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Date: 08/02/2025
Time: 01 pm

MPHYCC 10

Larmor frequency of precession is independent of θ between orbit normal $\vec{l}$ & field direction $\vec{B}$.

Space quantisation

When an atom is placed in external magnetic field $\vec{B}$, the orbit of e^- precesses about the field direction considering direction of $\vec{B}$ ($\hat{z}$) as an axis. (Larmor precession)

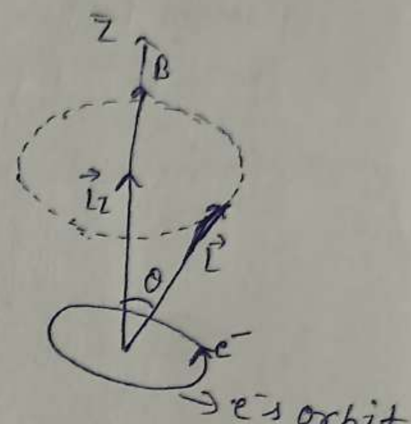

fig.

The e^- orbit angular momentum $\vec{l}$ traces a cone around $\vec{B}$ in such a way θ (angle) between $\vec{B}$ & $\vec{l}$ remains constant

$\vec{B}$ is considered along the z axis. Then the component of $\vec{l}$ along the field direction $\vec{B}$ is

$$L_Z = L\cos\theta$$

$$\cos\theta = \frac{L_Z}{L}$$

quantum mechanically the magnitude of angular momentum $\vec{l}$ and its z-component L_Z are quantized

$$L = \sqrt{l(l+1)}\,\frac{h}{2\pi} \qquad l = \text{orbital quantum number}$$

$$L_Z = m_l \frac{h}{2\pi} \qquad m_l = \text{magnetic quantum number}$$

$$\boxed{\cos\theta = \frac{L_Z}{L} = \frac{m_l\, h/2\pi}{\sqrt{l(l+1)}\, h/2\pi} = \frac{m_l}{\sqrt{l(l+1)}}}$$

for given l, there are $2l+1$ possible values of m_l

$m_l = (0, \pm 1, \pm 2 \cdots \pm l) \Rightarrow \theta$ can have $2l+1$ discrete values

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i.e. We can say that the angular momentum vector $\vec{L}$ can have $2l+1$ discrete values / orientation with respect to the magnetic field. This quantisation of the orientation of atoms in space is known as 'space quantization'.

example:- space quantisation of the orbital **angular momentum** vector $\vec{L}$ corresponding to $l=1$

$$L = \sqrt{l(l+1)}\frac{h}{2\pi} = \sqrt{1(2)}\frac{h}{2\pi} = \sqrt{2}\frac{h}{2\pi}$$

$l = 1$, $m_l = 1 \quad 0 \quad -1$

Therefore $L_Z = m_l \frac{h}{2\pi}$

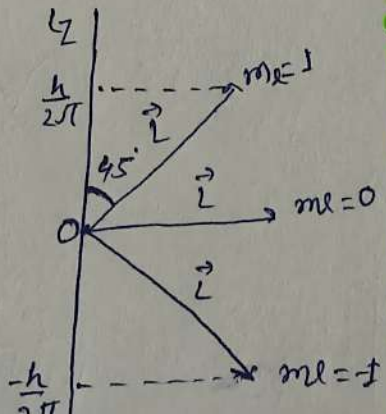
$$L_Z = (1)\frac{h}{2\pi}, (0)\frac{h}{2\pi}, (-1)\frac{h}{2\pi}$$

The orientation θ of $\vec{L}$ with respect to field $\vec{B}$ along z axis can be given as

$$\cos\theta = \frac{m_l}{\sqrt{(l+1)l}} = \underset{45^\circ}{\frac{1}{\sqrt{2}}}, \underset{90^\circ}{\frac{0}{\sqrt{2}}}, \underset{135^\circ}{\frac{-1}{\sqrt{2}}}$$

orientation of $\vec{L}$ w.r.t. $\vec{B}$ can be represented as fig given below

$\vec{L}$ can never be aligned exactly parellel / antiparellel to $\vec{B}$. because $|m_l|$ is always smaller than $\sqrt{l(l+1)}$



Goudsmit & Uhlenbeck in 1925 proposed that an e^- (electron) must be looked as a charged sphere spining about its own axis having intrinsic angular momentum & hence intrinsic magnetic dipole moment.

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Assignment

Question 01 :→ Determine the magnitude of the orbital angular momentum $\vec{L}$ corresponding to $l=2$. Also calculate the values of m_l and hence determine the value of L_z. Show the orientations θ of $\vec{L}$ with respect to the field $\vec{B}$ (z-axis) with the help of diagram.

Question 02 :→ Determine the magnitude of the orbital angular momentum $\vec{L}$ corresponding to $l=3$. Also calculate the values of m_l and hence determine the value of L_z. Represent the orientations θ of $\vec{L}$ with respect to the field $\vec{B}$ (z-axis) with the help of required diagram.