Laboratory 6: Light and the Laser

WARNING – NEVER LOOK DIRECTLY AT LASER LIGHT

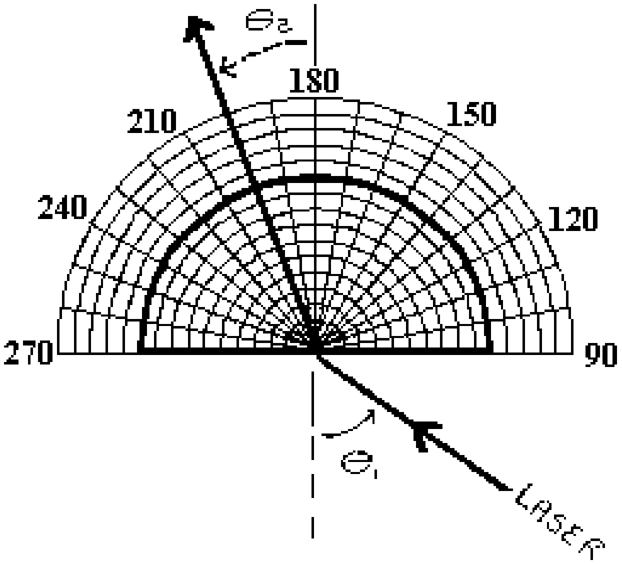
Index of Refraction: Snell's Law

1. Read the section on physical optics in some introductory physics text.
2. Set the semicircular Lucite sample on the compass board as shown in Figure 1. Elevate the support board so the laser light just grazes the paper. Adjusted properly you can measure the angle of incidence and the exit angle as the laser beam grazes the paper. Use Snell's Law to determine the index of refraction of Lucite,

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2) \tag{1}$$

   Use $n_1 = 1$ for air. n_2 is the index of refraction of the unknown substance.
3. Repeat step 2 for the water and olive oil samples.

Figure 1: Setup for Snell's Law



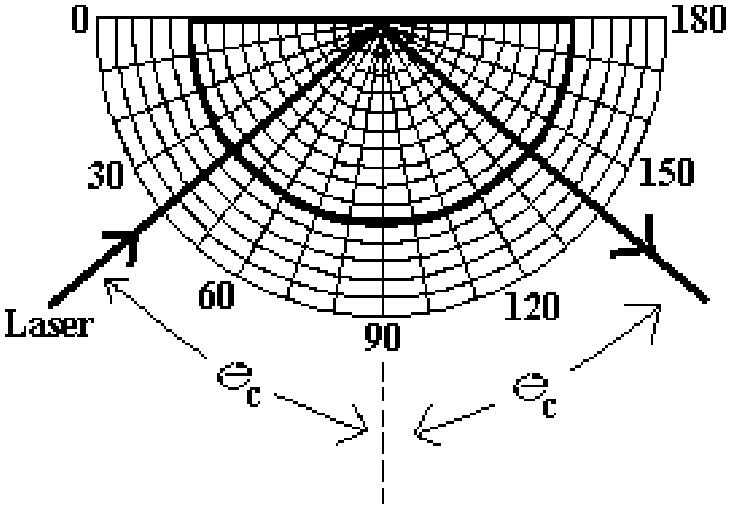
Index of Refraction: Total Internal Reflection

4. Place the Lucite sample on the compass board as shown in Figure 2. Find the minimum angle for total internal conversion to occur. Determine the index of refraction of Lucite.

In this case the laser light is incident from the medium into air; therefore, n_1 = index of refraction of the medium and n_2 = index of refraction of air = 1.

5. Repeat step 2 for the water and olive oil samples.

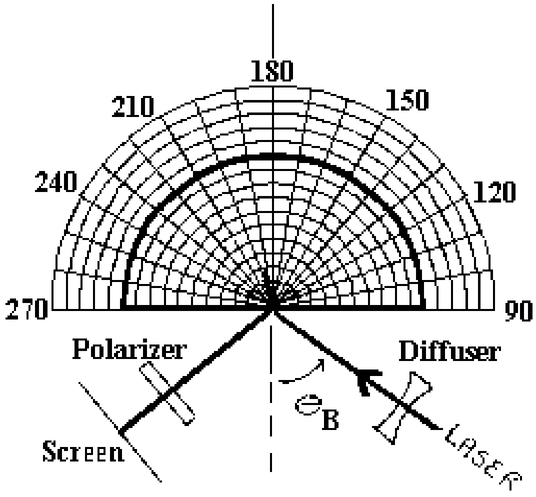
Figure 2: Total Internal conversion



Index of Refraction: Brewster's Angle

6. Place the Lucite sample on the compass board as shown in Figure 3. The diffusing lens is optional, but does make the laser spot bigger. By rotating the polarizer and looking for beam extinction, find the angle where the reflected beam is totally polarized. Determine the index of refraction of Lucite.
7. Repeat step 6 for the water and olive oil samples.

Figure 3: Brewster's Angle Setup



Index of Refraction Results

8. Tabulate your results and report your best estimates of the index of refraction of the three samples including your best estimate for the uncertainty. Compare your results to the accepted values.

Polarization: Malus' Law

1. Read the section on polarization in an introductory physics textbook.
2. Earlier you made use of a Polaroid film in order to determine the angle at which the reflected laser beam was fully polarized. You will now examine the effects of using two polarizers together in series. In the darkroom place the lamp and light detector on optics bench, they each snap into place. A separation of 30cm between these elements will give you space to make adjustments. Use loggerPro to collect intensity data from the sensor.
3. Attach a polarizer to the bench in front of the light source and record the new intensity. If the light from the lamp is un-polarized the resulting intensity should be reduced by ½ for a single ideal polarizer. For real Polaroid film this number will be less. Can you explain why?
4. Now attach the analyzer (polarizer with rotary motion sensor) to the optical bench between the polarizer and the light detector and rotate the analyzer until the maximum amount of light is blocked to the detector. Record this intensity. At this point the angle between the two film's polarization axes should be 90°. Rotate the analyzer 90° to bring it into alignment with the polarizer. Collect data while slowly rotating the analyzer between 0° and 90°. Repeat this set of measurements until you have at least six currents at each angle.
5. Normalize your results so that the current is zero when the intensity of the light is at its minimum and is equal to one when the light is at its maximum intensity (i.e. subtract the minimum from all data and then divide all results by the resulting maximum current).
6. Plot the resulting data for normalized intensity as a function of the angle between the analyzer and the initial Polaroid film from 0 degrees to +90 degrees. Include on this graph your estimate for the uncertainty in the measurement of the normalized intensity. Use the fact that a polarizer reduces the electric field of an initially polarized light source to $E' = E_o \cos(\theta)$ and the relationship between electric field strength and light intensity to explain the observed angular dependence of the normalized intensity.

Diffraction: Single Slit Diffraction

1. Read the section on diffraction in some introduction physics text.
2. Set up the red laser on the optical bench as shown in Figure 4. Do not place the laser too close to the slit, it helps if the beam disperses a little first. Turning the lights out helps in this lab, but is not necessary. The light sensor mounted on the linear position sensor has a neutral density filter on the front that can be rotated to adjust the intensity of the light hitting the detector.
3. Illuminate the single slit. Use the adjustment screws on the back of the laser stand to evenly light both sides of the slit.
4. Observe the characteristic single slit pattern minima and maxima. Record the intensity vs lateral position data using loggerPro.
5. Carefully measure the distance, L, between the slit and the optical sensor. From your loggerPro data measure the positions of *several minima* on the lateral scale, d. From these data you can calculate the deflection angles to the maxima and minima

$$\theta = \text{asin}\left(\frac{d}{L}\right). \tag{2}$$

6. Recognize that the larger number of orders of interference used, the less measuring error is present. You will need to adapt the single slit formula for higher orders of interference.
7. From the data, determine the width of the slit.
8. You will want to know that the red Helium-Neon laser wavelength is λ = 633nm.
9. Repeat steps 2-9 using the green He-Ne Laser with λ = 532nm.

Figure 4: Setup for Slit Diffraction

Diffraction: Double Slit Diffraction

10. Adjust the slit plate to illuminate the double slit. Observe the characteristic double slit interference pattern. Note also, that this pattern is modulated by diffraction from the single slits.
11. From the data, determine the distance between double slits *and* the width of the individual slits. Note that it is crucial that you know λ to complete your analysis.

Diffraction: Multiple Slit Diffraction

12. Adjust the slit plate to illuminate the multiple slit. Observe the characteristic multiple slit interference pattern. Record as many orders of diffraction as possible. From the data, determine the distance between slits.

Diffraction: Width of human hair

13. Locate the 35 mm slide with a human hair attached to it and position it in the laser beam. Adjust the position to obtain the sharpest diffraction pattern. If you want, you may add one of your own hairs. Just make sure it is separated by a few millimeters from any others and is straight.
14. Use loggerPro to collect intensity and lateral to measure the positions of the maxima and minima.
15. Note that you are essentially doing the reverse of the single slit experiment, i.e. a slit barrier, everything else open.
16. From your data determine the thickness of the hair. Explain your method and reasoning.
17. Use a second laser with a different wavelength to get an additional measurement.
18. Try some other hairs to see how thickness varies.