Physics Notes

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Class:10+2
Unit: III
Topic: Magnets and Earth's Magnetism

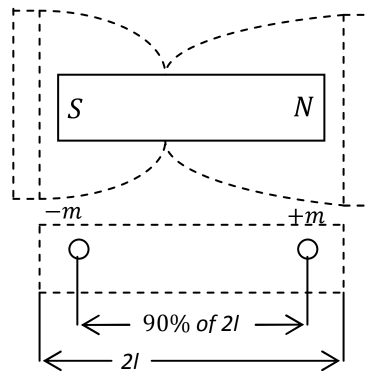
SYLLABUS: UNIT-III-*C*

Concept of magnetic field, Oersted's experiment, Biot-Savart law, magnetic field due to an infinitely long current carrying straight wire and a circular loop; Ampere's circuit law and its applications to straight and toroidal solenoids; Force on a moving charge in uniform magnetic and electric fields, Cyclotron; Force on current – carrying conductor in a uniform magnetic field. Forces between two parallel current- carrying conductors- definition of ampere; Torque experienced by a current loop in a uniform magnetic field, moving coil galvanometer- its current sensitivity and conversion to ammeter and voltmeter.

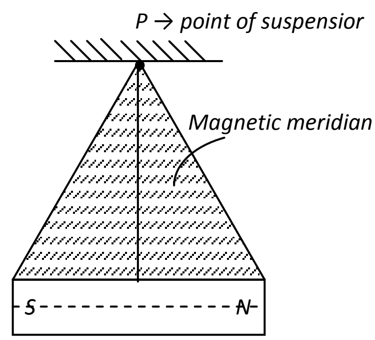
Current loop as a magnetic dipole and its magnetic dipole moment; Magnetic dipole moment of a revolving electron; Magnetic field intensity due to magnetic dipole (bar magnet) along the axis and perpendicular to the axis; Torque on a magnetic dipole (bar magnet) in a uniform magnetic field; Bar magnet as an equivalent solenoid, Magnetic field lines' Earth's magnetic field and magnetic elements; Para-dia and ferro-magnetic substances with examples, Electromagnets and permanent magnets.

Q.1. Discuss basic properties of magnets?

Ans.i) The attraction appears to be maximum at the two ends of the magnet. The effect of magnet is minimum at centre of magnet i.e. at *C*.



ii) A vertical plane passing through N-S line of a freely suspended magnet is called magnetic meridian. This plane also passes through point of suspension *P*.



ii) Like poles repel each other and unlike poles attract each other.

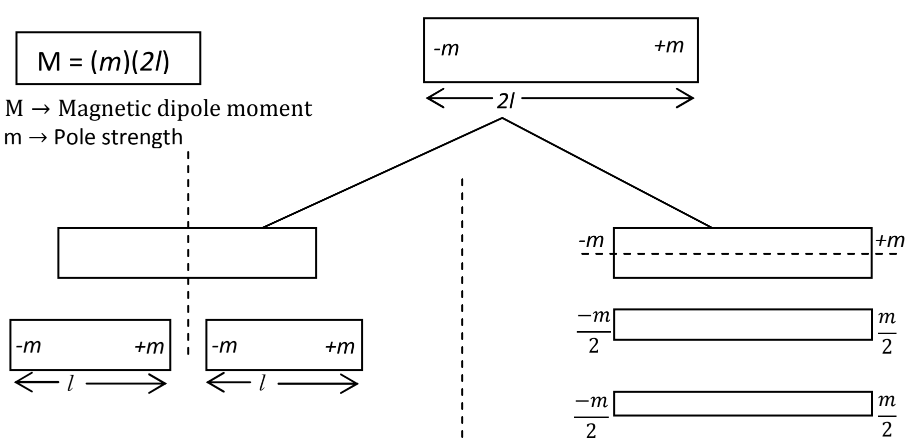
iv) Coulomb's Law of Magnetic Force

$$F = \frac{\mu_0}{4\pi}\frac{m_1 m_2}{r^2} \qquad \left(F_{electric} = \frac{1}{4.\pi.\epsilon_0}.\frac{q_1.q_2}{r^2}\right)$$

v) The magnetic poles always exist in pairs

M = (*m*)(2*l*)

M → Magnetic dipole moment
m → Pole strength



Total = *ml* + *ml*
= 2*ml*

Length gets halved
Pole strength remains same

$M_{total} = \left(\frac{m}{2}.2l\right) + \left(\frac{m}{2}.2l\right)$

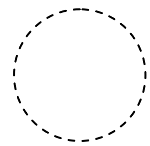
M_{total} = 2*ml*

Length remains same
Pole strength gets halved

Q2. What causes magnetism in some materials? Explain the basis of atomic theory?

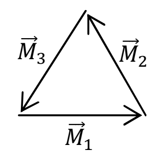
Ans.1. Every molecule of a magnetic substance is a complete magnet.

Electrons moving in the circle is equivalent to current in the ring. It is equivalent to a magnet.



2. **Random Distribution**:-.

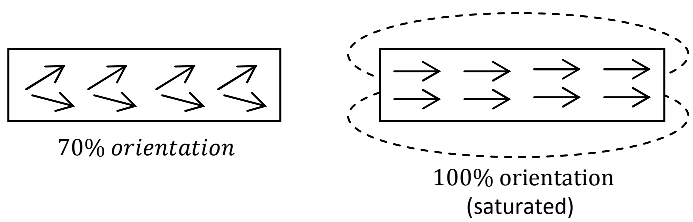
In an unmagnetised substance, the molecular magnetic are **randomly oriented** such that they form closed chains.



$\vec{M}_{res}$ = $\vec{M}_1 + \vec{M}_2 + \vec{M}_3$

= 0

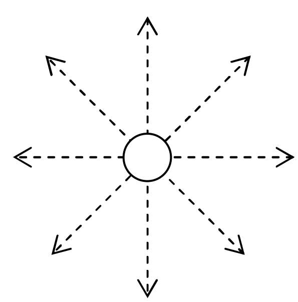
3. When all the molecular magnets are fully aligned the substance is said to be *saturated* with magnetism.



4. Two poles will have equal strength.

5. Magnetism reduces on
   i) Heating
   ii) Hammering

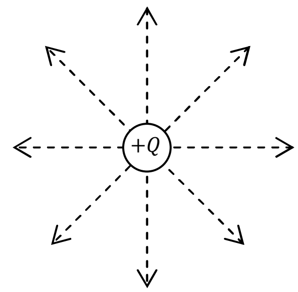
Reason: Heating or Hammering causes randomness. Increase in randomness means decrease in magnetism.
As alignment increases, magnetism increases.



Q3. **Define:**

a) Electric field

b) Magnetic Field.

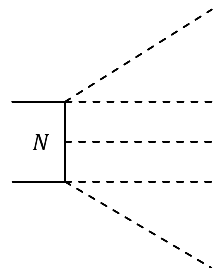


Ans. **<u>Electric Field</u>**:-

Space surrounding a charge where its influence can be experienced.

<u>Magnetic Field</u>:-

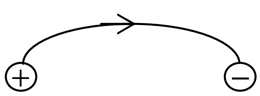
Space surrounding a magnet where its influence can be experienced.



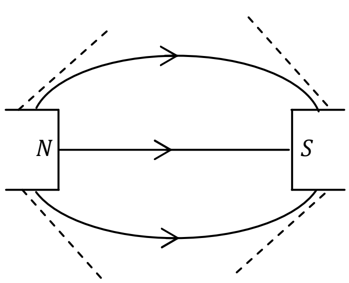
Q4. **Compare properties of Electric Field Lines and Magnetic Field Lines?**

Ans.

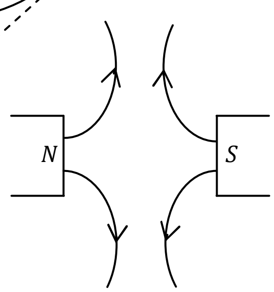
Electric Lines



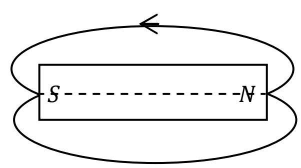
1. Electric Lines of force start from *+ve* charge and end up at *–ve* charge.
2. Electric Lines of force are continuous but not closed loop.
3. Contract Longitudinally



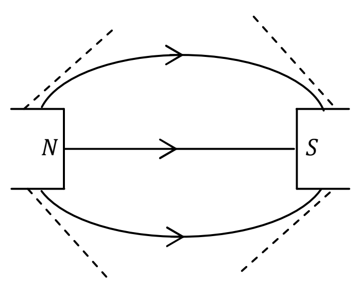
Dilate laterally



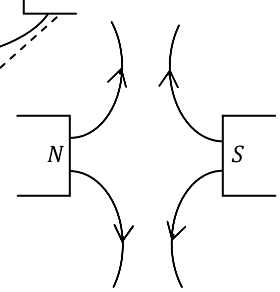
Magnetic Lines



1. Outside the body of the magnet, the direction of magnetic lines of force, is from North Pole to South Pole.
2. Magnetic Lines of force are closed continuous curves.
3. Contract Longitudinally

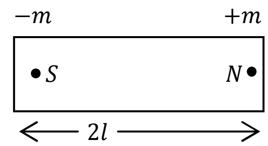


Dilate laterally



Q5. What is Magnetic Dipole? Give its S.I. Units.

Ans. Magnetic dipole moment is defined as the product of pole strength and the distance between the two poles.



M = m(*2l*)

↓ Magnetic dipole moment ↓ Pole strength

S.I. unit of *M*, Magnetic dipole moment are $\frac{Joule}{Tesla}$ or ampere $metre^2$

τ = $\vec{M} \times \vec{B}$

U = $- \vec{M} . \vec{B}$

M = $\frac{U}{B}$ = $\frac{Joule}{Tesla}$

M = IA

= ampere m^2

S.I. unit of pole strength ⇒

M = *ml*

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

m = $\frac{\text{ampere } m^2}{m}$

= ampere metre

Q6. a) Derive an Expression for $\vec{V}$ and $\vec{E}$ due to electric dipole?

b) Derive an Expression $\vec{B}$ due to Magnetic Dipole?

Ans.

$$V = V_1 + V_2$$

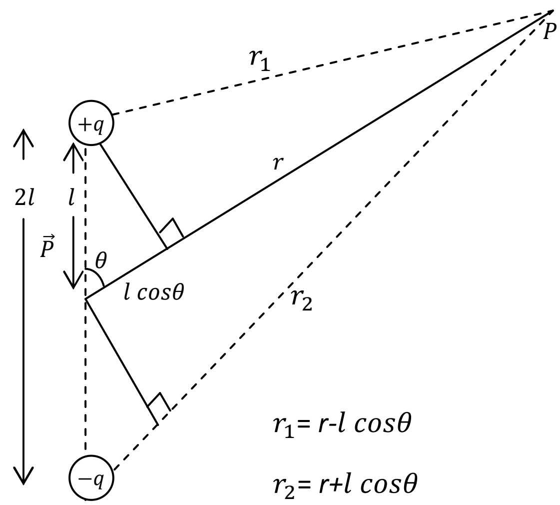
$$= \frac{q}{4\pi\epsilon_0 r_1} + \frac{-q}{4\pi\epsilon_0 r_2}$$

$$V = \frac{q}{4\pi\epsilon_0(r - l\,cos\theta)} + \frac{-q}{4\pi\epsilon_0(r + l\,cos\theta)}$$

$$V = \frac{q}{4\pi\epsilon_0}\left\{\frac{(r+l\,cos\theta)-(r-l\,cos\theta)}{r^2-l^2\,cos^2\theta}\right\}$$

$$= \frac{q}{4\pi\epsilon_0}\;\frac{2l\,cos\theta}{(r^2-l^2\,cos^2\theta)}$$

$$= \frac{2ql\,cos\theta}{4\pi\epsilon_0 r^2}$$



$r_1 = r - l\,cos\theta$

$r_2 = r + l\,cos\theta$

$$\boxed{V = \frac{P\,cos\theta}{4\pi\epsilon_0 r^2}}$$

$\vec{E}$ = - differentiation of V

$$= -\left[+\frac{dV}{dr}\,\hat{r} + \frac{dV}{rd\theta}\,\hat{\theta}\right]$$

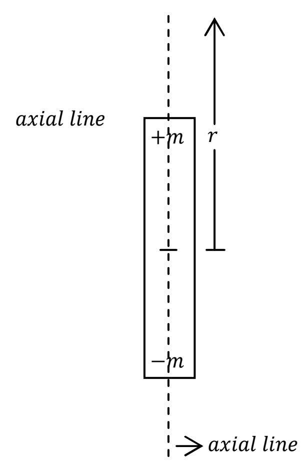
$$= -\left[+\frac{d}{dr}\left(\frac{P\,cos\theta}{4\pi\epsilon_0 r^2}\right)\hat{r} + \frac{d}{d\theta}\left(\frac{P\,cos\theta}{4\pi\epsilon_0 r^2}\right)\hat{\theta}\right]$$

$$= -\left[\frac{P\,cos\theta}{4\pi\epsilon_0}\;\frac{d}{dr}\left(\frac{1}{r^2}\right)\hat{r} + \frac{1}{r}\;\frac{P}{4\pi\epsilon_0 r^2}\;\frac{d}{d\theta}\,(cos\theta)\,\hat{\theta}\right]$$

$$= \left(\frac{2P\,cos\theta}{4\pi\epsilon_0 r^3}\right)\hat{r} - \left(\frac{P - sin\theta}{4\pi\epsilon_0 r^3}\right)\hat{\theta}$$

$$\vec{E} = \frac{2P\,cos\theta}{4\pi\epsilon_0 r^3}.\,\hat{r} + \frac{P - sin\theta}{4\pi\epsilon_0 r^3}.\,\hat{\theta}$$

Similarly, $$\boxed{\vec{B} = \left(\frac{\mu_0}{4\pi}\right)\frac{2M\,cos\theta}{r^3}\,\hat{r} + \left(\frac{\mu_0}{4\pi}\right)\frac{M\,sin\theta}{r^3}\,\hat{\theta}}$$



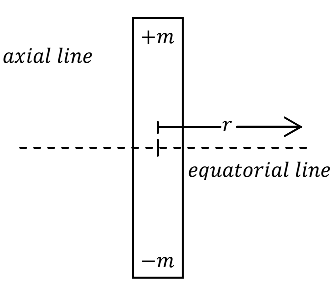
Case I on axial line $\theta = 0^\circ$

$$= \left(\frac{\mu_0}{4\pi}\right)\frac{2M\cos 0}{r^3}\,\hat{r} + \left(\frac{\mu_0}{4\pi}\right)\frac{M\sin 0}{r^3}$$

$$= \frac{\mu_0\,2M\,(1)}{4\pi\,r^3} + 0$$

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

Case II on equatorial line $\theta = 90^\circ$



$$= \left(\frac{\mu_0}{4\pi}\right)\frac{2M\cos 90^\circ}{r^3}\,\hat{r} + \left(\frac{\mu_0}{4\pi}\right)\frac{M\sin 90^\circ}{r^3}$$

$$= \frac{\mu_0\,M\,(1)}{4\pi\,r^3} + 0$$

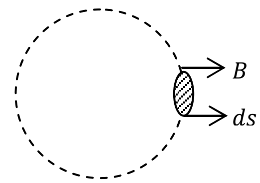
$$= \frac{\mu_0}{4\pi}\;\frac{M}{r^3}$$

- Ratio of axial line to equatorial line at same distance 2 : 1
- Strength on axial line is more for points at same distance

Q7. Gauss's Law for Magnetism?

Ans. Total magnetic flux out of a closed surface is zero.

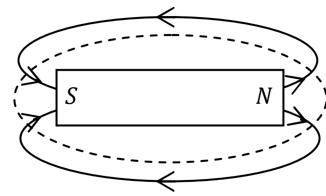
$$\oint B.ds = 0$$



Concept Examples:-

Example 1.

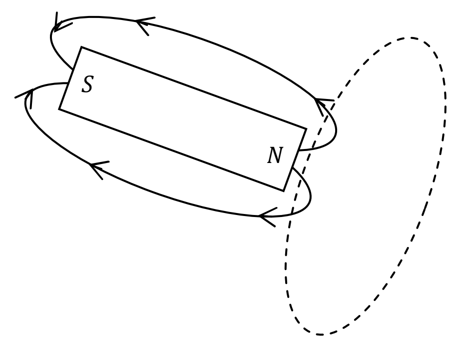
Magnet is inside the closed surface



Number of lines leaving	=	+2
Number of lines entering	=	-2
Total	=	0

Example 2.

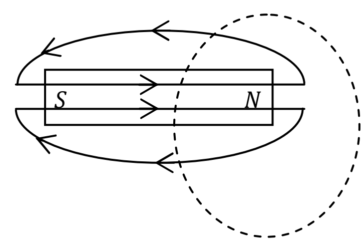
Magnet is outside the closed surface



Total number of lines leaving	=	+2
Number of lines entering	=	-2
Total	=	0

Example 3.

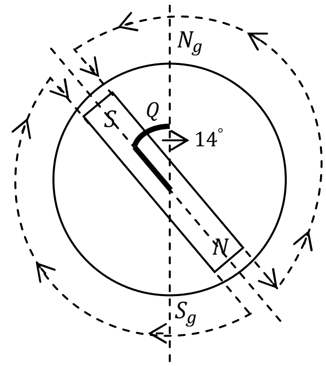
Magnet is partially inside and partially outside



Total number of lines leaving	=	+2
Number of lines entering	=	-2
Total	=	0

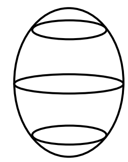
Lines, inside the magnet start from South to North.

Q8. Mark Earth's Magnetic Field? What are magnetic elements of earth?

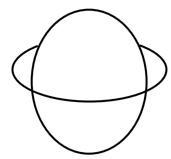


Ans. Angle change with time, at present Q $\simeq 14^{\circ}$. After thousands of years, Q may become 180°. Cause of Earth's magnetic field.

a) Iron charges equivalent to current loop Inside the Earth.



b) Charge rotation outside Earth



Magnetic Elements of Earth are:

1. Magnetic Declination
2. Magnetic dip
3. Horizontal component

1. **Magnetic Declination**:-
   Magnetic declination is defined at a place as the angle between magnetic meridian and geographic meridian at that place. Here *Q* in figure.

2. **Magnetic dip**:-
   Magnetic dip 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.

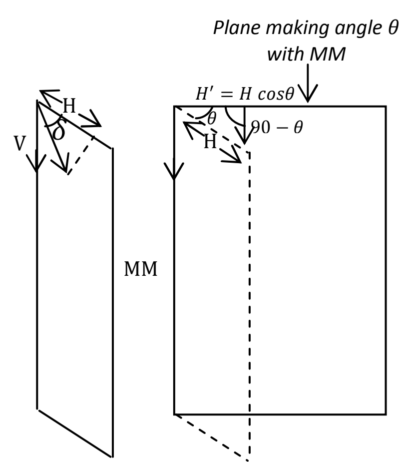
3. **Horizontal component**:-

   H = R cos δ

   V = R sin δ

More about angle of dip δ

i) Apparent dip δ'



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

$Tan\ \delta' = \frac{V}{H'}$

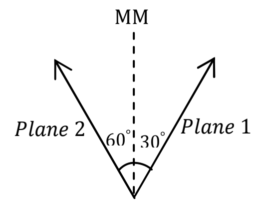
$= \left(\frac{V}{H}\right) \cos\theta$

$$\text{Tan } \delta' = \frac{Tan\ \delta}{\cos\theta}$$

$\text{Tan } \delta_1{}' = \frac{Tan\ \delta}{\cos\theta_1}$ $\text{Tan } \delta_2{}' = \frac{Tan\ \delta}{\cos\theta_2}$

$= \frac{Tan\ \delta}{\cos\theta_1}$ $= \frac{Tan\ \delta}{\cos(90-\theta_1)}$

$\text{Tan } \delta_2{}' = \frac{Tan\ \delta}{\sin\theta_1}$



$\boxed{\cos\theta_1 = \frac{Tan\ \delta}{\text{Tan } \delta_1'}}$ $\boxed{\sin\theta_1 = \frac{Tan\ \delta}{\text{Tan } \delta_2'}}$ $\boxed{\theta_1 + \theta_2 = 90^\circ}$

$sin^2\,\theta_1 + cos^2\,\theta_1 = 1$

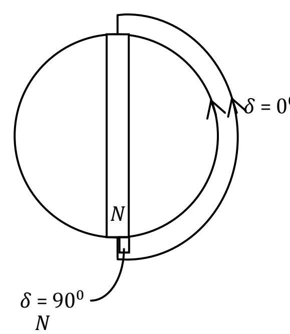
$\left(\frac{Tan\ \delta}{\text{Tan } \delta_2'}\right)^2 + \left(\frac{Tan\ \delta}{\text{Tan } \delta_1'}\right)^2 = 1\delta_2'$

$\frac{Tan^2\ \delta}{Tan^2\ \delta_2'} + \frac{Tan^2\ \delta}{Tan^2\ \delta_1'} = 1$

$Tan^2\delta\ \ Cot^2\delta_2'{}' + Tan^2\delta\ \ Cot^2\delta_1' = 1$

$Cot^2\delta_2' + Cot^2\delta_1' = \frac{1}{Tan^2\ \delta}$

$\boxed{Cot^2\delta_2' + Cot^2\delta_1' = Cot^2\ \delta}$



ii) At a place on the poles, Earth's magnetic field is perpendicular to the surface of Earth i.e. *Vertical*

At poles, $\delta = 90^\circ$

iii) At a place on the equator, Earth's magnetic field is parallel to the surface of Earth, i.e. *Horizontal*.

At poles, $\delta = 0^\circ$

Q9. a) What is "Tangent Law"?
b) Discuss three cases where Tangent Law is used extensively?

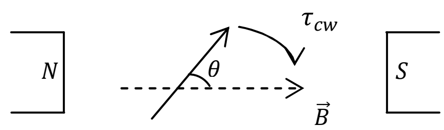
Ans.a) **<u>Tangent Law</u>**:-

Tangent Law is used to find radio of two magnetic fields.

i.e. $$Tan\,\theta = \frac{B_1}{B_2}$$

1. If a needle is place in a magnetic field B, at an angle θ

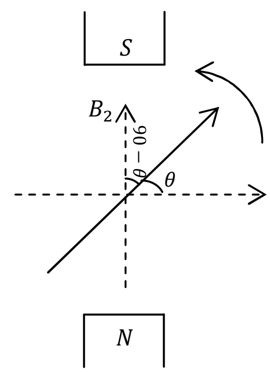
Needle experiences a clockwise Torque



$\vec{\tau}_{cw} = \vec{M} \times \vec{B_1}$

$$\vec{\tau}_{cw} = M\,B_1 \sin\theta$$

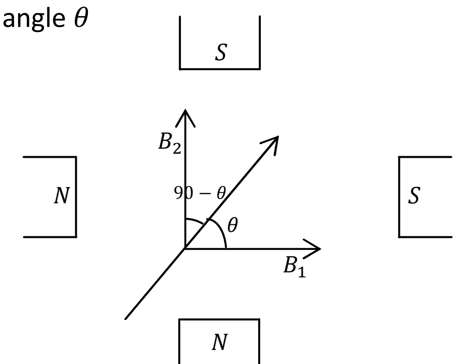
2. Needle is placed is magnetic field B_2. Needle makes angle θ with x-axis and angle (90- θ) with B_2



$$\vec{\tau}_{cw} = M\,B_2 \sin(90-\theta)$$

$\tau_{cw} = M\,B_2 \cos\theta$

3. Under influence of Both B_1 and B_2 needle is stable at angle θ when



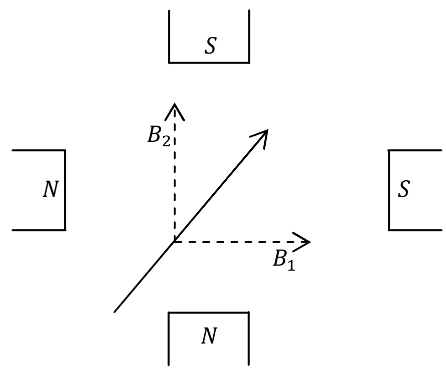
$|\vec{\tau}_{acw}| = |\tau_{cw}|$

$MB_2\cos\theta = MB_1\sin\theta$

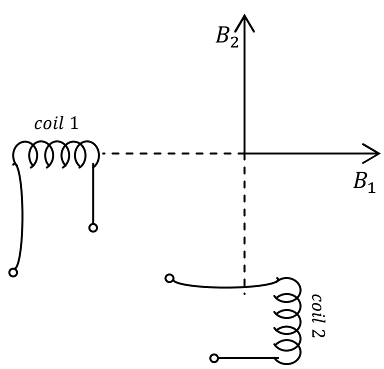
$$\frac{B_2}{B_1} = Tan\,\theta$$

θ is the angle which the needle makes with magnetic field in denominator b)

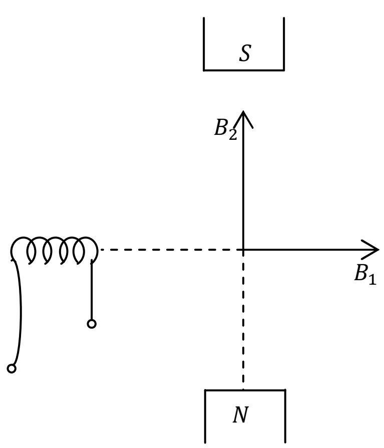
i) **Case I**: Two magnetic field due to two magnets.



ii) **Case II**: Two magnetic field due to two coils/solenoids carrying currents.



iii) **Case III**: One magnetic field due to magnetic and 2nd due to coil carrying current.



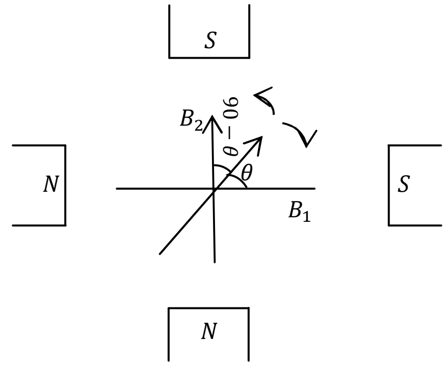
Q10. Give Principle, Construction and Working of Tangent Galvanometer?

Ans. **<u>Principle</u>**:-

$$M\,B_1 \sin\theta = M\,B_2 \sin(90-\theta)$$

$$B_1 \sin\theta = B_2 \cos\theta$$

$$\boxed{Tan\ \theta = \frac{B_2}{B_1}}$$

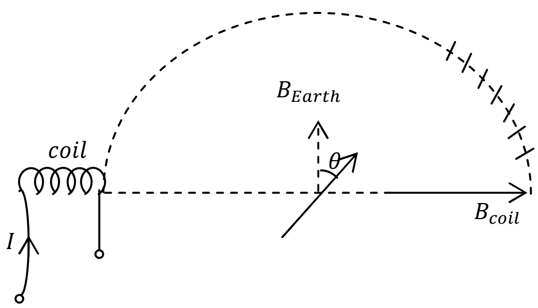


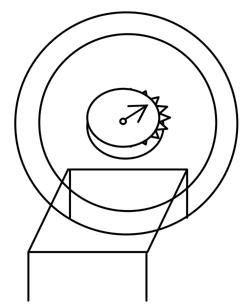
<u>Construction</u>:-

Earth's magnetic field is used as one of the orthogonal fields.

2nd magnetic field is established using current coil.

Needle (Pointer) is placed on a horizontal platform.





<u>Working</u>:-

$$Tan\ \theta = \frac{B_{coil}}{B_{earth}}$$

$$= \frac{\left(\frac{\mu_0 I}{2R}N\right)}{B_E}$$

$$I = \left(\frac{2RB_E}{\mu_0 N}\right) Tan\ \theta$$

$$\boxed{I = K\ Tan\ \theta}$$

K ↓ Reduction factor