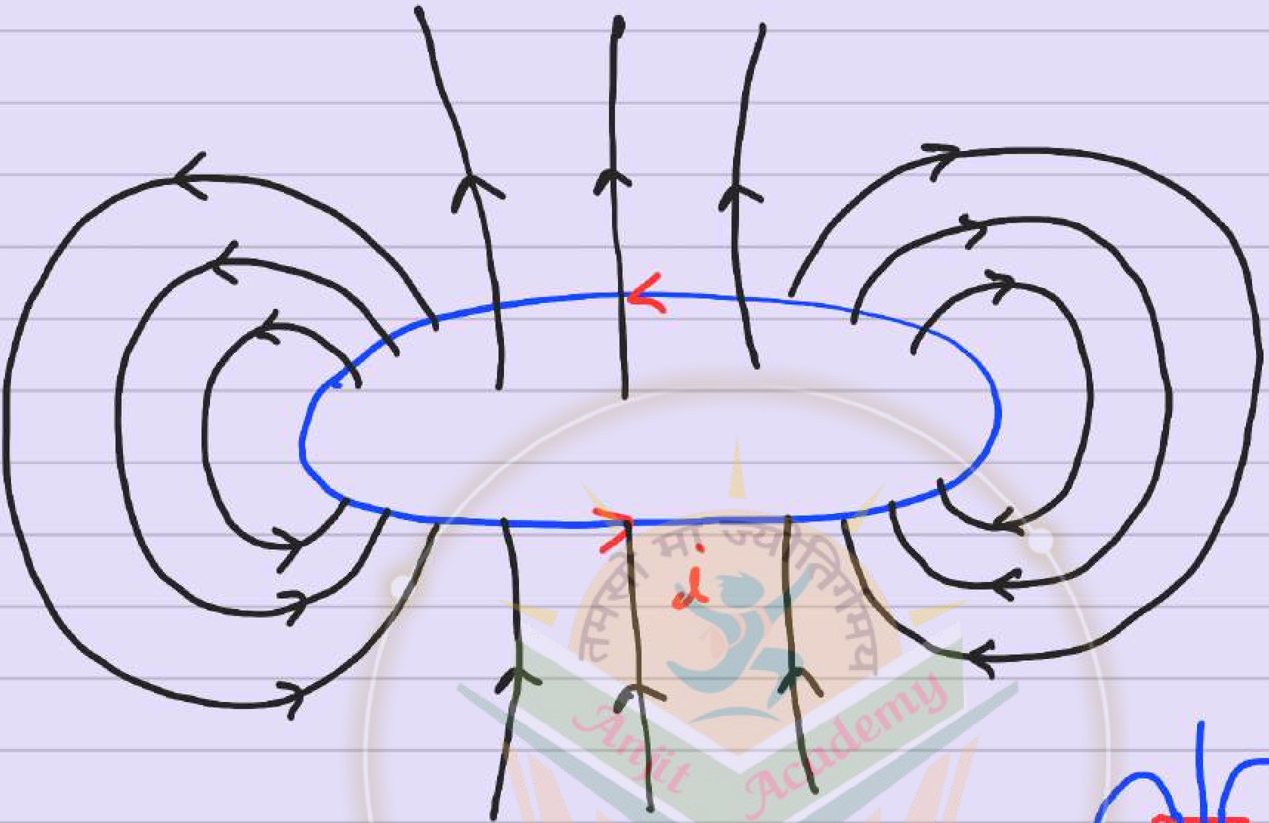
(1)

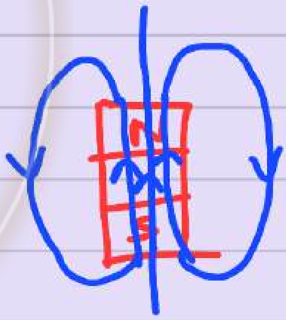


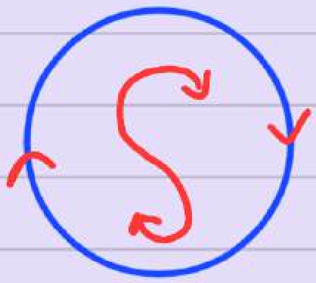
2)

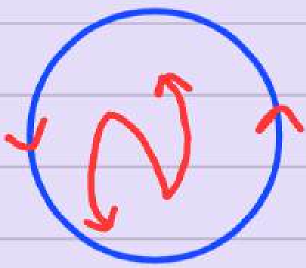


3) Current Carrying Loop









Clockwise
current → S pole

Anticlockwise
current → N pole

Bar magnet $\rightarrow$ magnetic Dipole

Analogy with electric Dipole

$+q \longrightarrow$ north pole

$-q \longrightarrow$ south pole

Electric Dipole	Magnetic Dipole
① $\vec{E}$ field due to point charge 'q'	$\vec{B}$ field due to a monopole m
(q) - - - - - - $\underset{r}{}$ $E = \frac{Kq}{r^2}$	m - - - - - - $\underset{r}{}$ $\vec{B} = \frac{km}{r^2}$
$K = \frac{1}{4\pi\varepsilon_0}$	$K = \frac{\mu_0}{4\pi}$
away from $+q$ & towards $-q$	away from N towards S

Note: Monopoles Don't exist But analogy does

② V due to Point charge 'q'

q - - - - - - r $V = \frac{kq}{r}$

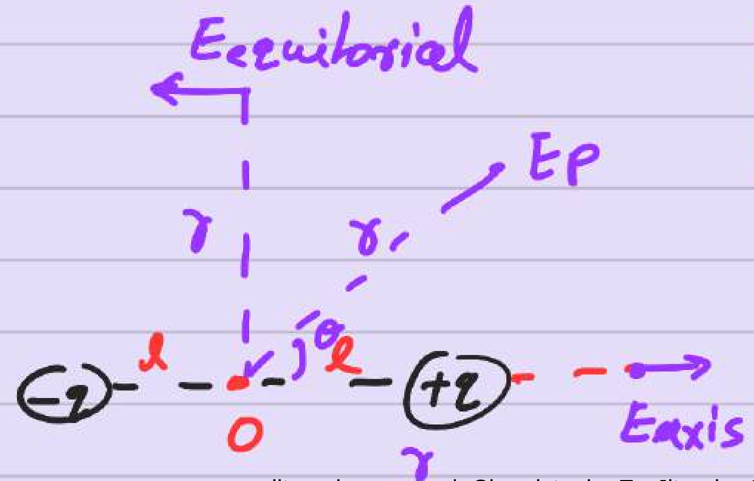
③ Dipole moment

(-q) - - l - O - l - - (+q)

$\vec{P} = q \cdot 2l$

from -q to +q

④ E field due to Dipole



V due to monopole m

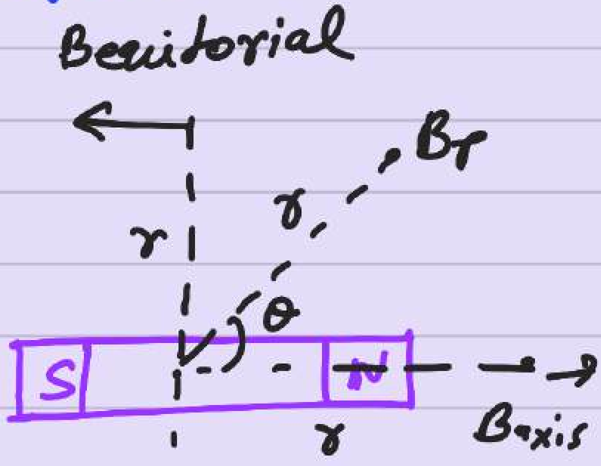
m - - - - - - r $V = \frac{km}{r}$

Pole strength

$\vec{M} = m \cdot 2l$

from S to N

$\vec{B}$ field due to Dipole



$E_{axis} = \frac{2kp}{r^3}$ (along $\vec{p}$)

$B_{axis} = \frac{2KM}{r^3}$ (along $\vec{m}$)

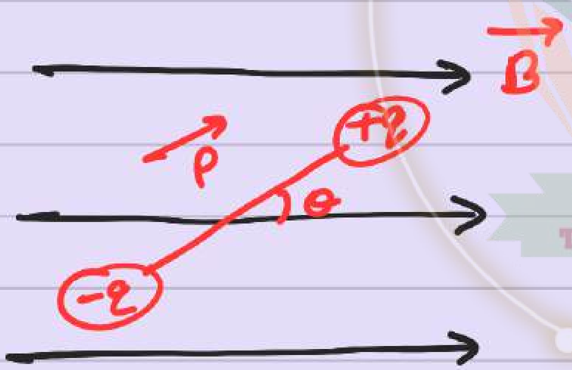
$E_{equitorial} = \frac{Kp}{r^3}$ (opp. to $\vec{p}$)

$B_{equitorial} = \frac{KM}{r^3}$ (opp. $\vec{m}$)

$$E_p = \frac{kp}{r^3}\sqrt{1+3\cos^2\theta}$$

$$B_p = \frac{km}{r^3}\sqrt{1+3\cos^2\theta}$$

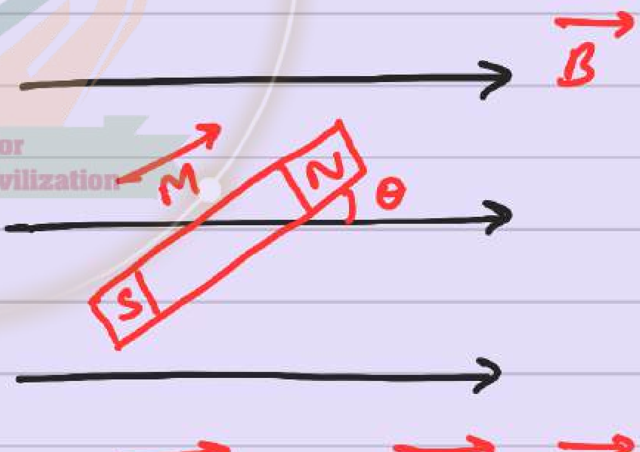
⑤ Torque on electric Dipole in Uniform $\vec{E}$ field



$$\vec{\tau} = \vec{p} \times \vec{E}$$

$$\tau = pE\sin\theta$$

Torque on Magnetic Dipole in Uniform $\vec{B}$ field



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

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

⑥ Potential Energy of Dipole in Uniform $\vec{E}$ field

Potential Energy of Dipole in Uniform $\vec{B}$

field

$U(\theta) = -\vec{P}.\vec{E}$

$= -PE\cos\theta$

$U(\theta) = -\vec{M}.\vec{B}$

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

Earth's magnetism

⇒ magnesia → 600 BC

↓

wooden shoes (with iron nails) of shepherds at times stayed struck to the ground.

⇒ A thin long piece of magnet, when suspended freely always comes to rest in the North - south Direction.

Both these evidences suggest Some form of magnetic field due to earth.

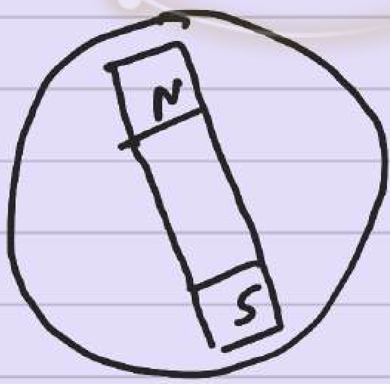
Earth's magnetic field is found to vary place to place.

It's value is approximately 0.1 Gauss.

$$(1G = 10^{-4} \text{ Tesla})$$

Assumption ① A giant Bar Magnet inside earth.

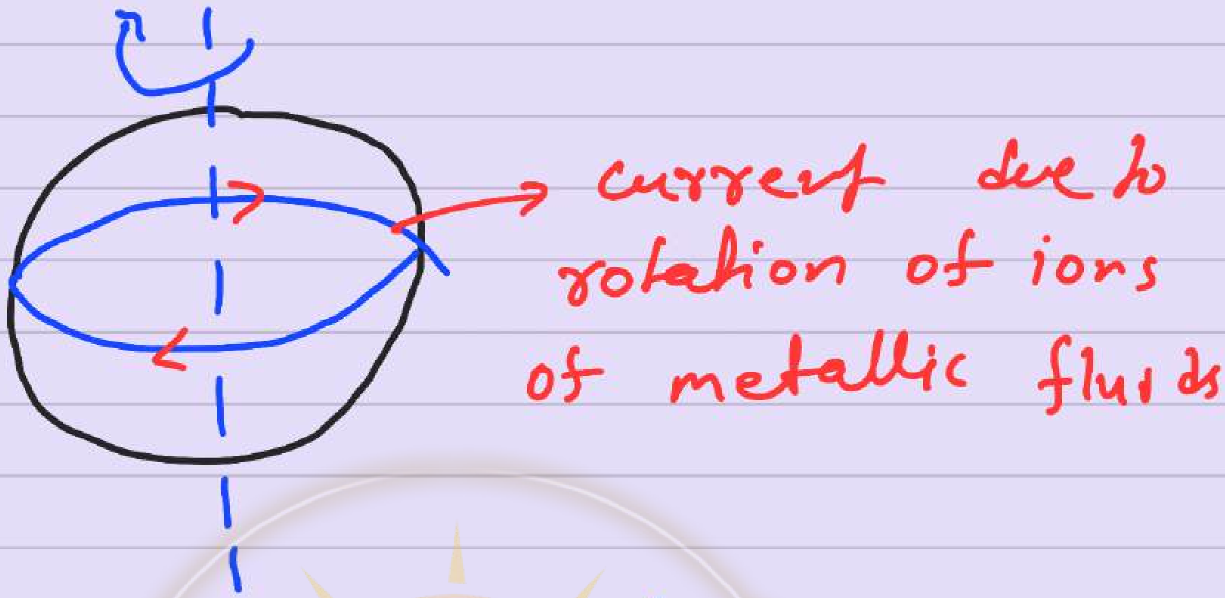
×

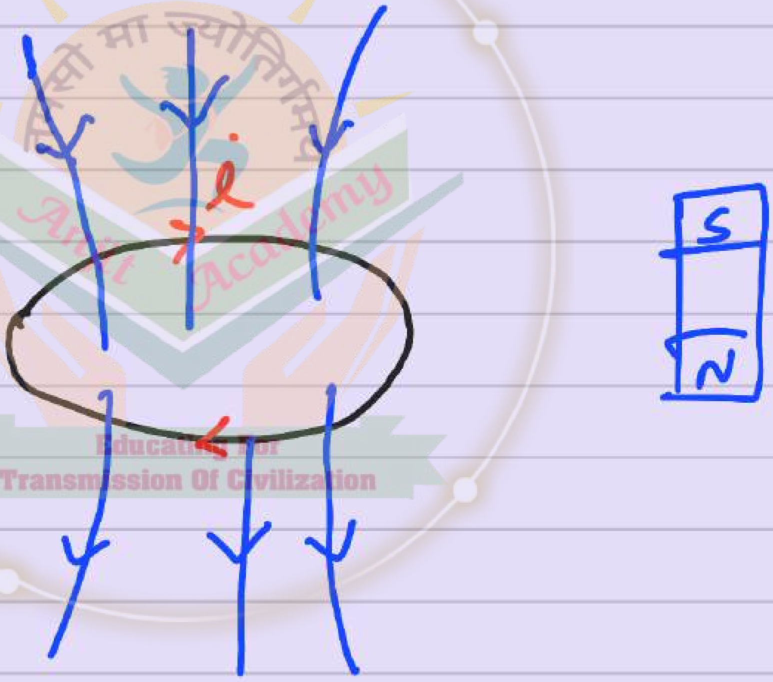


earth

failed : Temp. inside earth is very high.

② Assumption ② :

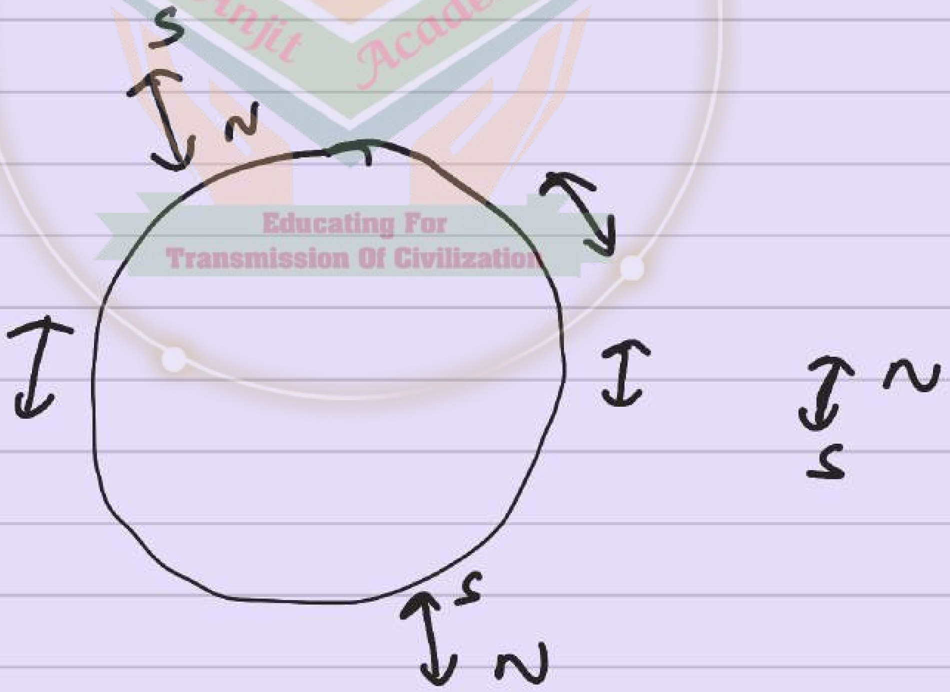




Magnetic Needle & Nomenclature of Poles.

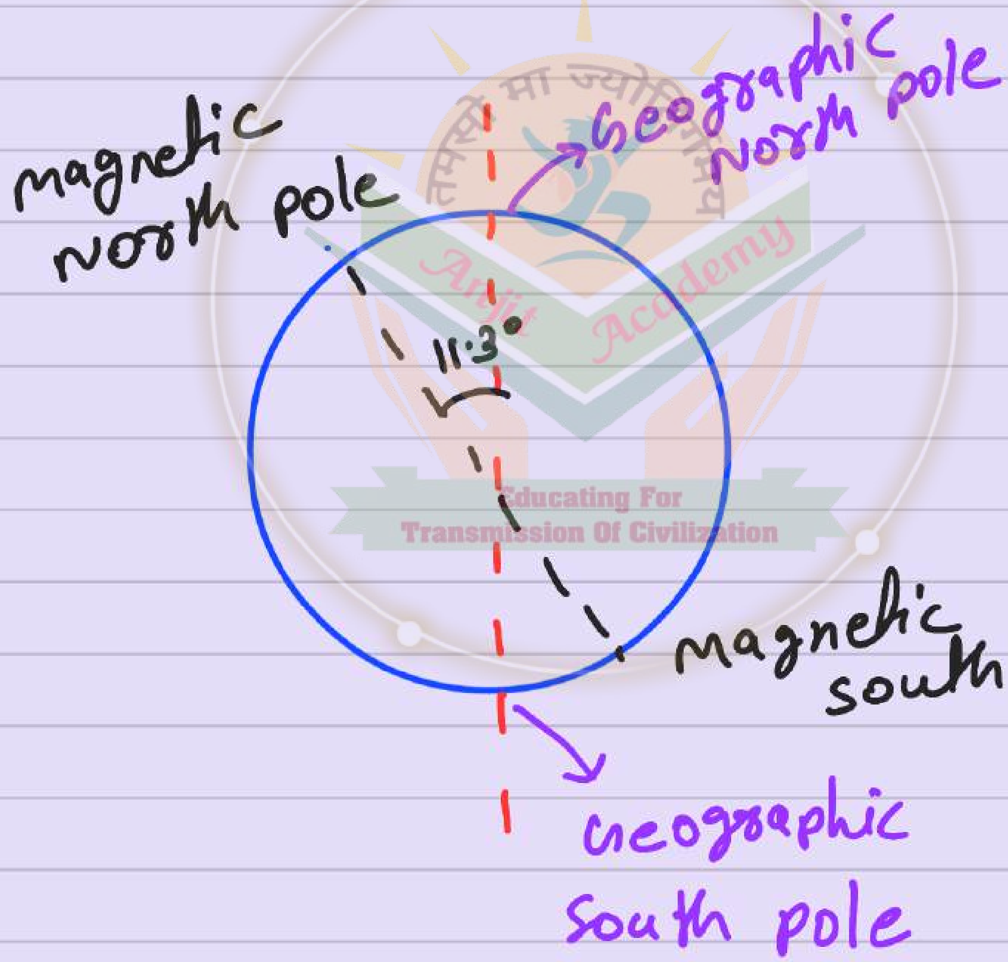
① when a magnetic needle is Brought close to earth's surface then at two point it becomes vertical to surface.

②

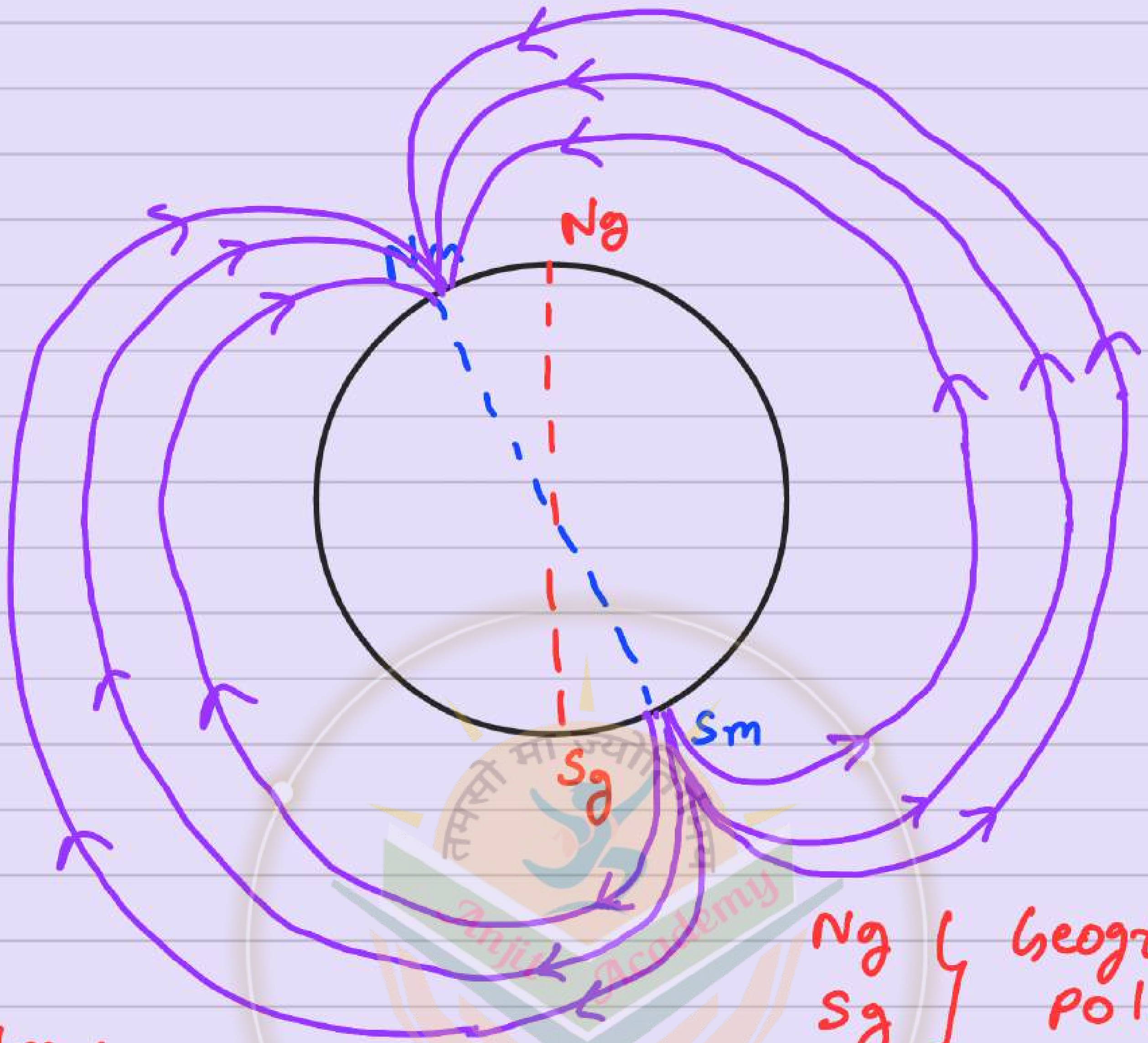


=) The place, where N pole of magnetic needle points vertically downward, that point on earth's surface is termed as magnetic North pole

⇒ The place where S pole of magnetic needle points vertically downward that point on earth's surface is termed as magnetic South pole.

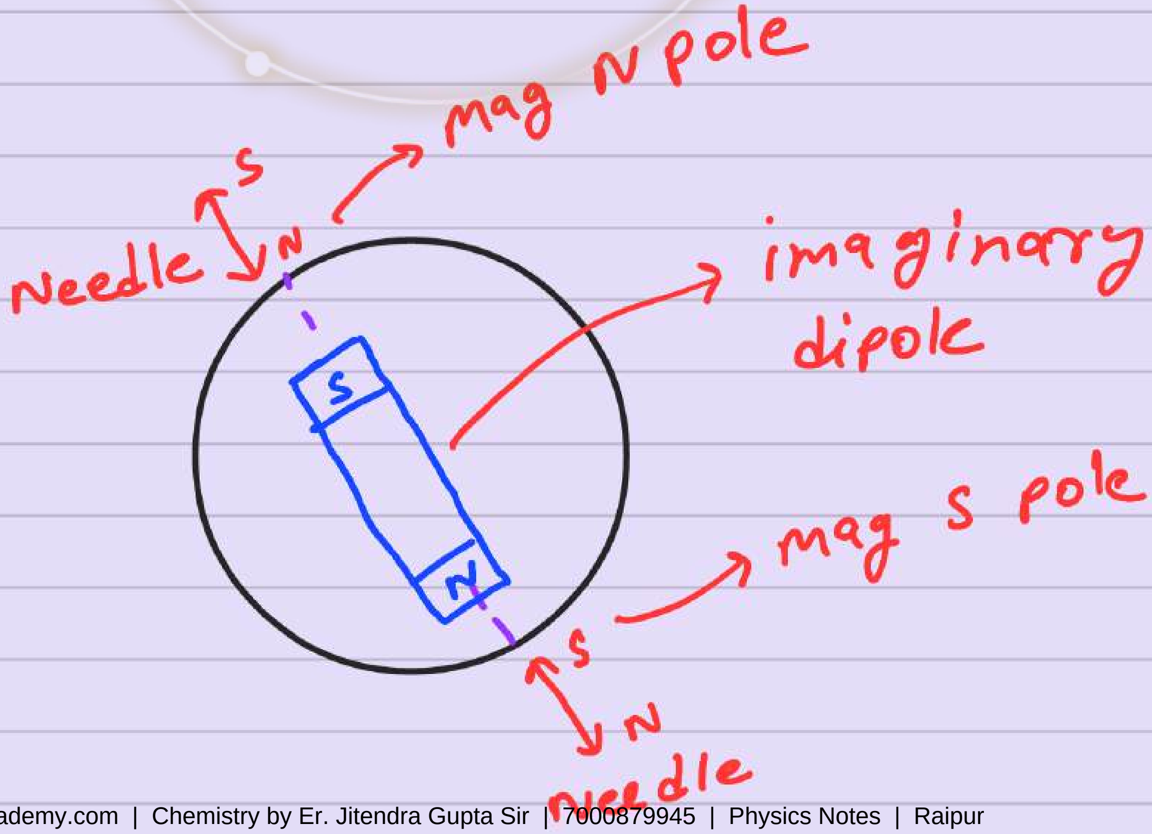


The magnetic field Lines are from magnetic south to magnetic North pole outside the earth.

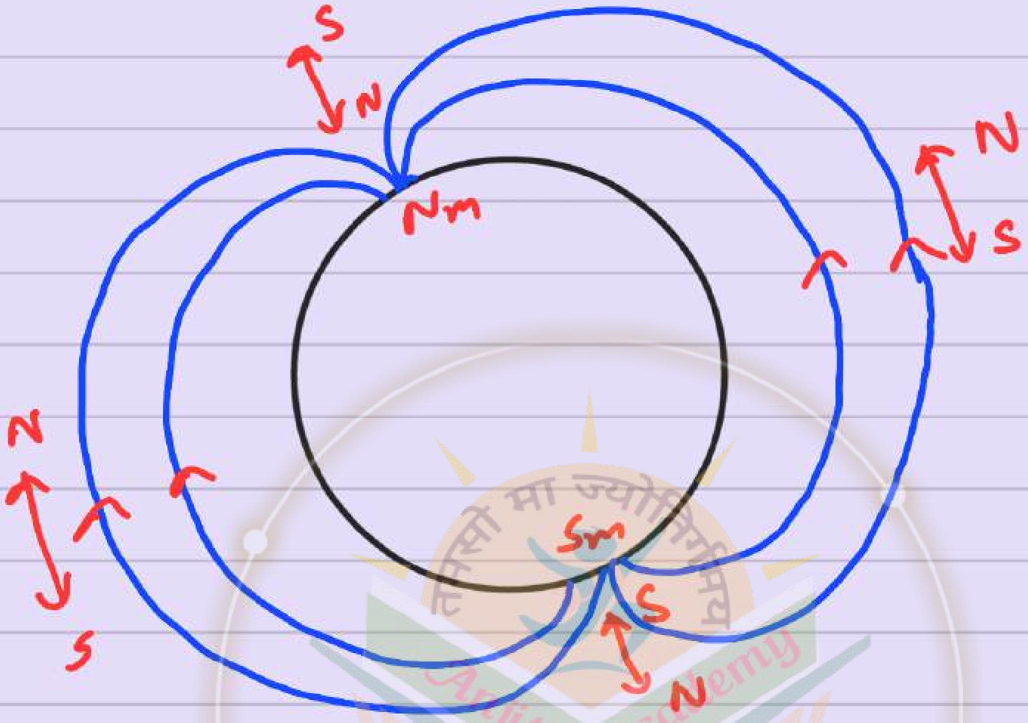


Ng, Sg } Geographical poles

Nm, Sm } Magnetic poles



Angle of Dip or Inclination (I)

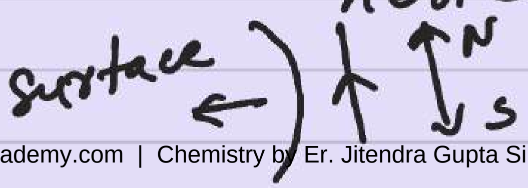


The angle made by needle with horizontal (to Earth's surface) is called Angle of Dip (I)

at magnetic equator

$$I = 0$$

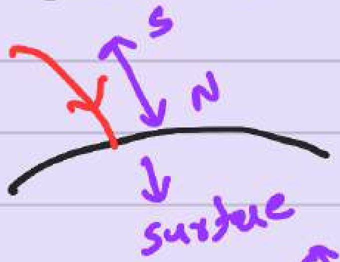
needle is alligned with Horizontal

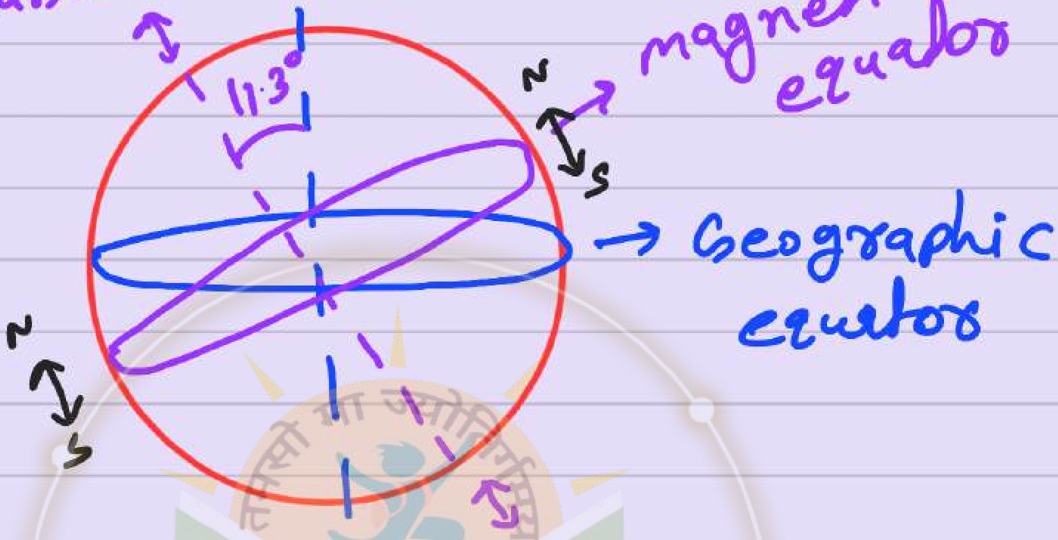


at magnetic poles

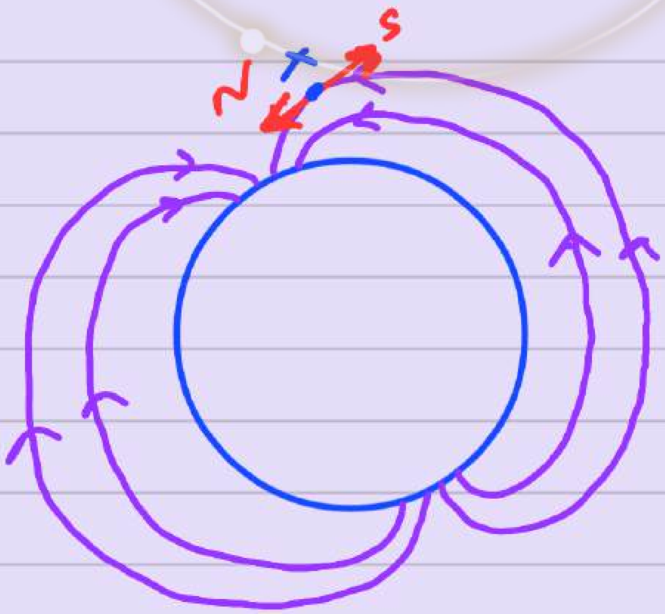
$I = 90°$

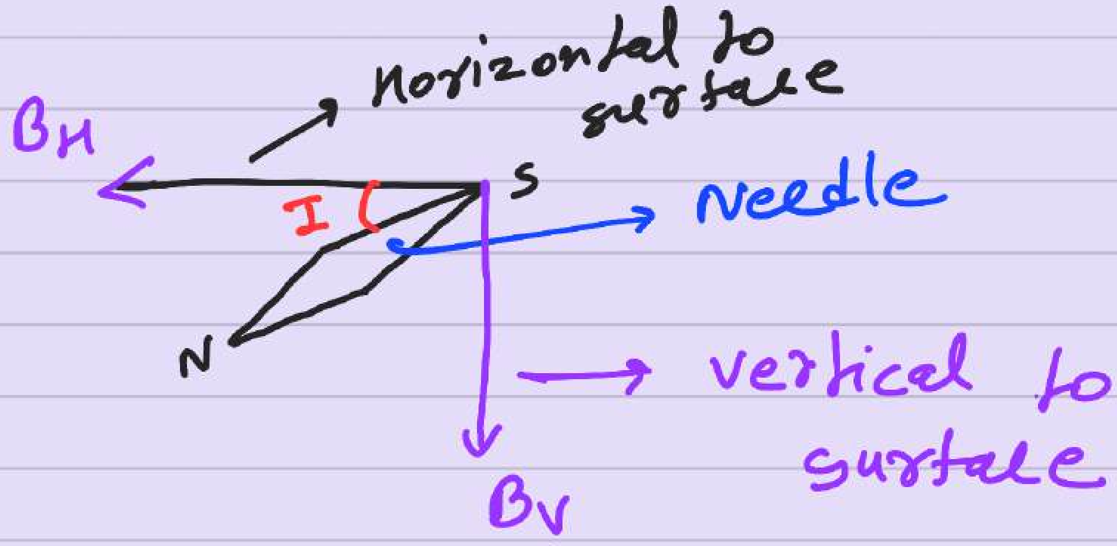
need ⊥ to horizontal



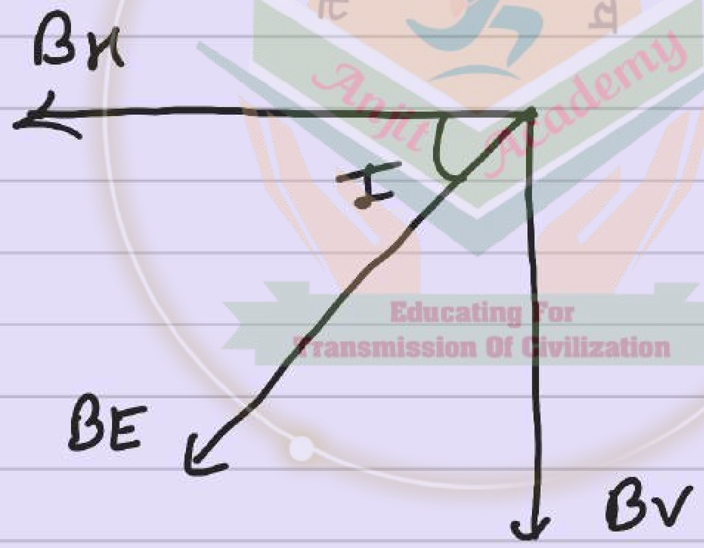


At any point





The needle must be pointing in the direction of net magnetic field due to earth.



$B_E \rightarrow$ Earth's magnetic field

$B_H \rightarrow$ Horizontal component of Earth's magnetic field

$B_V \rightarrow$ Vertical component of Earth's magnetic field.

$$B_H = B_E \cos I \quad — (1)$$

$$B_V = B_E \sin I \quad — (2)$$

(2) $\div$ (1)

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

Que. In the magnetic meridian of a certain place, the Horizontal component of the Earth's Magnetic field is 0.26 G and dip angle is 60°. What is magnetic field of Earth at this location.

Ans $B_E = 0.52$ G

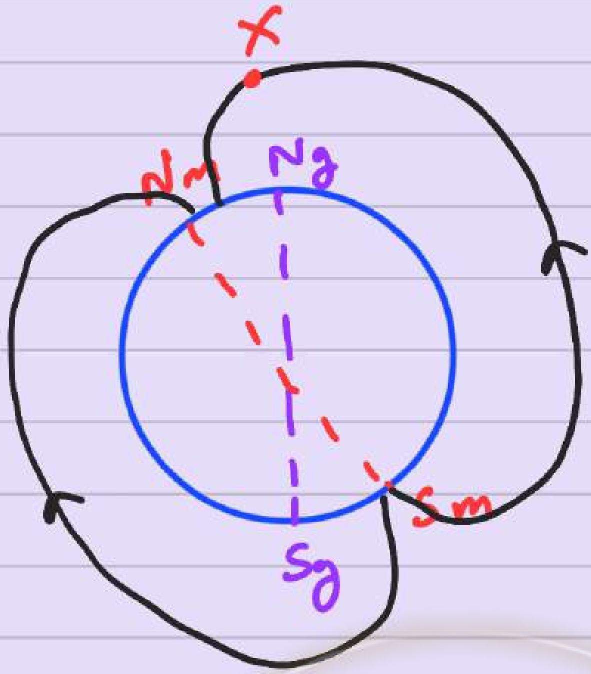
Geographic / magnetic Meridian & Angle of Declination (D)

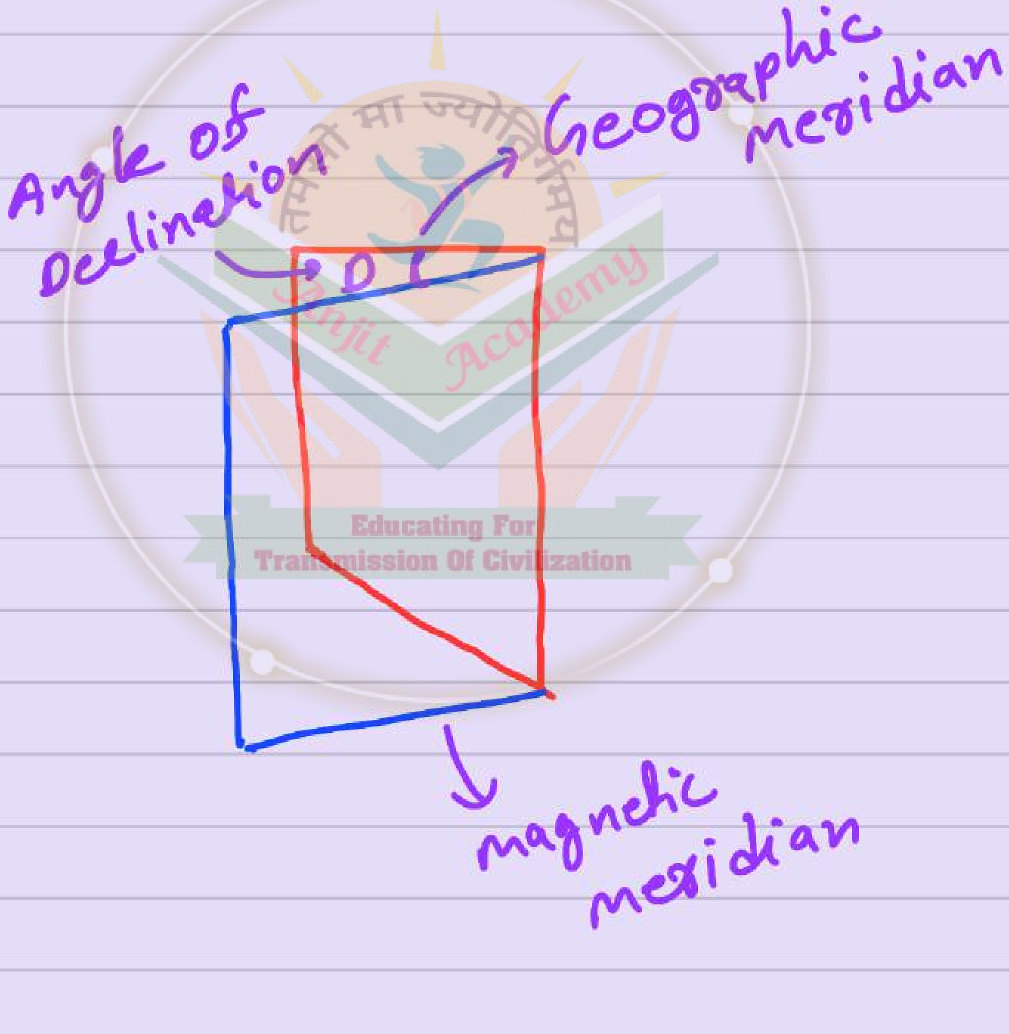
Geographic meridian → At any Point on Earth's surface a plane passing through Geographic poles & that point.

Magnetic Meridian → At any point on Earth's surface, a plane passing through magnetic poles & that point.

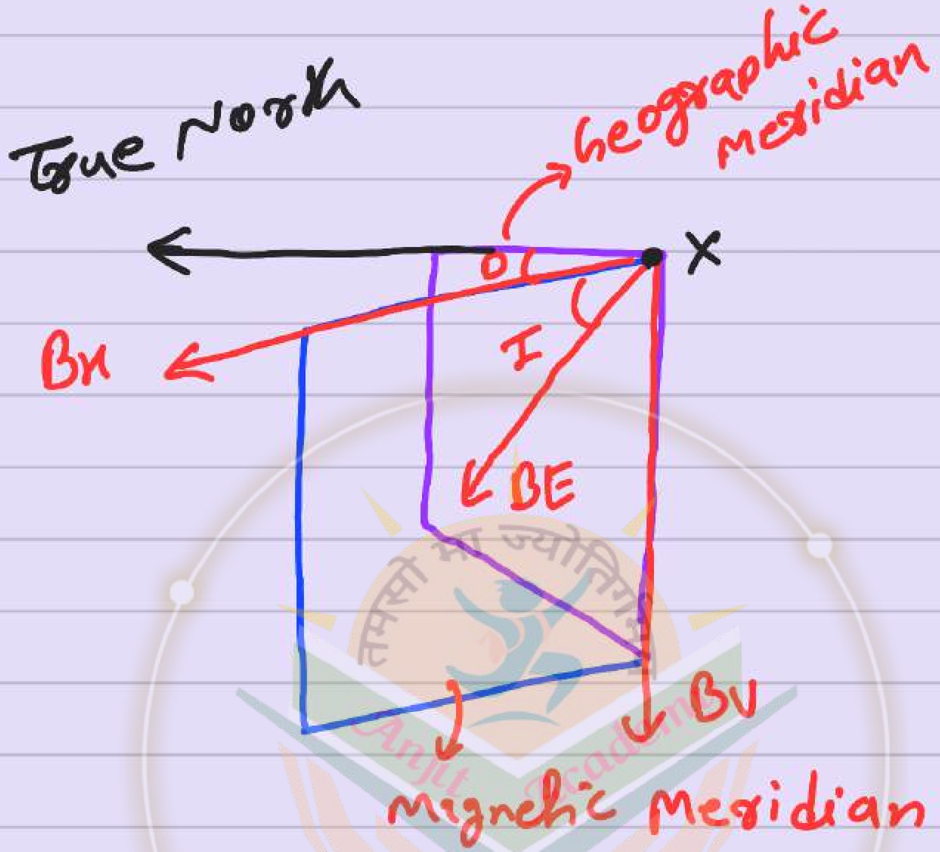
Angle of Declination (D)

At any point on Earth's surface the angle B/w Geographic Meridian & Magnetic meridian.





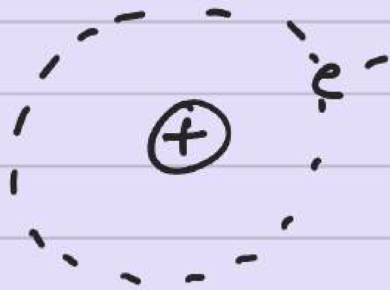
- The magnetic needle will always lie in the magnetic Meridian & By knowing Angle of Declination, We can know Direction of True North (i.e. Geographical North)



Magnetisation & Magnetic Intensity

Magnetisation

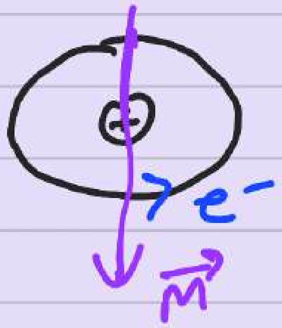
① matter → Atoms →



② When e^- revolves around Nucleus of an atom, it consititutes a Current Loop.

③ This current loop has magnetic moment

$$\vec{M} = i \cdot \vec{A}$$



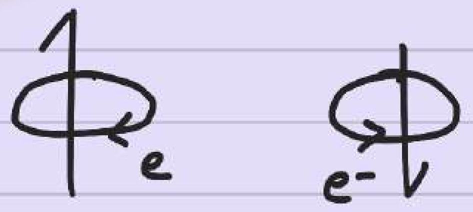
④ Magnetic moment

$\Downarrow$

① Orbital motion of e^- } major

② Due to spin of e^-

⑤ $\boxed{\uparrow\downarrow}$



Magnetic moment $= 0$

(Diamagnetic)

$He = 1s^2 \Rightarrow \boxed{\uparrow\downarrow}$

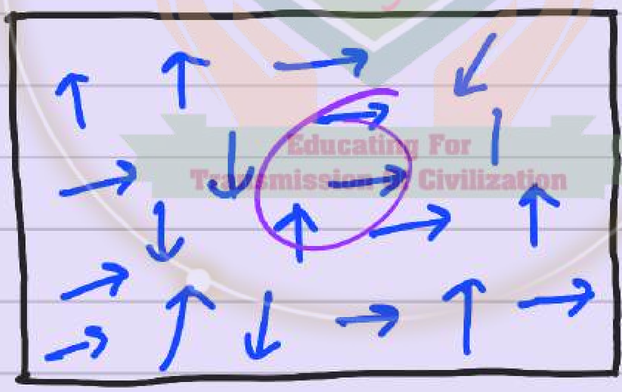
(6) Magnetic moment $\neq 0$

unpaired e^-

$\Downarrow$

paramagnetic & Ferromagnetic

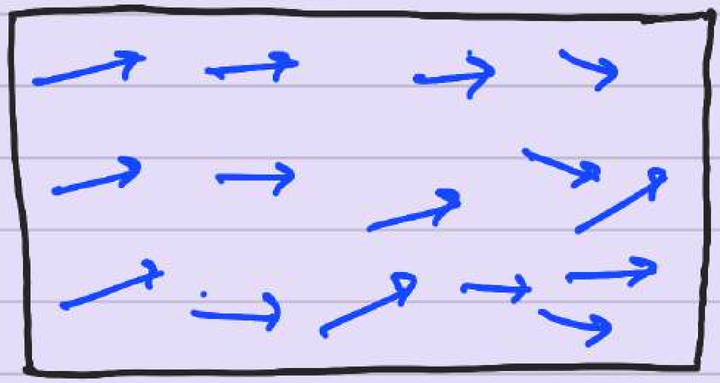
(7) Object of finite size $\longrightarrow$ Atoms



$\vec{M} = 0$

magnetic moments of atoms are randomly oriented and the net magnetic moment is still zero.

⑧ $\xrightarrow{B_{external}}$



$\vec{M} \neq 0$

⑨ Magnetisation :

I = magnetic moment per unit volume.

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

Unit → Am^{-1}

Magnetic Intensity ($\vec{H}$)

magnetic field inside the material

= Applied magnetic field + magnetic field due to magnetisation

External magnetic field is represented by 'H' called magnetic Intensity.

$H \rightarrow$ unit $\rightarrow$ A/m

$\Rightarrow$ $B_{net} \propto H + I \rightarrow$ magnetisation

$H \downarrow$ magnetic intensity

$B_{net} = \mu_0 (H + I)$

$\mu_0 \downarrow$ permeability of free space

$\Rightarrow$ The magnetisation of material is influenced by external factors.

$I \propto H$

$I = \chi H$

$\chi \rightarrow$ suspectibility

$\Rightarrow$ $$B_{net} = \mu_0(H + I)$$

$$B = \mu_0(H + \chi H)$$

$$= \mu_0(1 + \chi)H$$

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

$\mu \rightarrow$ permeability of medium

$\Rightarrow$ In case of Vaccum

$$I = 0$$

$\Rightarrow$ Relative Permeability μ_r

$$\mu_r = \frac{\mu_m}{\mu_0}$$

$\mu_m \rightarrow$ of medium

$\mu_0 \rightarrow$ of vacuum

$$\mu_r = \frac{\mu_0(1+\chi)}{\mu_0}$$

$$\boxed{\mu_r = 1+\chi}$$

Classifications of material on the basis of χ & μ_r

i) Diamagnetic : weakly repelled in external magnetic field.

- magnetisation occurs opposite to external magnetic intensity

I & H are of opp sign

$\chi \Rightarrow$ -ve & small

$\mu_r = 1+\chi$

$\downarrow$

slightly less than 1

eg nitrogen $\chi = -5 \times 10^{-9}$

ii) paramagnetic : weakly attracted in magnetic field

I & H are of same sign

$\chi \Rightarrow$ +ve & small

$\mu_r = 1 + \chi$

$\downarrow$

slightly greater than 1

eg oxygen $\chi = 2.1 \times 10^{-6}$

iii) Ferromagnetic : Strongly attracted in external magnetic field

I & H are of same sign

$\chi \Rightarrow$ +ve & Large