UNIT – II

Zeeman Effect

Zeeman (1896) → A sodium flame placed between the poles of a powerful electro magnet → The two lines of the first principal doublet are considerably broadened.

Lorentz → Predicted from theoretical considerations that the light from these lines should be polarized by the magnetic field, circularly polarized if viewed in a direction parallel to the lines of forces and plane polarized if viewed at right angles to the field.

Zeeman → verified these predictions by means of prisms and analyzers.

Classical Theory of Lorentz:– If a light source be placed in a magnetic field, the motion of the electrons → modified in such a way as to change their periods of motion.

an electron moving in a circular orbit, the plane of which is normal to the field direction H, the electron will be speeded up or slowed down by an amount which depends upon magnetic field strength H, the mass and charge of electron, and velocity of light.

According to the classical treatment, if ν_0 → orbital frequency of the electron without field, the frequency in presence of the field will be given

by $\nu_0 \pm \Delta\nu$, where $\Delta\nu = \frac{eH}{4\pi mc}$ —— (1)

If the field is normal to and up from this page of the book → electrons moving in a counterclockwise direction in the plane of the paper and speeded up by an amount $\Delta\nu$ and those moving in clockwise are speeded down by the same amount.

Vector Model and Normal Zeeman Effect

If we neglect spin of the electron, the angular momentum of the electron is $l^* = \sqrt{l(l+1)}$

$$p_l = \frac{l^* h}{2\pi} \quad —— (2)$$

and magnetic moment $\mu_l = e\frac{l^* h}{4\pi m_0} = \frac{e}{2m_0}p_l$ —(3)

In the presence of external field the vector l precesses around the field direction. The frequency of this precession is given by

$$\omega_l = B\frac{\mu_l}{p_l} = \frac{e}{2m_0}B \quad —(3)$$

The additional energy of the electron due to his motion is given by $\Delta E = \omega_L \times$ projection of mechanical momentum on the field direction

$$\Delta E = \frac{e}{2m_0} B P_l \cos\theta$$

$$= \frac{eB}{2m_0} \frac{l^* h}{2\pi} \cos\theta$$

$l^* \cos\theta = m_l$

$$\Delta E = \frac{eBh}{2\pi m_0} m_l.$$

m_l can have $(2l+1)$ values from $-l$ to $+l$

Effect of magnetic field → to split up each energy level into $(2l+1)$ levels and the magnitude of separation is proportional to the strength of the magnetic field...

Suppose E_1 and E_2 are the energies of the two levels in the presence of magnetic field and $E^{(1)}$ and $E^{(2)}$ in the absence of the field with the two values m_l as m_{l_1} and m_{l_2}.

$$E_1 = E^{(1)} + \Delta E_1 = E^{(1)} + m_{l_1} \frac{ehB}{4\pi m_0}$$

$$E_2 = E^{(2)} + \Delta E_2 = E^{(2)} + m_{l_2} \frac{ehB}{4\pi m_0}$$

The quantity of energy radiated in the presence of magnetic field is

$$E_1 - E_2 = E^{(1)} - E^{(2)} + \frac{ehB}{4\pi m_0}(m_{l_1} - m_{l_2})$$

$$h\nu = h\nu_0 + \Delta m_l \frac{ehB}{4\pi m_0}$$

$$\Rightarrow \nu = \nu_0 + \frac{eB}{4\pi m_0} \Delta m_l$$

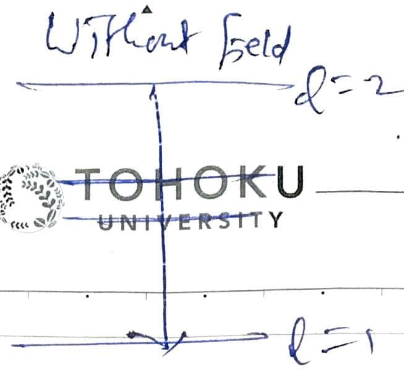
ν_0 → frequency of lines in the absence of the field.

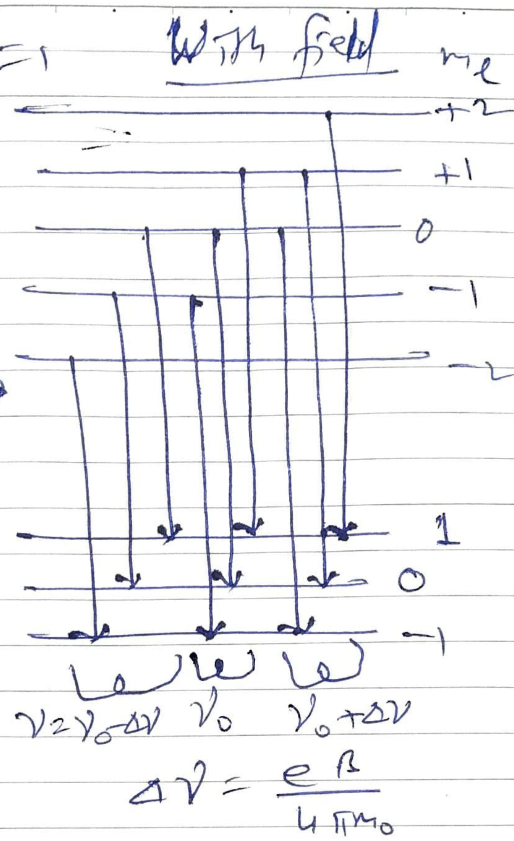
Δm_l → 0 or ±1

$\nu_1 = \nu_0$

$\nu_2 = \nu_0 + \frac{eB}{4\pi m_0}$

$\nu_3 = \nu_0 - \frac{eB}{4\pi m_0}$

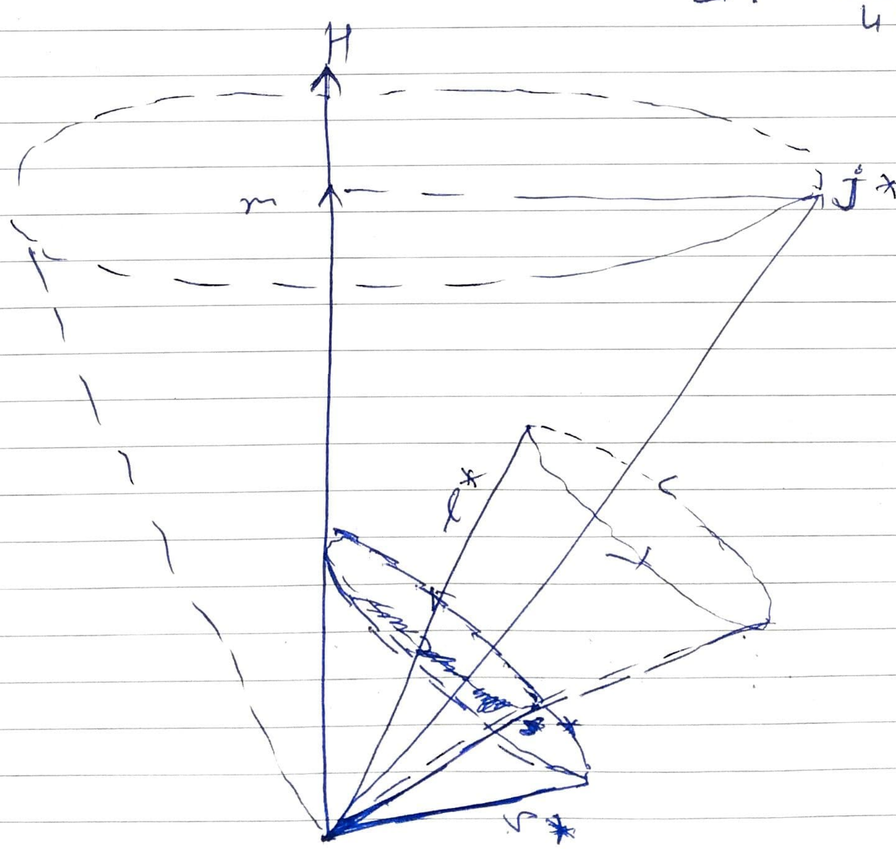




Normal Zeeman Effect

Change is the frequency by amount $\Delta\nu = \frac{eB}{4\pi m_0}$

→ Lorentz Unit



Precession of Single valence Electron around the field direction.