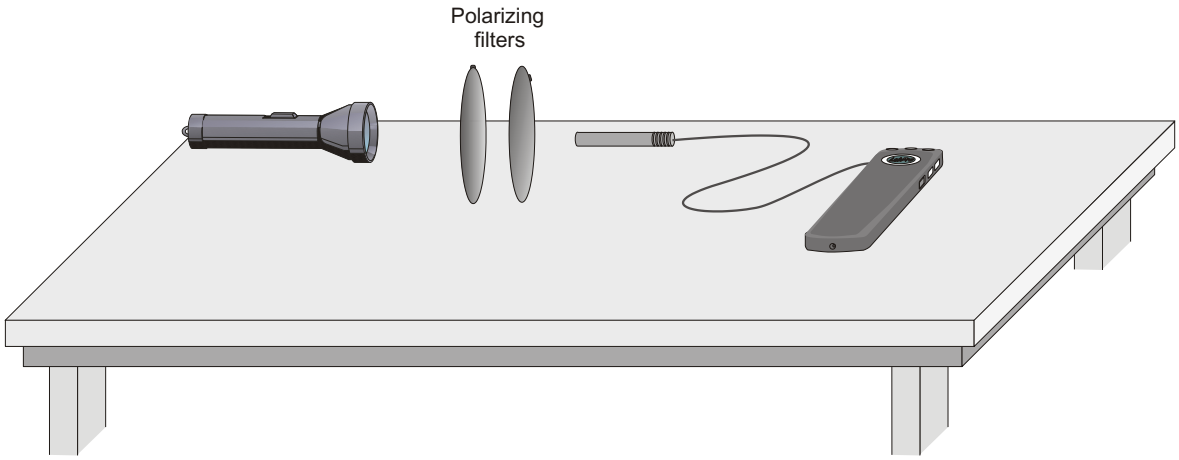
Lab 3: Polarization of Light

Perhaps you have seen a display of polarized sunglasses in a store. You can quickly test to see if the glasses are really polarized by looking through the lenses of two glasses and rotating one pair by 90º. If both pair of glasses are polarized, the lenses will appear to go black. Why is that?

To explain the darkened lenses, we need to think of the light as an electromagnetic wave. An electromagnetic wave has varying electric and magnetic fields perpendicular to the direction the wave is traveling. This experiment focuses only on the electric field variation, represented by a vector. Light emitted from a typical source such as a flashlight is randomly polarized, meaning that the electric vector points in varying directions.

An ideal polarizing filter will remove all but electric fields that are parallel to the axis of the filter. The light remaining is then said to be *polarized*. A second filter can be used to detect the polarization; in this case, the second filter is called an *analyzer*. The transmission through the second filter depends on the angle between its axis and the axis of the first filter. In this experiment you will study the relationship between the light intensity transmitted through two polarizing filters and the angle between the filter axes.



OBJECTIVES

- Observe the change in light intensity of light passing through crossed polarizing filters.
- Measure the transmission of light through two polarizing filters as a function of the angle between their axes and compare it to Malus's law.

MATERIALS

computer
Vernier computer interface
Logger *Pro*
Light Sensor + Holder from Optics Set
light source from Optics Set
polarizing filters (2)
Protractor

PRELIMINARY QUESTIONS

1. Place one polarizing filter on top of a second so you have to look through both of them. Rotate the top filter until the pair of filters let through the maximum amount of light. The filters are aligned. Draw arrows with a sharpie in the same direction on *each of the two filters* to indicate their alignment.

2. Ensure that the axes are parallel. Look through the pair and rotate the top filter about your viewing axis by 180º. In your notebook, sketch a *qualitative* graph of the transmitted light intensity you observed as a function of the angle.

PROCEDURES

1. Arrange the light source, polarizing filters, and Light Sensor so light passes through the filters and then into the sensor. It's probably best if you hold your polarizing filters directly in front of your light sensor. You will rotate only one filter to change the transmission; the other filter, the light source, and the sensor must not move. Turn on the light source.

2. Connect the Light Sensor to Channel 1 of the interface. If your sensor has a range switch, set it to the 600 lux range.

3. Open the file "28 Polarization of Light" in the *Physics with Vernier* folder. Light intensity is plotted *vs*. analyzer angle. Data will be collected in Events with Entry mode, meaning that the light intensity will only be measured when the Keep button is clicked. You will then type the analyzer angle in degrees and click OK to complete the data point.

4. Rotate the analyzer until the Light Sensor reading is maximized. The Light Sensor reading is shown in the status bar at the bottom of the Logger *Pro* window. If the reading is larger than 600 lux, reduce the intensity of the light source (by moving it further back) and rotate the analyzer again for maximum sensor reading. This is your zero angle. The axis marks on the two filters should be parallel.

5. Set the filters so their axes are at right angles. Very little light should get through the pair of filters. Define the light level as zero by clicking Zero. The intensity reading should now be near zero.

6. Return the analyzer to the parallel position. Click Collect to begin data collection. Click Keep to take the first point and enter **0** for the angle. Click OK to complete the entry.

7. Rotate the analyzer by about 15º, click Keep, and enter whatever angle you measure. Repeat this process, rotating by about 15 additional degrees each time until you have rotated the analyzer through one revolution, or 360º. Click Stop to end data collection.

ANALYSIS

1. Describe your graph of light intensity *vs*. angle, giving important patterns and points.

2. In the 1800's Malus proposed

$$I = I_0 \cos^2(\theta)$$

to predict the light transmission through two polarizing filters, where I_0 is the intensity when the angle θ between the polarizer axes is zero.

You can use the Manual Fit feature of Logger *Pro* to superimpose this relationship on your experimental data. Select Curve Fit from the Analyze menu. Select a Manual Fit Type and click the Define Function button. Enter A*(cos(x))^2. In this equation x stands for the angle θ. Click OK .

3. To compare your data to the model, you must adjust the value of A so that A matches the maximum intensity of your data. To do this, either enter a number in the A field or click ▲ to the right of the A parameter field. Adjust A as needed to achieve a good fit to your experimental data.

4. Click OK to plot your data and the Malus's law model on the graph at the same time.

5. Compare the data to the model. Are your data consistent with Malus's law?

QUICK EXPERIMENTAL FOLLOW-UPS

1. Polarized sunglasses selectively remove glare caused by light reflected by horizontal surfaces, *e.g.*, the hood of a car or a wet highway. For polarized sunglasses to be effective, the glare must be polarized. Measure how strongly polarized the glare off a smooth surface is compared to sunlight or to a flashlight. You will need a smooth horizontal surface to create glare, a bright light source, and a polarizing filter. How is the axis of the polarizer oriented when the glare is minimized? What direction do you think polarized sunglasses *should* be polarized in order to be effective?

2. Using your polarized filter, observe the blue sky. Is the blue sky polarized? In what direction is it polarized?

3. Set your two filters so that the polarizing axes are at 90º. Add a third polarizing filter between the first two and observe the change in transmitted intensity as a function of the angle of the middle filter. What do you notice? Can you explain what you see?