S. S. College. Jehanabad (Magadh University)

Department : Physics

Subject : Quantum Mechanics

Class : B.Sc(H) Physics Part III

Topic: Spin Angular Momentum and Zeeman Effect

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Spin Angular Momentum

Effect of external magnetic fied :-

The magnetic dipole of moment $\vec{\mu}$ is placed in a magnetic field $\vec{B}$,

$$\vec{\tau} = \vec{\mu} \times \vec{B} \quad \text{—(1)}$$

and Potential energy of the dipole

$$U = -\vec{\mu} \cdot \vec{B} \quad \text{—(2)}$$

and

$$\vec{\mu} = -\frac{e}{2m} \vec{L} \quad \text{—(3)}$$

Then

$$U = \left(\frac{e}{2m}\right) \vec{B} \cdot \vec{L} \quad \text{—(4)}$$

Let the magnetic field is directed along the z-axis

$$U = \frac{e}{2m} B L_z \quad \text{—(5)}$$

and Total energy is given by

$$E' = E_n + \frac{e\hbar}{2m} B m_l \quad \text{—(6)}$$

$E_n \rightarrow$ eigen energy value and U is energy due to magnetic field interaction with dipole

The change in energy :-

$$\Delta E = m_l \left(\frac{e\hbar}{2m}\right) B = m_l \mu_l B \quad \text{—(7)}$$

Since there are $(2l+1)$ values of m_l for a given value of l, an energy level with a particular l contains $(2l+1)$ different orbital states.

This is known as <u>Zeeman effect</u>

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The Anomalous Zeeman effect

The phenomenon of interaction of orbital magnetic moment of the electron with the magnetic field, then each line must be split into three components. However, in most cases a line is split into more than three lines. This is known as anamalous Zeeman effect.

The Stern - Gerlach Experiment

The anomalous zeeman effect is explained on the basis of Stern-Gerlach experiment. In his experiment, a beam of neutral atoms through a non-uniform magnetic field. If there is only orbital angular momentum, then the beam split into odd number of different components. However, it is found that beams split into an even number of components.

The spliting is explained on the basis of S. Goudsmidt and G. Uhlenbeck. They states that the electron has an intrinsic angular momentum and associated with this angular momentum, a magnetic moment.

This intrinsic angular momentum is called spin angular momentum.

The name spin gives the impression that the electron is a tiny charged sphere spinning about an axis.

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The concept of spin revolves around the sun as well as rotates (spins) about its own axis. The spin has no classical counterpart and is purely quantum mechanical effect. The concept of spin appears in this theory naturally. All electrons have the same spin angular momentum whether they are free or bound in atoms. The spin is a fundamental property of the electron, like its charge and mass.

- The spin angular momentum is described in terms of the spin quantum number s, usually called simply spin. The only value s can have is

$$s = \frac{1}{2} \text{ (spin quantum number)}$$

- The properties of the spin angular momentum are quite similar to those of orbital angular momentum. The spin angular momentum is described by a vector $\vec{s}$

$$S = \sqrt{s(s+1)}\,\hbar = \sqrt{\frac{1}{2}\left(\frac{1}{2}+1\right)}\,\hbar = \sqrt{3}\,\hbar$$

Magnitude of spin angular momentum

This is similar with the corresponding formula

$$L = \sqrt{l(l+1)}\,\hbar$$

- The space quantization of the spin angular momentum can be specified by giving its z-component s_z. This component is given in terms of the spin magnetic quantum number m_s.

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and its value, $m_s = \pm 1/2$ [spin magnetic quantum number]

- The orbital magnetic quantum number m_l can have $(2l+1)$ value ranging from $-l$ to $+l$ in integer steps.

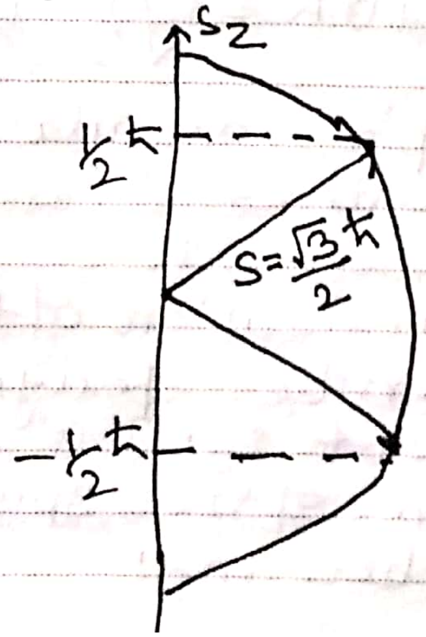
- Therefore, the vector $\vec{L}$ can have $(2l+1)$ possible orientations with respect to z-axis. Similarly, the spin angular momentum $\vec{S}$ can have $(2s+1) = (2 \times \frac{1}{2} + 1) = 2$ orientation.

- The z-component of spin angular momentum;

$$S_z = m_s \hbar = \pm \frac{1}{2} \hbar$$

$S_z = +\frac{1}{2}\hbar \rightarrow$ spin up

$S_z = -\frac{1}{2}\hbar \rightarrow$ spin down



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