Liquid Crystals in Physics Teaching

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People meet various states of matter every day, but they usually recognize only gaseous, liquid and solid states of matter although there are many others. We are surrounded with substances that possess special phases between solid crystalline and liquid phases. The ordering in these special phases is lower than in crystalline but still higher from liquid phase. These medium phases were discovered about century ago and were named as liquid crystalline phases. The transfer from science to technology was rapid and it results in the presence of liquid crystals in various devices, e. g. displays, LCDs, thermometers, welding goggles, cosmetics etc. The liquid crystals are still a topic of current scientific research [1, 2].

Liquid crystals are one of the interesting and new topics that can serve as a link-up between the science and education since they are in tight connection with a real life. The liquid crystals with many attractive physical properties such as birefringence and colours could be motivating and interesting thematic in physics and science classes. Although people handle with the technology containing liquid crystals and their phase transitions, there is a great gap in understanding of these phenomena. The awareness of phases in other chemical substances is often compared to the properties water. Since the liquid crystalline phase has no analogy in phases of water, students are in lack of imagination. Introduction of liquid crystals as a modern and interdisciplinary topic into physics lessons needs a variety of different teaching strategies and adequate teaching materials. In this contribution the concepts which are important for understanding liquid crystals and their properties will be discussed. A teaching unit about liquid crystals will be presented as well as accompanying mechanical models that serves for development of conceptual understanding. The key experiments of this contribution about liquid crystals are shortly described below. The hands-on fabricated liquid crystalline cells will be shown to demonstrate some optical properties of liquid crystals. The cells can be made of a microscope glass, cover glass and tape, filled by the MBBA liquid crystal, which can be synthesized in a school lab (Figure 1), [3].

An important property of liquid crystals is anisotropy (e.g. in refractive index). A nice mechanical model for introducing the anisotropy can be found in wood. Wood has strong anisotropic dielectric properties in the microwave range, like liquid crystals in the visible range. A piece of wood can be used for interesting microwave experiments demonstrating optical anisotropy (Figure 2). Selection of microwaves and wood in comparison to liquid crystals and visible light, is useful, because it is easier to work with microwaves due to their

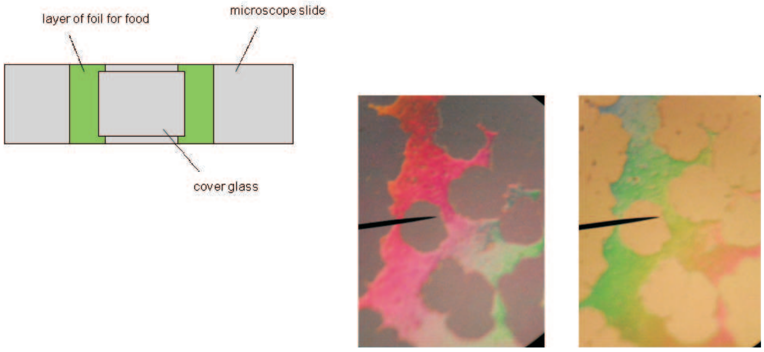

Figure 1: Liquid crystalline planar cell (left) under the crossed (middle) and parallel polarizers (right) observed under the microscope.

wavelength and because wood has pronounced an easily observable anisotropic structure [4].

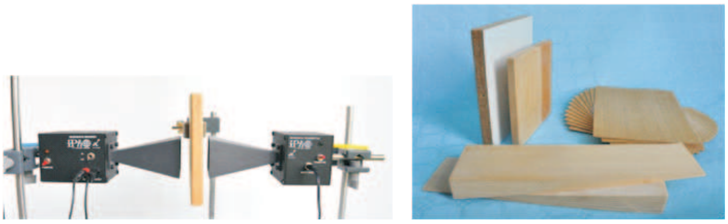

Figure 2: Setup for experiments with microwaves and wood (left) and wood models (right).

On the Faculty of Education, University of Ljubljana, a set of experiments for visualization and explanation of conoscopy was developed. The experiments discuss in detail various sample properties affecting the conoscopic figure (Figure 3), where different anisotropic materials (uniaxial and biaxial) of different thicknesses and different light sources (monochromatic and white light) are used. The experiences gained in this set of experiments are than used to experimentally consider the effect of the external electric field on the liquid crystal in the cell [5].

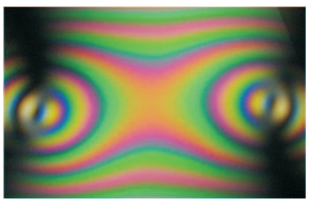

Figure 3: Conoscopic figure.

With ambition to introduce the topic of liquid crystals as plastic and picturesque as possible the mechanical model for the ordering and phase transitions in liquid crystals will be presented as well. The thermo-dynamical properties of matter in a vicinity of phase transition are rather abstract and seem to be difficult to visualize. For this reason it is worth to help students with a simple mechanical model. Although the model was developed for liquid crystals it can be used as a universal model for phase transitions at secondary school level as well as in undergraduate and graduate studies. A mechanical model is a simple device made out of helical springs and/or elastic rods (Figure 4). Using the mechanical model one can visualize the difference between the first and the second order phase transitions. The analogy between the mechanical model and phase transitions will be discussed and generalized to other phase transitions as well [6, 7].

Figure 4: A mechanical model for phase transitions.

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