BASIC PRINCIPLES

Optically isotropic, transparent, non-magnetic materials become optically active in a magnetic field. They rotate the plane of polarisation of linearly polarised light passing through them in the direction of the magnetic field because clockwise and anti-clockwise circularly polarised components of the light take differing amounts of time to pass through. This effect is known as the Faraday effect.

The difference in the time it takes the polarised light to pass can be explained in terms of the change in frequency experienced by the polarised light in the magnetic field using a simple model. Light with a clockwise polarisation undergoes a slight increase in frequency $f$ by an amount called the Larmor frequency

$$f_L = c / 4 m_e B$$

$c = 1.6021 \times 10^{-19}$ As: Charge of an electron

$m_e = 9.1 \times 10^{-31}$ kg: Rest mass of an electron

The frequency of anti-clockwise polarised light decreases by the same amount, i.e.

$$f = f_L$$

The differing frequencies can be attributed to differing refractive indices in the material. This means that the speed of propagation of waves inside the material differs as well.

These statements make it possible to determine the rotation of the plane of polarisation in optically active materials, as follows:

$$\phi = 2 \pi f / c \cdot L \cdot \frac{d}{c}$$

The angle of rotation $\phi$ is proportional to the magnetic field $B$ and the length of material $d$ through which the light passes.

$B$ is given to a good approximation by a Cauchy formula.

$$B = \frac{D}{e} \cdot \frac{1}{\lambda^2}$$

where $D = 1.62 \times 10^{-7}$ T m ($1 = 1 \text{ T m}$)

$e = 4.803 \times 10^{-10}$ C: Electric charge

$\lambda$ is the wavelength of the light.

The amount, i.e.

$$n = \frac{c}{\lambda f}$$

Since the Larmor frequency $f_L$ is much smaller than $f$, it follows that:

$$\phi = 2 \pi f / c \cdot L \cdot \frac{d}{c}$$

The angle of rotation $\phi$ is also proportional to the magnetic field $B$ and the length of material $d$ through which the light passes.

$\phi = \frac{B}{d}$

The constant of proportionality $\nu$ is called the Verdet constant and is dependent on the dispersion of the light in the material through which it passes and on the frequency $f$ of that light. The following can be derived:

$$\nu = \frac{e}{m_e} \cdot c$$

$\nu$ is given to a good approximation by a Cauchy formula.

$$\nu = \frac{B}{d}$$

In this experiment, measurements are made of the Faraday effect in flint glass. This particular type of glass exhibits a high degree of very uniform optical dispersion. The way that the frequency depends on the refractive index is given to a good approximation by a Cauchy formula.

$$n(f) = \frac{B}{d} \cdot f^2$$

where $a = 1.62 \times 10^{-7}$ T m

To improve the accuracy of the measurement for small angles of rotation, this experiment is set up in such a way that when the magnetic field $B$ is positive, the polarisation of the light is such that the analyser filter causes the transmitted light to go dark at precisely 0°. When the magnetic field is switched to a negative one $-B$, the analyser must be rotated by an angle $2 \phi$ in order to shut out the light again.