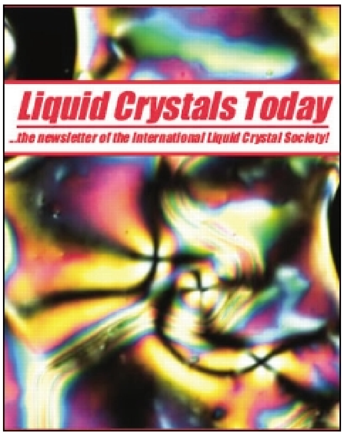

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The Nematic-Isotropic Transition

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Liquid Crystals in Education

The Nematic–Isotropic Transition

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We describe simple classroom experiments that can model the nematic phase, the first order nematic–isotropic phase transition, and the effect external stimuli, such as surface treatment, have on the phase transition. These experiments are suitable for the high school level but can be easily adapted to fit the middle school mathematics and science curriculum. With even more simplification, it can also be used to fit the elementary level to qualitatively demonstrate the total loss of order as a liquid crystal melts into a liquid.

Experiment no. 1 — The order parameter of a two-dimensional system

Ten toothpicks are used to represent a collection of LC molecules. The students simply drop the bundle of toothpicks from a height of 10 cm onto a sheet of notebook paper. From such a low height, the toothpicks will fall on the paper with a preferred direction. Using the lines of the notebook paper as a convenient reference, the students can record the angle, α, that each toothpick makes with these lines. Each angle will have a value such that $0° \leq \alpha < 180°$ when measured counter clockwise.

The students can then calculate the average angle (α_{avg}) that the toothpicks make with a line. This average angle represents the direction of the nematic director. By subtracting each recorded angle from α_{avg}, each molecule's deviation from the director can be found and substituted into the expressions

$$S_i = 2\cos^2\theta_i - 1 \qquad (1)$$

$$\boldsymbol{S} = (1/n)\,\Sigma\, S_i \qquad (2)$$

where n represents the total number of toothpicks. Note that equation (1) is a special case of the three-dimensional result $S = \langle \frac{1}{2}(3\cos^2\theta - 1)\rangle$ when restricted to two dimensions. It could be very advantageous for the class to combine their measurements for a larger sample. Students can perform calculations for such a collection of data using a spreadsheet such as Quattro Pro or Lotus 123. Results of 10 data points can be seen in Table 1.

α_i	α_{avg}	θ_i	S_i	$\boldsymbol{S}$
56.00	71.50	15.50	0.857	0.764
67.00		4.50	0.988	
81.00		-9.50	0.946	
77.00		-5.50	0.982	
43.00		28.50	0.545	
109.00		-37.50	0.259	
39.00		32.50	0.423	
73.00		-1.50	0.999	
94.00		-22.50	0.707	
61.00		10.50	0.934	

Table 1. Determination of the order parameter

Experiment no. 2 — Simulation of the nematic–isotropic phase change

One important area of research in the study of liquid crystals is the determination of phase transition temperatures. That is to say, scientists are very interested in seeing what happens to the order parameter of a LC sample as thermal energy is added to or subtracted from the system. A simulation of this experiment can be easily accomplished by performing the experiment described above for different drop heights. The difference of height, such as heating, represents an addition of energy to the system. Just as an increase in thermal energy causes increased disorder in the liquid crystal sample, a greater amount of gravitational potential energy will cause the toothpicks to strike the paper at a higher velocity yielding a less ordered system. The results for 40 toothpicks dropped from heights ranging from 10 cm to 60 cm in 10 cm increments are graphically represented in Fig. 1.

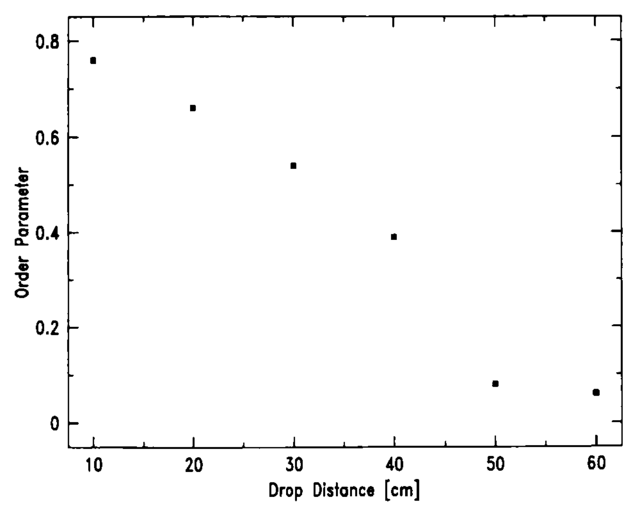
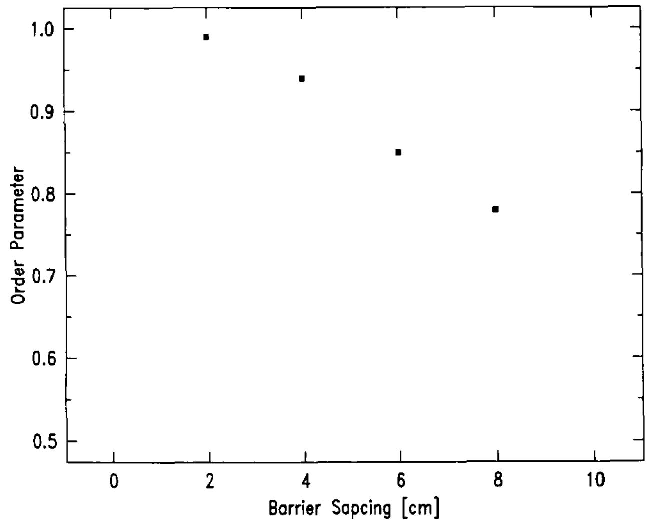


Figure 1. Order parameter as a function of drop height.

Experiment no. 3 — Simulation of the effect of surface treatment on the transition temperature of a nematic liquid crystal

Another simple simulation can be performed in the classroom to demonstrate the effect that surface interactions have on the alignment of liquid crystal molecules. One reason for this interest is the fact that control of the molecular alignment at the surface is vital to the operation of liquid crystal displays. Once again the experiment is the same as that first described with the exception that the toothpicks are dropped between two boards which are 2 cm apart. Keeping the drop height constant, the board spacing can be increased and its effect on the order of the system studied. A plot of the results of such an experiment for 40 toothpicks can be seen in Fig. 2 overleaf.



The above results were obtained by Thomas Ciferno and Renata Marroum during the 1994 Summer Teacher Intern held at the Liquid Crystal Institute at Kent State University. Thomas Ciferno is a science teacher at Bedford High School, Bedford, OH, and Renata Marroum is the Education Outreach project Coordinator for NSF Science and Technology Center for Advanced Liquid Crystalline Optical Materials (ALCOM), Liquid Crystal Institute, Kent, OH.

Figure 2. Order parameter as a function of barrier spacing.