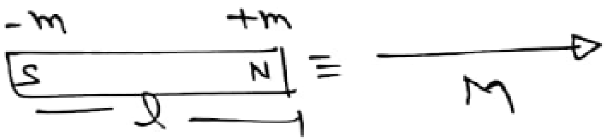
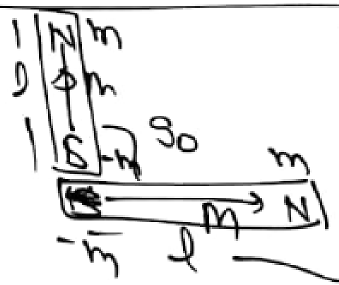
⇒ Magnetic dipole moment:



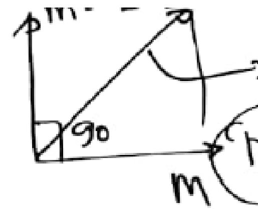
m → Pole Strength

$\vec{M} = ml$ [dirn −m to m]

Q1)



Find Net Magnetic moment



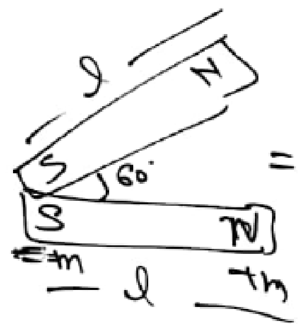
$M_{net} = M\sqrt{2}$

$M_{net} = ml\sqrt{2}$

$M_{net} = \sqrt{m^2 + m^2 + 2mm\cos 90}$

$M_{net} = \sqrt{2m^2} = M\sqrt{2}$

Q2)



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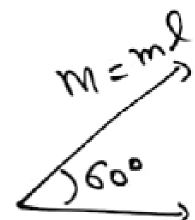


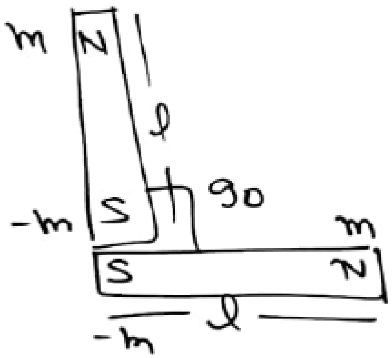
$M = ml$

$M_{net} = \sqrt{M^2 + M^2 + 2MM \times \frac{1}{2}}$

$= \sqrt{M^2 \times 3} = M\sqrt{3}$

$M_{net} = ml\sqrt{3}$

⇒ Magnetic dipole moment:



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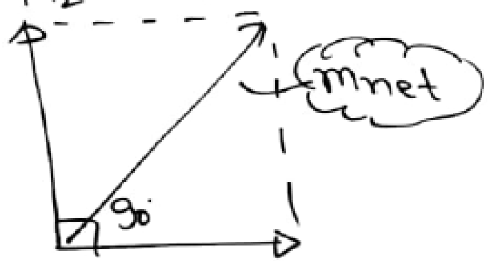


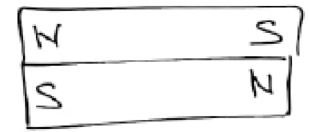
$$R = \sqrt{M_1^2 + M_2^2 + 2M_1M_2\cos\theta}$$

$$M_{net} = \sqrt{M^2 + M^2 + 2MM\cos 90}$$

$$= \sqrt{2M^2} = M\sqrt{2}$$

$$M_{net} = ml\sqrt{2}$$

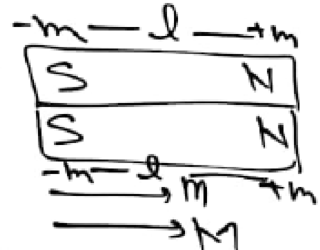
Q3)



$$M_{net} = \sqrt{m^2 + m^2 + 2mm\cos 180}$$
$$= \sqrt{2m^2 - 2m^2} = 0$$

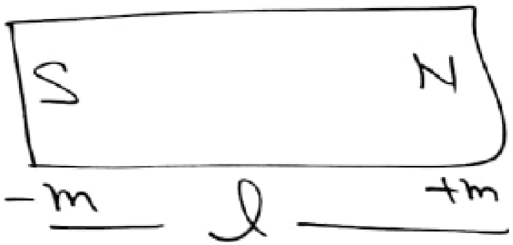
$M_{net} = 0$

Q9)

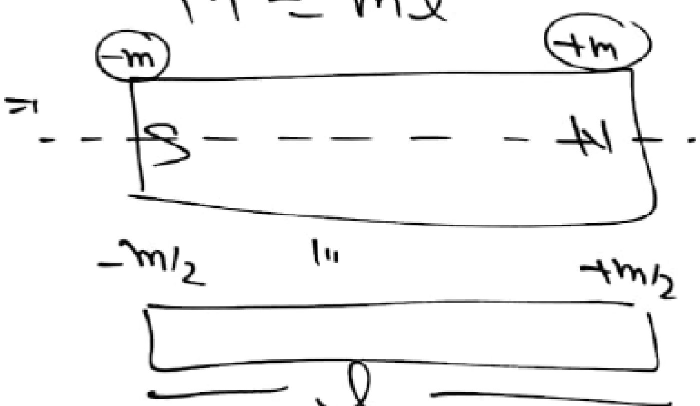


$$M_{net} = 2M = 2ml$$

⇒ Magnetic dipole moment :

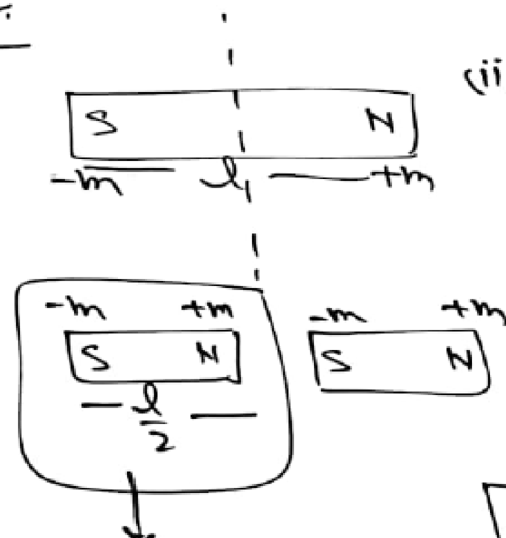


$$M = ml$$



$$M' = \left(\frac{m}{2}\right) l = \frac{ml}{2} = \frac{M}{2}$$

(ii)

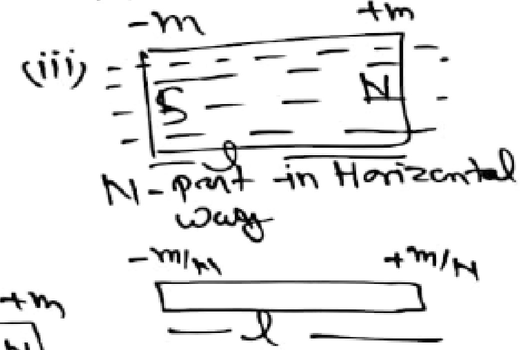


$$M'' = m\left[\frac{l}{2}\right]$$

$$M'' = \frac{M}{2}$$

$$M = ml$$

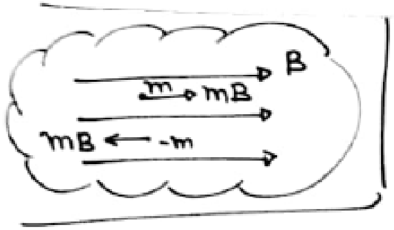
(iii)



$$M''' = \left(\frac{m}{N}\right) l$$

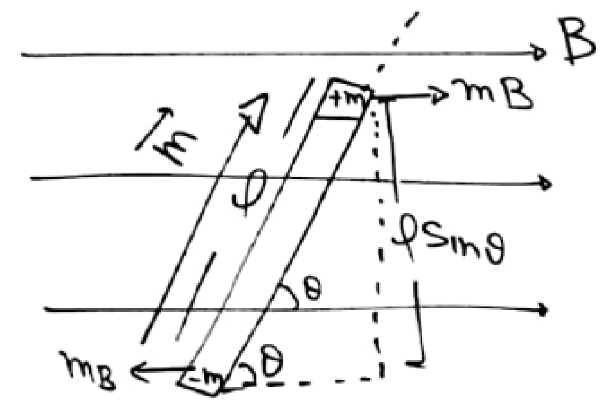
$$M''' = \frac{ml}{N} = \frac{M}{N}$$

Force & Torque on magnetic dipole in uniform magnetic field.



(i) Net Force on magnetic dipole = 0

(ii) Torque on magnetic dipole. [on bar magnet]



$\tau = (\text{Couple of Force}) \times \text{distance b/w them}$

$\tau = (mB)\, \ell \sin\theta$

$\tau = (m\ell)\, B \sin\theta$

$= M B \sin\theta$

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

* $\tau = r F \sin\theta$

$$\vec{\tau} = \vec{r} \times \vec{F}$$

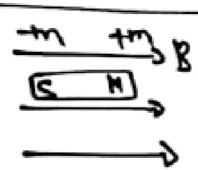
$\tau = (\ell)\, m B \sin\theta$

$\tau = (m\ell)\, B \sin\theta$

$\tau = M B \sin\theta$

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

(i) $\theta = 0$



$\tau = 0$

(ii)

$\theta = 180°$

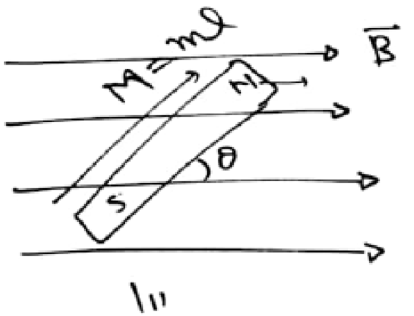
$\tau = 0$

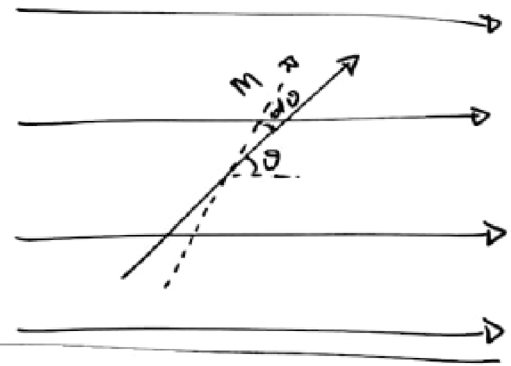
(iii) $\theta = 90°$

$\tau = MB \sin 90°$

$\tau_{max} = MB$

Work done to rotate magnetic dipole (bar magnet) in uniform magnetic field.





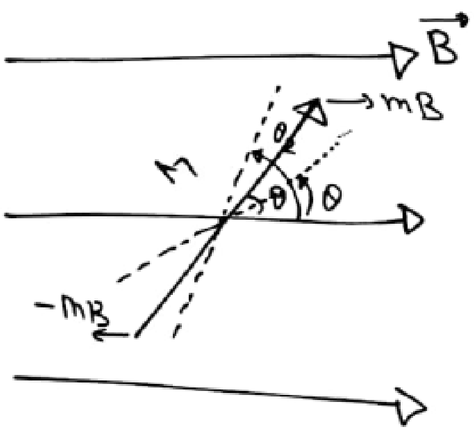
$$dW = \tau \cdot d\theta$$

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

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

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

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



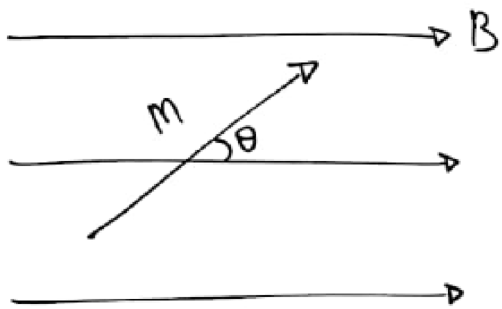
$$W = MB(\cos\theta_1 - \cos\theta_2)$$

Q1) Find work done to rotate a magnetic dipole moment is 2 A-m² from 60° to 90° in uniform magnetic field 10 Tesla.

$$W = MB\left[\cos 60^\circ - \cos 90^\circ\right] = 2 \times 10\left[\frac{1}{2} - 0\right]$$

$$= 2 \times 10 \times \frac{1}{2} = 10\,J$$

Potential Energy of magnetic dipole moment in Uniform magnetic field:-



$$W_{ext} = MB[\cos\theta_1 - \cos\theta_2]$$

⇓

work done to rotate magnetic dipole from θ_1 to θ_2

$$W_{ext} = U_f - U_i$$

$$U_{\theta_2} - U_{\theta_1} = MB[\cos\theta_1 - \cos\theta_2]$$

$\theta_1 = \theta$, $\theta_2 = 90^\circ$ $[U_{90} = 0]$

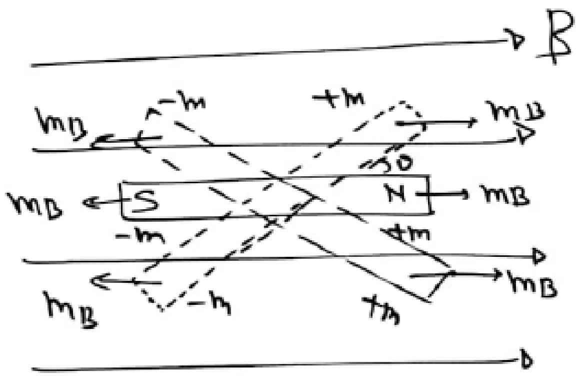
$$U_{90} - U_\theta = MB[\cos\theta - \cos 90]$$

$$0 - U_\theta = MB\cos\theta \cdot\cdot$$

$$U_\theta = -MB\cos\theta$$

$$U_\theta = -\vec{M}\cdot\vec{B}$$

Equilibrium of magnetic dipole moment in Uniform magnetic field.

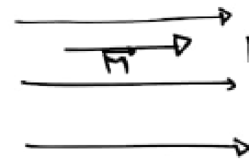


$F_{net} = 0$

→ Equilibrium ⇒ $F_{net} = 0$ & $\tau_{net} = 0$

$\theta = 0$, $F = 0$, $\tau = 0$

$\tau = MB\sin\theta$

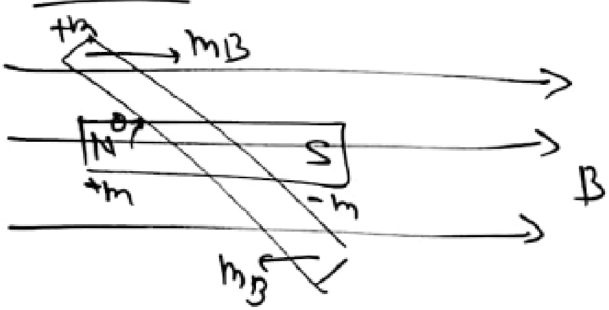


Stable equilibrium

$U = -MB\cos 0$ ⇒

$U = -mB$ $U_{min} = -mB$

$\theta = 180$



$\theta = 180$

Equilibrium $F_{net} = 0$, $\theta = 180$ $\tau = 0$

$U = -mB\cos 180$

$U = +MB$ ⇒ U_{max}

Unstable equilibrium

Magnetic moment due to current carrying wire.