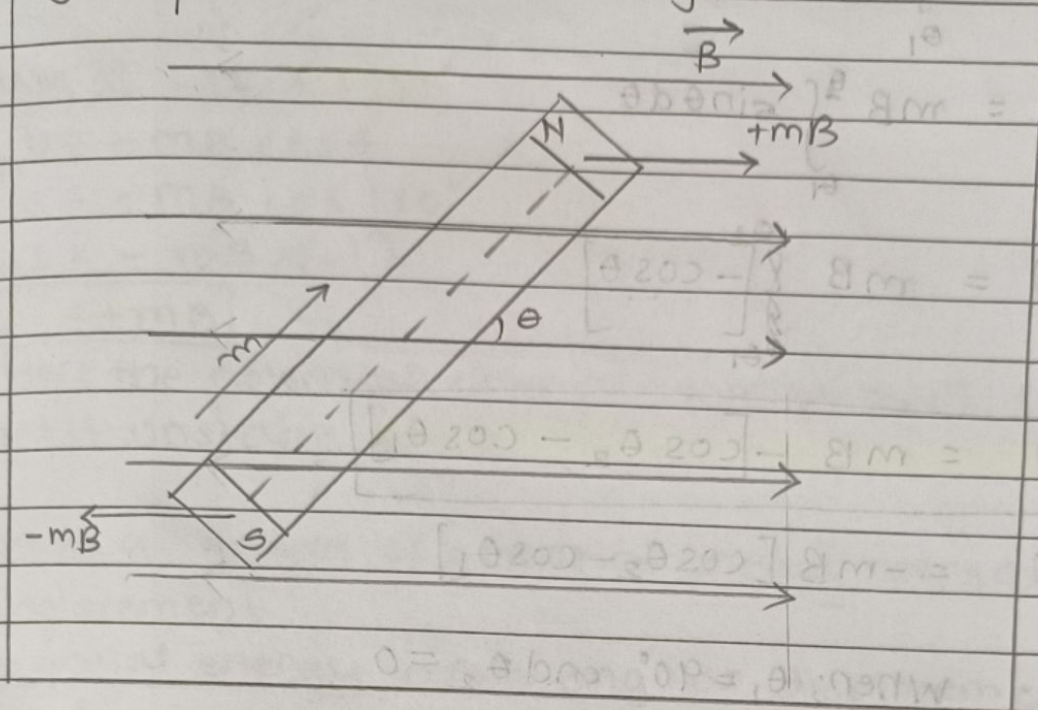
Magnetic material.

3mrk Derive an expression for potential energy of a bar magnet placed in uniform magnetic field.



① Consider a bar magnet kept at an angle θ with direction of magnetic field B vector.

② The torque(τ) acting on a bar magnet is given by

$\tau = mB\sin\theta$ ...(i)

where m = magnetic dipole moment.

③ Due to torque the bar magnetic undergoes rotation from θ_1 to θ_2.

④ Since displacement takes place that means work is done and it is in the form of potential energy (U)

⑤ Work done = potential energy

$$W = U = \int_{\theta_1}^{\theta_2} \tau \, d\theta$$

$$U = \int_{\theta_1}^{\theta_2} mB\sin\theta \, d\theta$$

$$U = mB \int_{\theta_1}^{\theta_2} \sin\theta \, d\theta$$

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

$$\boxed{U = mB - [\cos\theta_2 - \cos\theta_1]}$$

$$U = -mB[\cos\theta_2 - \cos\theta_1]$$

When; $\theta_1 = 90°$ and $\theta_2 = 0$

$$U = -mB[\cos\theta]$$

$$\boxed{W = U = -mB\cos\theta}$$

* Various position of bar magnetin uniform magn field.

Ans: ① we know that

$u = -mB\cos\theta$

② case I: if $\theta = 0°$,

$u = -mB \cos 0°$

$u = -mB \times 1$

$\boxed{u = -mB}$

Here the potential energy is minimum. It is the most stable state.

③ case II: if $\theta = 90°$

$U = -mB\cos 90°$

$U = -mB \times 0$

$\boxed{U = 0}$

Here the bar magnet is $\perp$ to the magnetic field.

(4) case III : If $\theta = 180^\circ$

$$U = -mB\cos\theta$$

$$U = -mB\cos 180^\circ$$

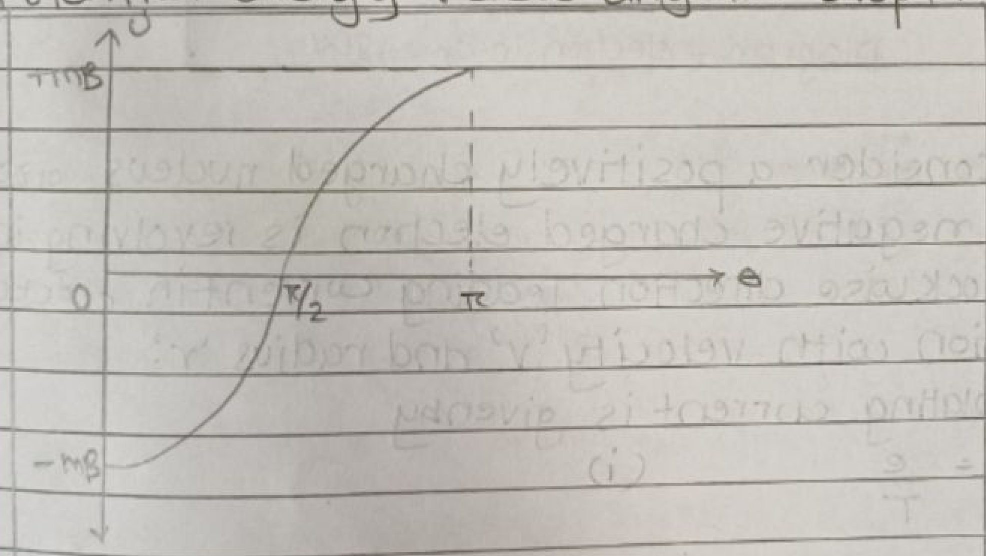
$$U = -mB \times (-1)$$

$$\boxed{U = +mB}$$

Here the potential energy is maximum. It is the most unstable state.

Q) Draw a graph of potential energy versus angular displacement.

* Potential energy versus angular displacement.



Potential Energy Vs Angular displacement

* ~~Derive an expression for~~

3mk * Derive an expression for orbital magnetic movement of a revolving electron around the nucleus.

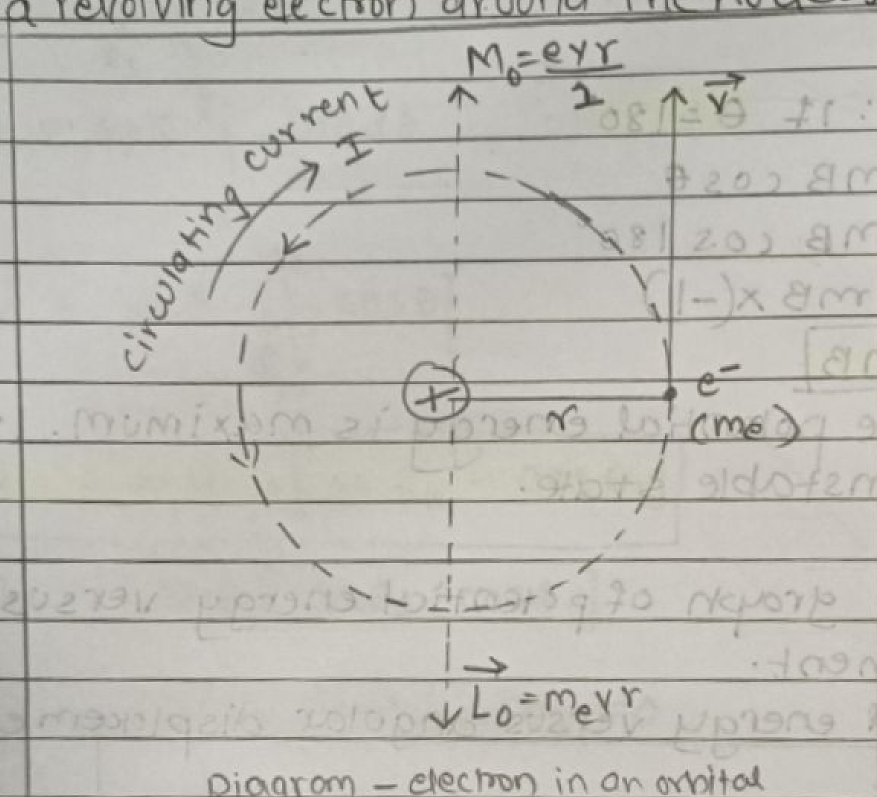


Diagram – electron in an orbital

① 'O' consider a positively charged nucleus around which negative charged electron is revolving in anticlockwise direction leading current in clockwise direction with velocity 'v' and radius 'r'.

② circulating current is given by

$$I = \frac{e}{T} \quad (i)$$

• Time period of revolution of e^- is

$$T = \frac{\text{circumference}}{\text{velocity}}$$

$$\boxed{T = \frac{2\pi r}{v}}$$

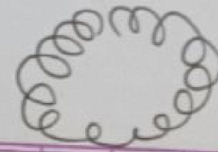
Put in equation (i)

$$I = \frac{e}{T}$$

$$\therefore I = \frac{e}{2\pi r/v}$$

 magnetic moment

 → angular moment

 → magnetis and angular moment

ie → spin.

$$\therefore \boxed{I = \frac{ev}{2\pi r}}$$

- orbital magnetic moment of a revolving e^- is

$M_0 = I \times A$ (current × area)

$m_0 = \frac{ev}{2\cancel{\pi}\cancel{r}} \times \cancel{\pi} r^{\cancel{2}}$

$$\boxed{m_0 = \frac{evr}{2}}$$

- multiply and divide numerator and denominator by mass of e^- (m_e)

$m_0 = \frac{evr}{2} \times \frac{m_e}{m_e}$

$$\boxed{m_0 = \frac{e}{2m_e}(m_e v r)}$$

($L = m_e v r$)

In vector form

$\vec{m_0} = -\left(\frac{e}{2m_e}\right)\vec{L_0}$ ($\vec{m_0}$ and $\vec{L_0}$ are opposite in direction)

$\vec{m_0}$ ↑ orbital magnetic momentum

$\vec{L_0}$ ↑ orbital angular momentum

Q) What is gyromagnetic ratio? (1 mk)

A. ① It is the ratio of orbital magnetic dipole moment with orbital angular momentum.

② gyromagnetic ratio $= \boxed{\frac{m_0}{L_0} = \frac{e}{2m_e}}$

③ $\boxed{8.8 \times 10^{10}\ C\,kg^{-1}}$ is it's value.

* Derivation 3:

Q) What is Bohr magneton. Derive it.

A. ① According to Bohr theory, angular momentum (L_0) of electron ~~#~~ is integral 'n' multiple of $\frac{h}{2\pi}$.

$$\therefore L = n\frac{h}{2\pi}$$

we know; $m_0 = \frac{e}{2m_e} \times L_0$

$$m_0 = \frac{neh}{2\pi \times 2m_e}$$

$$m_0 = \frac{nhe}{4m_e\pi}$$

$$\boxed{m_0 = \frac{nhe}{4\pi m_e}}$$

For 1^{st} orbital $n=1$

$$m_0 = \frac{1 \times he}{4\pi m_e}$$

$$\boxed{m_0 = \frac{eh}{4\pi m_e}}$$

The Quantity $\frac{eh}{4\pi m_e}$ is called Bohr magneton.

It's value is called $\boxed{9.274 \times 10^{-24}\ Am^2}$

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* Some important Definitions:
- What is magnetisation, unit, dimension:

(1) magnetisation: $\boxed{M_z = \frac{M_{net}}{Volume}}$

It is a ratio of net magnetic moment to the volume of material, ~~it~~.

$\boxed{SI\ unit = A/m}$

Dimension = $\boxed{[L^{-1}I^{1}]} = [M^0 L^{-1} M^0 T^0 I^1]$

(2) What is magnetic intensity: (H)

formula $\boxed{H = \frac{B}{\mu_0}}$

$\boxed{H = nI}$

It is the ratio of magnetising field to permeability of free space.

It's unit is $\boxed{A/m}$.

Dimension $\longrightarrow [L^{-1} M^0 T^0 I^1]$

Note: Relation between M_z and H is ~~mag~~ $\boxed{M_z = \chi H}$

(3) What is magnetic susceptibility (χ):

(Ability to magnetism the one under influence)

$\boxed{Susceptibility(\chi) = \frac{M_z}{H}}$

It is the ratio of magnetisation to magnetic intensity.
It is a unitless and dimensionless quantity.

OR

It is a measure of magnetic behaviour of the material when external field is applied.

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(4) what is magnetic permeability? (μ)

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

It is the ratio of total magnetic field inside the material to that of the magnetic intensity.

(5) what is relative permeability? (μ_r)

$$\boxed{\mu_r = \frac{\mu}{\mu_0}}$$

It is the ratio of magnetic permeability of any medium to the magnetic permeability of freespace.

Also;

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