Physics 319 Laboratory: Optics

Polarization 1

Malus's Law

Objective: You are to explore the nature of polarization of light by a Polaroid polarizer, by scattering off small particles (Rayleigh scattering), and by reflection off of glass.

Apparatus: You will need t a PASCO optical bench, incandescent source, standard instrument holder, two polarizers, linear translator, fiber optic cable, aperture mask, and light intensity meter. See figure 2.

Theory: Light is a transverse wave. We define the direction of polarization by the direction of the electric field vector **E.** Light from common sources, such as light bulbs, is unpolarized, meaning that the plane of vibration of the electric field vector changes its orientation very rapidly and in a completely random fashion. However, when light interacts with matter, the plane of vibration of the electric field may become fixed in a particular direction (linear polarization) or the plane may rotate or otherwise vary in a uniform manner (circular or elliptical polarization).

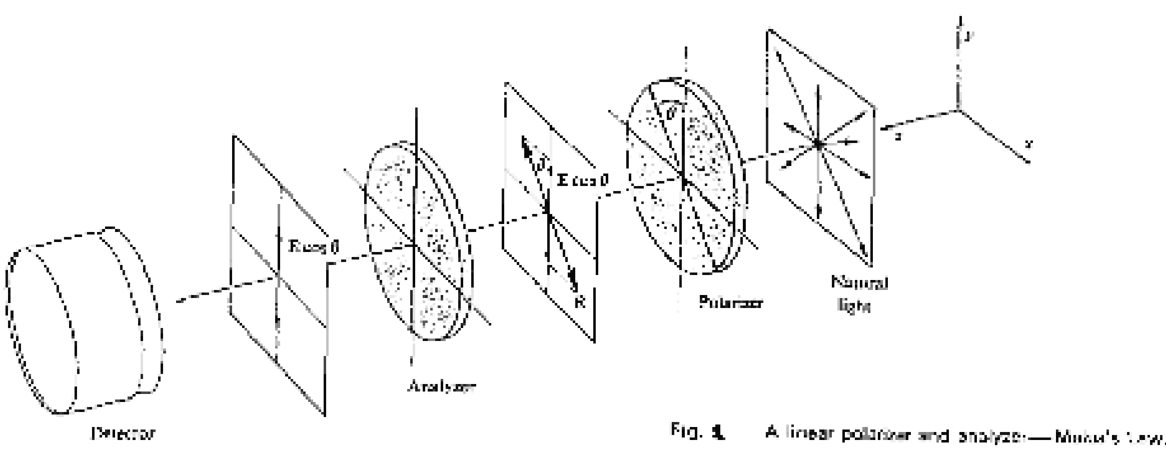


Fig. 1 A linear polarizer and analyzer—Malus's Law.

A Polaroid is a treated plastic which selectively passes only the component of the incident electric field that is parallel to the optical axis of the Polaroid.

Unpolarized light which is passed through a Polaroid will emerge linearly polarized in the direction of the optic axis of the Polaroid.

Figure 1 shows the polarization of natural light propagating in the z direction. The analyzer and the polarizer are identical Polaroids, differing only in their orientation. The electric field of the light passed by the polarizer is oscillating in a plane that makes an angle θ relative to the analyzing polarizer. Since the optic axis of the analyzer is parallel to the y-axis, the electric field has the magnitude Ecos(θ) after it leaves the analyzer. The output of the detector is proportional to the irradiance of the incident light. That is

$$I(\theta) = \frac{c\varepsilon_0}{2} E_{01}^2 \cos^2\theta = I(0)\cos^2\theta$$

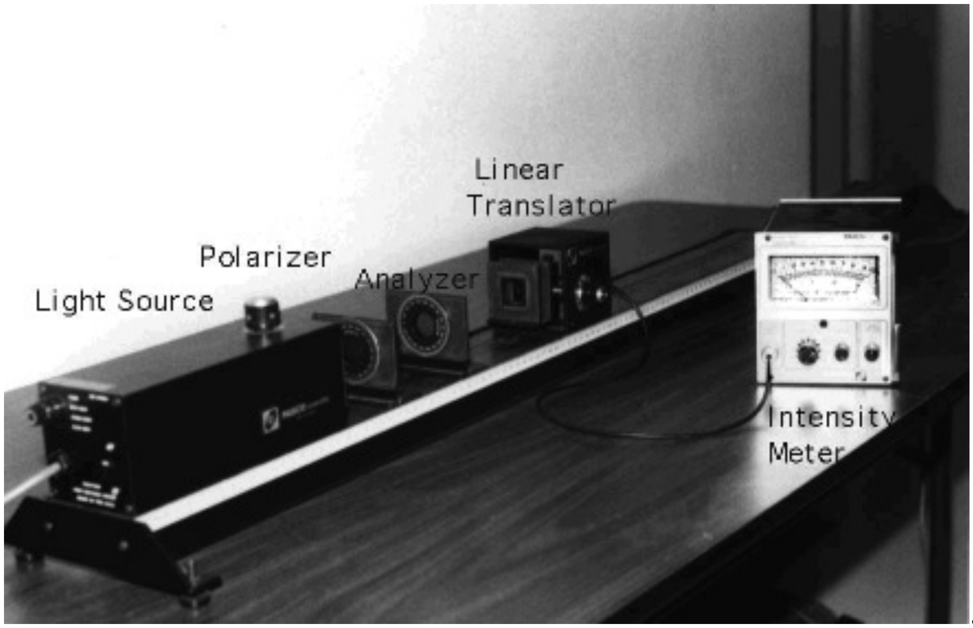
where $I(0) = \frac{c\varepsilon_0}{2} E_{01}^2$. **The angle θ is the angle between the polarization axis (along the direction of the E field) and the axis of the polarizer (which is at zero degrees on the polarizer's scale), not the angle indicated of the polarizer.** The second equality is known as **Malus's Law**

Light may also be polarized by scattering from small particles in suspension. This kind of scattering is known as Rayleigh scattering. An explanation of this kind of polarization is given in section 15-3 of the course text. It is responsible for blue skies and red sunsets. Reflection from glass may also cause polarization is accordance with the Fresnel equations (see section15-2).

Procedure:

I. **Verification of Malus's Law**

Place the polarizer on a holder about 30 mm from the source and rotate the polarizer until the 0 degree tick mark on the polarizer matches the vertical tick on the holder. Place the analyzer about 130 mm from the source.



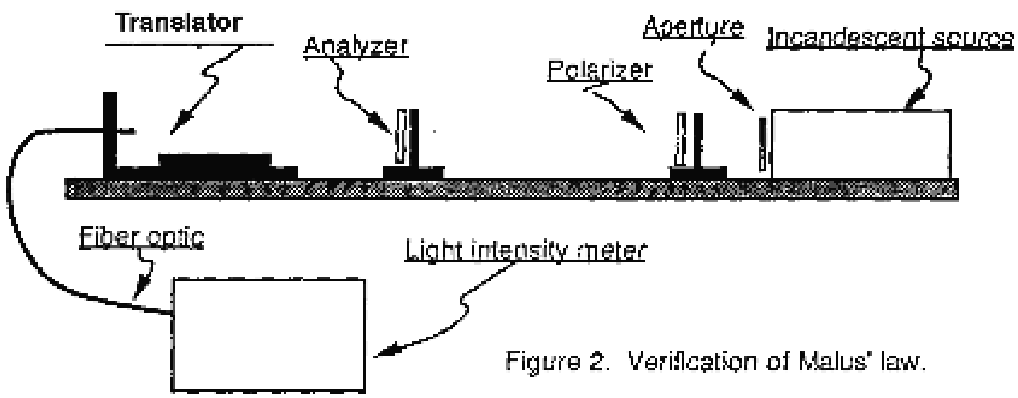
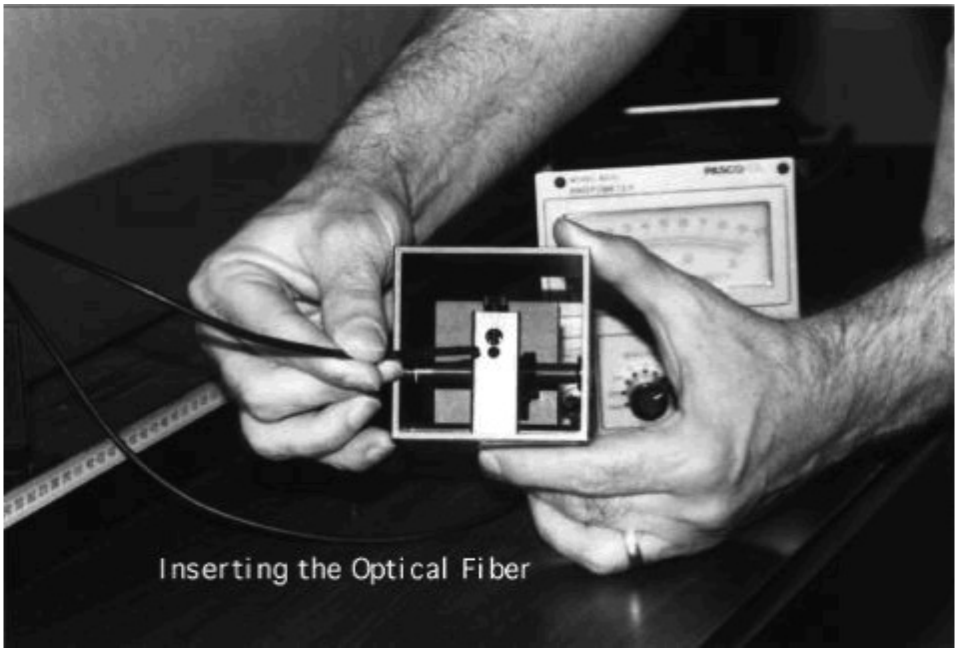


Figure 2. Verification of Malus' law.

Secure the end of the optical fiber coming from the light meter into the linear translator. Position the linear translator about 230 mm from the light source.



Set the light intensity meter's sensitivity scale to 1. Now **rotate the analyzer** until the light intensity meter reads its minimum value. Adjust the zero scale knob until the meter reads zero. Once the meter is zeroed, rotate the analyzer until the maximum deflection is achieved. Adjust the variable knob until the meter reads full scale deflection. Your meter should now be calibrated.

Collect intensity readings for 30 different angles of analyzer orientation between 0 and 180 degrees (leaving the polarizer fixed at zero degrees). Your report should include a neat data table, and a plot of intensity vs. relative angle from 0 to 180 degrees. On the same graph, plot the prediction of Malus' law. Do not connect the dots, it should be a smooth curve fit

II. Polarization by Rayleigh Scattering

If the day is sunny, grab a couple of polarizers out of the optics kit and take a walk, If one of the large Polaroids is available, take it too.

The round polarizers from the kit are marked in angles. The optic axis of the polarizer is the line between the 0 to 180 degree marks. This can be used to determine the optic axis of the large sheet polarizer (How? See Malus' Law). Use a piece of tape to mark the optic axis of the large sheet. Scan the sky through the polarizer, holding the polarizer with its optic axis parallel to the ground. Use this to determine where, with respect to the sun, the sky light is most polarized. What is the angle of this light to the ground? Record your findings and discuss. Note: Do not look directly into the sun

III. Polarization by Reflection

While you are outside, find a window (a car's front window will work) with a reflective glare coming off of it. If it is a cloudy day, use a white light source. Look at the reflection from a piece of glass or Plexiglas. Now look at the glare through the Polaroid. By rotating the Polaroid, determine the polarization of the light reflected off the window. Try this at different angles from the window and see if the degree of the polarization changes.

Questions:

1. Did your data from part 1 confirm Malus's law? Discuss

2. Why do polarized glasses help while driving? Without checking, try to reason out the direction of the optic axis of a pair of sunglasses.