Modern Optics

Project Polarization

I. Introduction

1. Acquaint yourself with a polarizer (more properly called an analyzer) by setting its dial to 0° and peering through it at several light sources (not laser beams). For example, find some glare (light that has been reflected at roughly 45° from a smooth horizontal surface). Glare is highly polarized in the horizontal direction. Taking this as a given fact, determine the proper analyzer angles θ for which one gets maximum transmission of horizontally polarized light. More easily, determine the angles

$\theta =$

for which the analyzer completely blocks horizontally polarized light. From these results, infer analyzer angles settings which maximize the transmission of vertically polarized light.

$\theta =$

Laser Safety Awareness: Anytime you put an object in a laser beam, pay attention to the reflections from the beam and where those reflections are going. The lasers in this lab are not particularly strong, but should be respected nonetheless.

2. You are provided with doubly refracting calcite crystals. Hold the crystal in a laser beam and rotate it until you see two spots on the screen. (You'll also see extra spots from multiple reflections within the crystal.) Further rotate it and see if you can find an incident direction where the two spots get very close to each other and coincide. This special direction is the optic axis. In most directions (except along the optic axis) light entering the crystal will split into two rays–ordinary and extraordinary ray. Observe these two rays through an analyzer and test to see if and/or how they are polarized.

Ray 1:

Ray 2:

If you rotate the crystal, the extraordinary ray rotates around the ordinary ray. Can you identify if ray 1 is the ordinary or the extraordinary ray?

3. By positioning a polarizer and analyzer in a laser beam, test some materials like plastic wrap, glass plates (tilt them and observe the effect), the pieces of plastic provided, corn syrup etc.]. Can you figure out how these materials affect the polarization of the laser light? Write down your observations and speculate on what might be happening.

Place a piece of plastic wrap between two initially crossed polarizers with a white light source. What does the plastic do to the plane of polarization of the light coming through the first polarizer? Stretch the wrap and repeat observation.

Test the mica, plastic boxes, crumpled plastic wrap, etc, with the polarizers and white light. Note your observations and any conclusions.

II. Polarization by Reflection: Brewster's Angle

Use the ray table to hold the cylindrical lens in the path of the laser beam. Adjust the components so that the beam is reflected and refracted at the flat surface of the cylindrical lens.

Rotate the ray table until the angle between the reflected and refracted rays is as close to 90° as possible. Place the ray table component holder so it is in line with the reflected ray. Look at the light coming out of the polarizer and rotate the polarizer through all angles. Measure the angle of incidence, which is Brewster's angle.

$\theta_B =$

1. Is the reflected light plane polarized? If so, at what angle from the vertical is the plane of polarization?

Is the transmitted light polarized?

2. Is the light plane polarized when the reflected light is not at an angle of 90° with respect to the refracted ray? Try it and record your observations.

3. Derive a relationship between Brewster's angle and refractive index of the lens by applying Snell's law. From your measured angle, calculate the refractive index of the material of the lens.

4. Explain how polarizing sunglasses reduce glare.

III. Malus' Law

Set up a polarized laser; place a polarizer and let the beam pass through it. Rotate the polarizer and observe the transmitted beam on a screen. Measure transmitted intensity as you rotate the polarizer through different angles. Sketch its polarization direction with respect to the vertical axis. Use θ as the angle between the 0–180° axis of your polarizer and the vertical.

This first polarizing sheet acts to polarize the light—it's called the polarizer.
The second polarizing sheet is used to analyze the existing polarization—hence, it's called the analyzer.

Use DataStudio and the light sensor to measure transmitted power $P(\theta)$ as a function of analyzer angle θ (the angle its 0–180° axis makes with respect to the first polarizer).
In DataStudio, pull the light sensor data onto a graph. If room lights are on, your data may be noisy; you may want to minimize that by using a piece of black tape with a hole in it, so only the laser light is incident on the probe. Collect data for about 10 seconds for each θ and use the statistics function (the [Σ] button on the graph) to find the mean value of the intensities.

θ	P

Put the data in Excel and plot P(θ) vs. θ.

The data should follow Malus' Law:

$$P(\theta) = P_0 \cos^2 \theta$$

Let your maximum transmitted laser power be P_o (corresponding to $\theta = 0$) and generate a set of theoretical points and plot them on the same graph against θ.

How do your data compare with the theoretical function?

Prove Malus' Law (you may refer to an optics text!).