Investigation of the Freedericksz Transition in Liquid Crystals

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Personal Details
In my first three years in DIT Kevin Street, I studied for the Diploma in Applied Sciences (Physics Option) and was awarded a Merit 2. After graduating I was offered a place in the Applied Sciences Degree course (Physics and Physics Technology). The subjects I studied included medical imaging, material science, microwaves and nuclear physics.

During the summer of 2001, I worked in the medical centre for Guinness at James Gate, Dublin. At Guinness I was involved in local community work, and awarded school children Certificates of Merit for attending school. I also attended other similar functions, as Guinness takes a big interest in the welfare of the community around it. During other summer holidays I worked for Irish Rail. My interests include travelling, and kick boxing. When I leave college I would like to go to New York, and then travel through Europe.

Project Summary
The aim of my project was to reproduce the Freedericksz Transition in a liquid crystal and show the dependence of the Freedericksz Transition threshold on the inverse sample thickness. The paper on which this work was based was written by T. Mosses and J. Jensen “The investigation of the Freedericksz Transition in liquid crystal for an undergraduate laboratory.”

The Fredericksz Transition occurs when there is competition between elastic and magnetic forces on the liquid crystal. If a magnetic field is applied to the crystal then the magnetic dipole moments are induced in the molecules. This causes the molecules to align along the magnetic field. This does not occur at the surface of the molecule, due to strong interactions within the substrate molecule that keeps them fixed. Reorientation takes place in the rest of the crystal along the field direction. This entails a distortion in the direction of the molecules. This distortion costs energy just as the deformation of any elastic medium requires energy. When the applied magnetic field $H$ is greater than a threshold value $H_0$, then reorientation occurs. If the magnetic field $H$ is less than this threshold then no reorientation occurs. This is so because when the magnetic field $H < H_0$, the energy reduction due to the magnetic poles reorienting is outweighed by the energy cost of the elastic deformation. When $H > H_0$, then it is energetically favourable for the molecules to reorientate despite the elastic energy cost. So therefore as the magnetic field increases beyond a threshold value, the Fredericksz Transition occurs. The threshold is seen when $H/H_0 = 1$.

There are three primary deformations of a nematic liquid crystal, known as the splay, twist, and bend. These are shown in Figure 1. The splay elastic constant is calculated from the following equation:

$$H_0 = \frac{\pi}{d} \left[ \frac{K_1}{\mu_0 \Delta \chi} \right]$$

where $H_0$ is the threshold field, $d$ is the spacer thickness.

![Figure 1. Primary liquid crystal deformations (a) splay, (b) twist, (c) bend.](image-url)
ness used to put in between two glass slides when forming the liquid crystal cell, \( \mu_0 \) is the permittivity of free space, \( \chi \) is the magnetic susceptibility and \( K_1 \) the splay constant.

A large splay constant \( K_1 \) increases the energy cost of deformation, raising \( H_0 \). Large magnetic susceptibility anisotropy makes reorientation more energetically constructive, decreasing \( H_0 \). A smaller sample thickness \( d \) decreases the distance over which the director must deform, raising the elastic energy cost and increasing \( H_0 \). According to the above equation, the Freedericksz Transition threshold field \( H_0 \) is inversely proportional to the sample thickness. This can be shown graphically which results in a straight-line graph.

To achieve this transition, the liquid crystal sample was placed in between two magnetic poles. A laser beam was passed through a polariser, through the first axial hole in the magnet, through the liquid crystal, through the second axial hole in the magnet, through a second polariser and then focused onto a photodector (see Fig. 2). The polarisers were crossed, with one of the polarisers parallel to the optic axis (nematic director) of the sample. The second was then adjusted so that minimum transmission was achieved. Five liquid crystal cells were made up with spacer thickness of 25-250µm.

The results, illustrated in Figures 3 and 4, concurred quite well with the expected behaviour of the Freedericksz Transition, particularly for phase shift versus field ratio. Some deviation from the expected linear relationship between threshold field and sample thickness was observed.