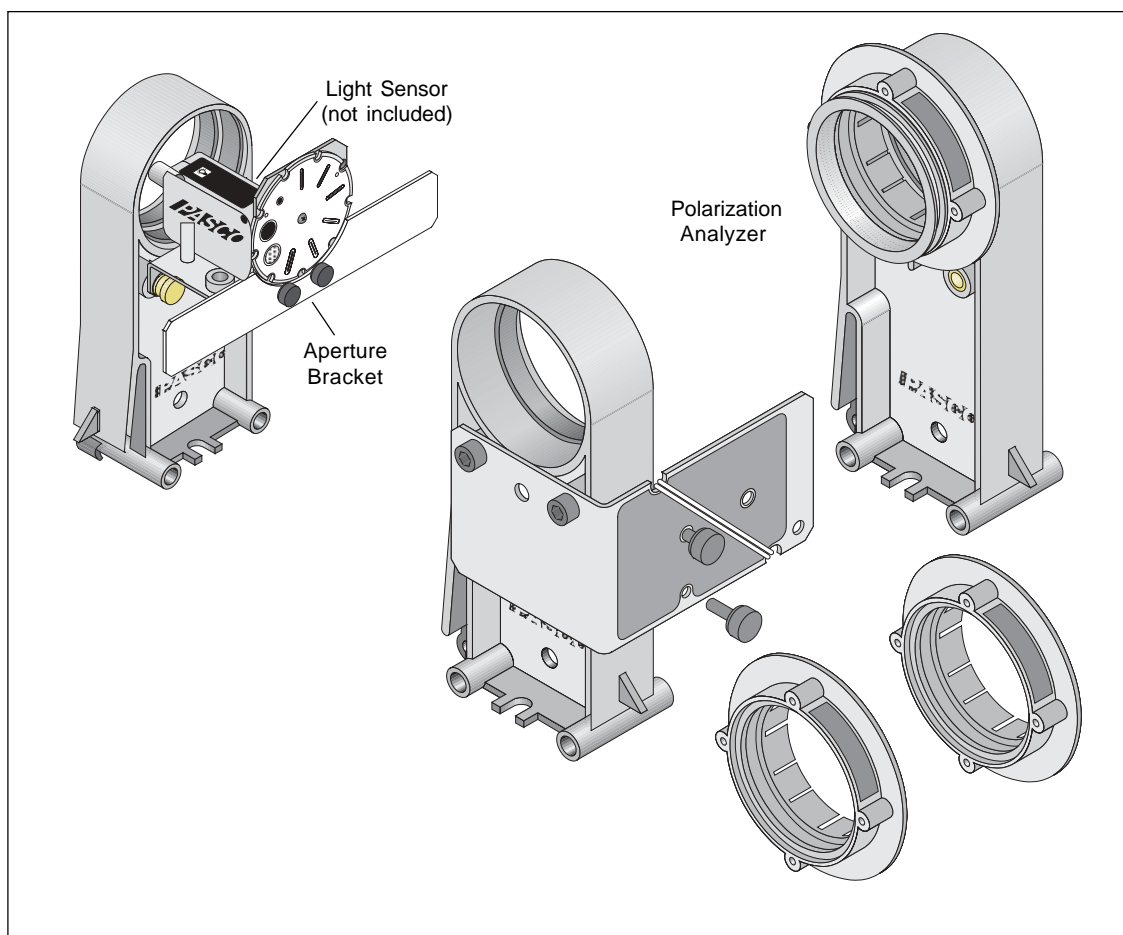


**Instruction Manual and  
Experiment Guide for  
the PASCO scientific  
Model OS-8533A**

012-09200A

# ***POLARIZATION ANALYZER***



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## **Credits**

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# Introduction

The PASCO OS-8533A Polarization Analyzer is designed to be mounted on the Optics Bench of the OS-8515 Basic Optics System and to be used with the Basic Optics Light Source (part of the OS-8515 Basic Optics System) and a Light Sensor such as the PASCO CI-6504A, or PS-2106 to explore polarization. When used with the PASCO CI-6538 or PS-2120 Rotary Motion Sensor, you can measure the relationship between the light intensity transmitted through a set of polarizers and the angle of the polarizers.

## Recommended Equipment

Basic Optics System (OS-8515)

Light Sensor (CI-6504A or PS-2106)

Rotary Motion Sensor (CI-6538, or PS-2120)

## Description

The Polarization Analyzer consists of a Polarizer Holder, an Accessory Holder with Mounting Bracket, two Polarizers, a Retarder and an Aperture Bracket. The mounting bracket is permanently attached to the Accessory Holder. The mounting bracket holds a Rotary Motion Sensor in position to measure the angle of one Polarizer as it turns relative to the other Polarizer. The mounting bracket includes two thumbscrews and a plastic belt. The thumbscrews attach the Rotary Motion Sensor to the bracket. The plastic belt is used with a Rotary Motion Sensor.

The Polarizers and Retarder snap into the opening at the top of the Accessory Holder or the Polarizer Holder. The Retarder is a one-quarter wavelength (140 nanometer) retarder. Each Polarizer has an angular scale near its outside edge marked in ten degree increments with additional marks at 45, 135, 225, and 315 degrees.

One of the Polarizers has a groove on its front edge. Use this Polarizer with the Accessory Holder. When the Rotary Motion Sensor is mounted on the Accessory Holder bracket, you can put the plastic belt over the groove on the front of the Polarizer and a groove on the three-step pulley on the Rotary Motion Sensor. This allows you to measure the angular position of the Polarizer as it turns.

## Mounting a Rotary Motion Sensor

### Prepare the Rotary Motion Sensor

You will need a Phillips head screwdriver with a small tip (e.g., #1).

The Rotary Motion Sensor comes with a rod clamp

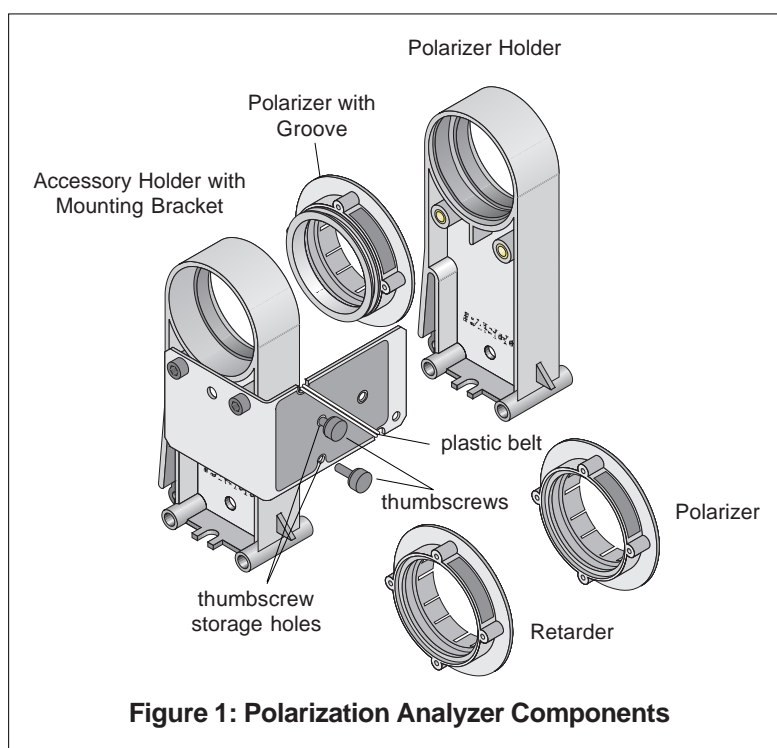


Figure 1: Polarization Analyzer Components

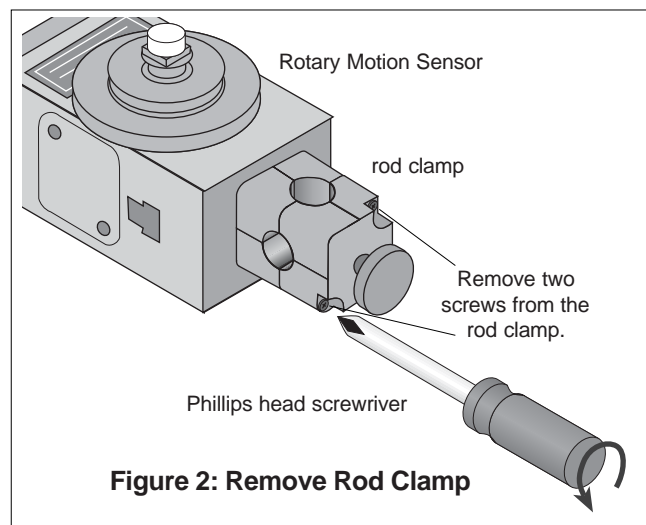
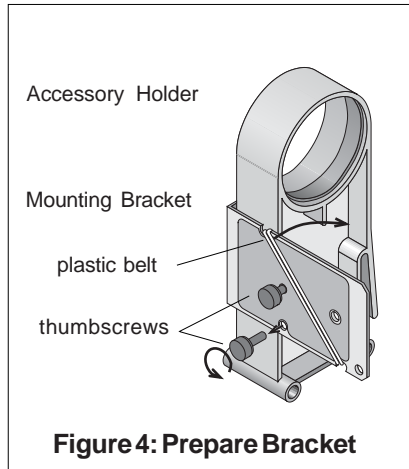


Figure 2: Remove Rod Clamp

attached to one end. Use a Phillips head screwdriver to loosen the two screws that hold the rod clamp. Remove the rod clamp and screws. (Please put the rod clamp and screws in a safe place for future use.)

The Rotary Motion Sensor also comes with a rubber “O” ring in the largest groove of the three-step pulley that is attached to the sensor’s shaft. Remove the “O” ring from the three-step pulley and put the ring in a safe place for future use. The sensor is now ready to mount on the Accessory Holder bracket.

### Prepare the Mounting Bracket



**Figure 4: Prepare Bracket**

The bracket comes with two thumbscrews stored in threaded holes on the side of the bracket. Remove the two thumbscrews and set them aside for now.

The bracket also holds the plastic belt. The belt is wrapped twice around two semi-circular notches on the top and bottom edges of the bracket. Unwrap the belt from the notches and set it aside for now.

### Attach the Rotary Motion Sensor

Turn the Rotary Motion Sensor so the three-step pulley faces the Accessory Holder and the threaded holes in the end of the

sensor line up with the holes of the Mounting Bracket. Use the two thumbscrews to attach the Rotary Motion Sensor to the Mounting Bracket.

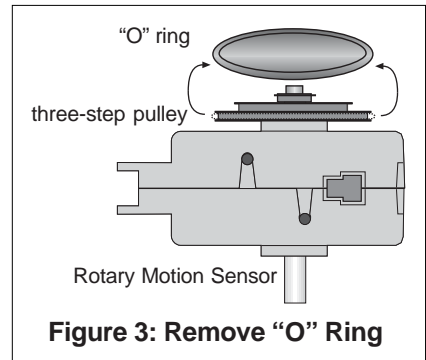
### Put on the Plastic Belt

Loop the bottom of the plastic belt around the three-step

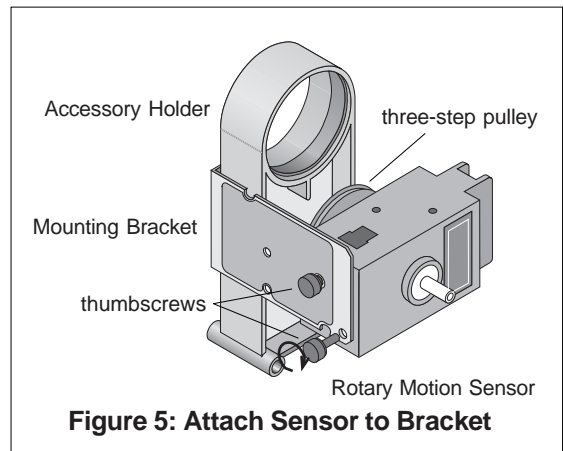
pulley of the Rotary Motion Sensor so the bottom of the belt is in the large-diameter groove of the step-pulley.

### Attach the Polarizer

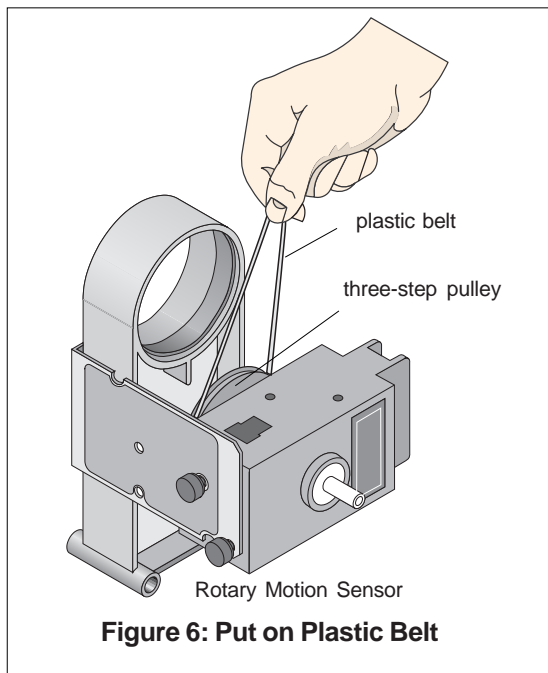
Get the Polarizer that has the groove on its front edge. Slip the top of the plastic belt into the groove on the front edge of the Polarizer. Snap the Polarizer into place on the Accessory Holder.



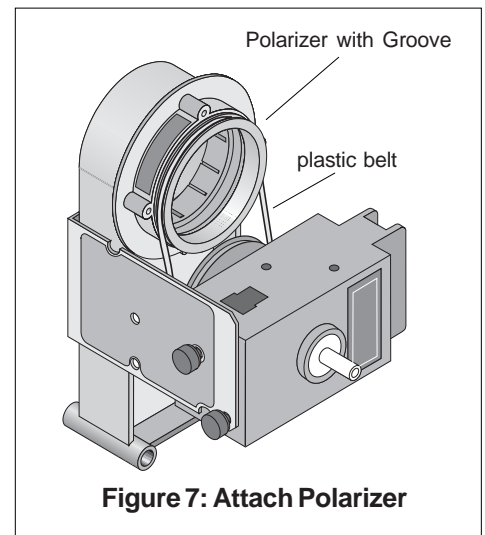
**Figure 3: Remove “O” Ring**



**Figure 5: Attach Sensor to Bracket**



**Figure 6: Put on Plastic Belt**

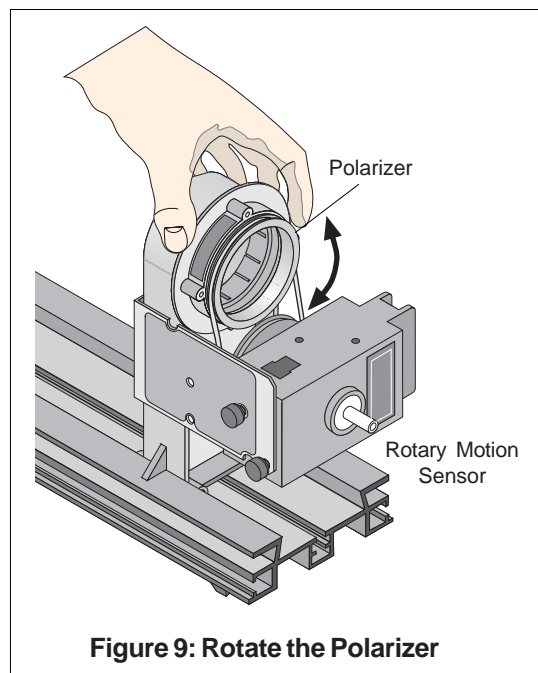


**Figure 7: Attach Polarizer**

## Using the Rotary Motion Sensor

### Mount the Accessory Holder on the Optics Bench

The Accessory Holder snaps into the Optics Bench. To move the Accessory Holder along the bench, grasp the base of the holder and squeeze the locking clip inward. Continue to squeeze inward on the locking clip as you move the holder to a new position. When you release the locking clip, the Accessory Holder is held firmly in place.

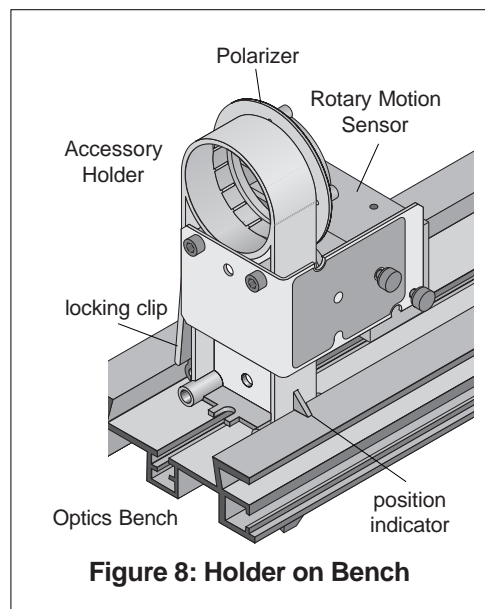


**Figure 9: Rotate the Polarizer**

### Rotate the Polarizer

Rotate the Polarizer by grasping the edge of the Polarizer. As you turn the Polarizer, the plastic belt will turn the three-step pulley on the Rotary Motion

Sensor by the same amount. When the Rotary Motion Sensor is connected to *ScienceWorkshop* or PASPORT interface, you can measure the angular position of the Polarizer to within one-quarter degree.



**Figure 8: Holder on Bench**

## Aperture Bracket

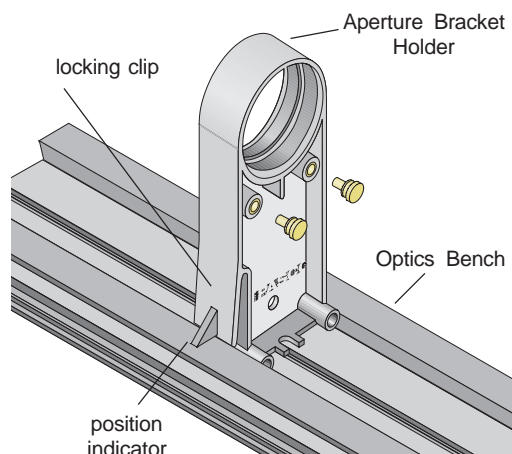
The Aperture Bracket has two main components: the Light Sensor Mount and the Aperture Bracket Holder.

### Light Sensor Mount

The Light Sensor Mount has an Aperture Bracket Screen, an Aperture Disk, a large thumbscrew, and a threaded post. You can use either the large thumbscrew or the threaded post to attach a Light Sensor to the Light Sensor Mount in one of two positions. Use the threaded post if you want to hold the Light Sensor Mount in a rod clamp. The large thumbscrew or the post is stored in the threaded storage hole on the Light Sensor Mount when not in use.

### Aperture Bracket Holder

Two metal thumbscrews attach the Aperture Bracket Holder to the back of the Light Sensor Mount. The Aperture Bracket Holder snaps into place anywhere along the center section of the Optics Bench that is part of the OS-8515 Basic Optics System. To move the holder along the bench, grasp the base of the holder and squeeze the locking clip inward. Continue to squeeze inward on the locking clip as you move the holder to the new position. When you release the locking clip, the holder is held firmly in place.



**Figure 10: Holder on Bench**



## Aperture Bracket Screen

The Aperture Bracket Screen is designed to help you align the Aperture Disk with a light source. Two small thumbscrews attach the Aperture Bracket Screen to the front of the Light Sensor Mount.

## Aperture Disk

The Aperture Disk has three circular apertures and six slit apertures (numbered one through six). The slit widths are as follows:

1 = 0.1 mm	2 = 0.2 mm
3 = 0.3 mm	4 = 0.5 mm
5 = 1.0 mm	6 = 1.5 mm

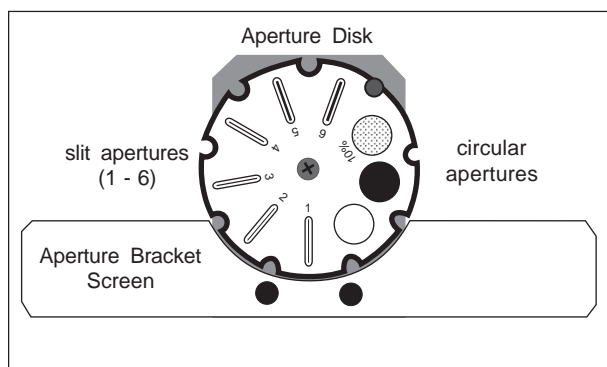


Figure 11: Aperture Disk

One circular aperture is 8 mm in diameter, the same dimension as the opening of the PASCO Model CI-6504A, CI-6604, or PS-2106 Light Sensor. A second circular aperture has the same diameter but has a grid pattern of small holes (0.25 mm diameter) that allows 10% transmission of light through the aperture. The third circular aperture is 2 mm in diameter, or one-fourth the diameter of the larger circular apertures, and translucent.

The Aperture Disk can be rotated to any of the nine positions to put one of the slits or circular apertures in line with a Light Sensor mounted behind the Aperture Disk.

## Using the Aperture Bracket

### Mounting a Light Sensor

You can use the Aperture Bracket to mount a Light Sensor on the Optics Bench. You can use the Light Sensor to measure the intensity of light through the Polarizers as you rotate one Polarizer relative to the other.

Use either the large thumbscrew or the post to mount a Light Sensor to the Light Sensor Mount. Position the Light Sensor on top of the Light Sensor Mount so the hole in the bottom of the sensor is in line with the *front* hole in the mount and the opening of the Light Sensor touches the vertical part of the Light Sensor Mount. Put the threaded end of the thumbscrew or post through the hole and turn the thumbscrew or post clockwise to tighten. See Figure 12 & 13.

Snap the Aperture Bracket Holder into the Optics Bench. Rotate the Aperture Disk so the open circular aperture is in line with the opening to the Light Sensor.

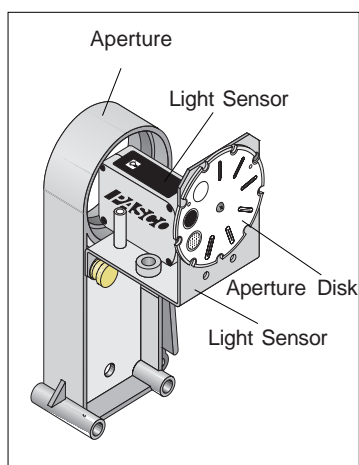


Figure 12: Mount the Light Sensor

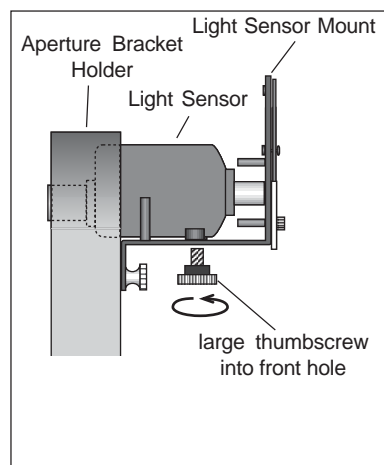


Figure 13: Light Sensor onto Mount

### Setup for Measuring Light Intensity

You can use the Basic Optics Bench, Basic Optics Light Source, Polarization Analyzer, Rotary Motion Sensor, Aperture Bracket, and a Light Sensor to measure the light intensity through the Polarizers as one Polarizer is rotated relative to the other.

#### Prepare the Polarizer

Put the second Polarizer in the empty Polarizer Mount that comes with the Polarization Analyzer.

#### Mount the Light Source

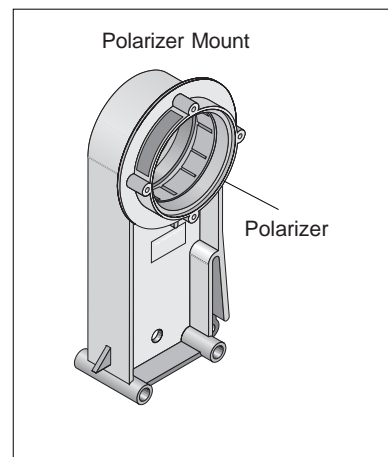
Put the Basic Optics Light Source at one end of the Basic Optics Bench. Refer to the OS-8515 instructions. Turn the Light Source so it produces a “point source” of light that is aimed toward the other end of the bench.

#### Mount the Polarization Analyzer

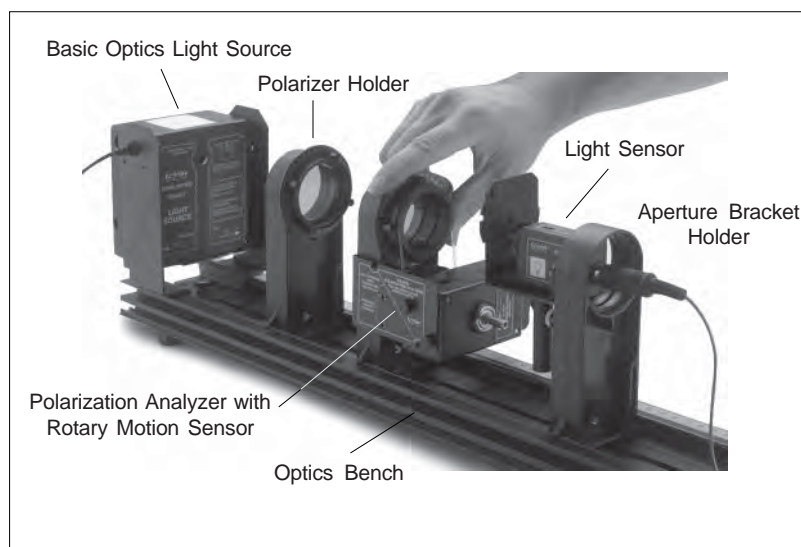
Snap the Polarizer Mount onto the Optics Bench. Snap the Polarization Analyzer with Rotary Motion Sensor onto the Optics Bench.

#### Mount the Light Sensor

Snap the Aperture Bracket Holder with the Light Sensor onto the Optics Bench with the Light Sensor opening toward the Light Source



**Figure 14: Prepare Polarizer**



**Figure 15: Setup for Measuring Light Intensity**



**Notes:**

# Verify Malus' Law of Polarization

## EQUIPMENT NEEDED

- Basic Optics Bench (part of OS-8515)
- Basic Optics Light Source (part of OS-8515)
- Polarization Analyzer with Aperture Bracket (OS-8533A)
- Light Sensor (CI-6504A or PS-2106)
- Rotary Motion Sensor (CI-6538 or PS-2120)

## Introduction

The purpose of this laboratory activity is to determine the relationship between the intensity of the transmitted light through two polarizers and the angle,  $\theta$ , of the axes of the two polarizers.

## Theory

A polarizer only allows light which is vibrating in a particular plane to pass through it. This plane forms the “axis” of polarization. Unpolarized light vibrates in all planes perpendicular to the direction of propagation. If unpolarized light is incident upon an “ideal” polarizer, only half will be transmitted through the polarizer. Since in reality no polarizer is “ideal”, less than half the light will be transmitted.

$$I = I_0 \cos^2 \phi$$

The transmitted light is polarized in one plane. If this polarized light is incident upon a second polarizer, the axis of which is oriented such that it is perpendicular to the plane of polarization of the incident light, no light will be transmitted through the second polarizer.

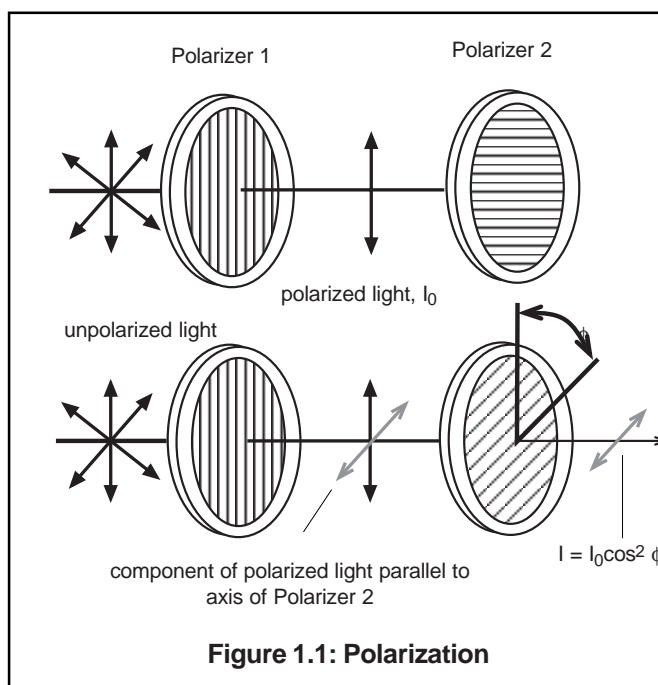
However, if the second polarizer is oriented at an angle so that it is not perpendicular to the first polarizer, there will be some component of the electric field of the polarized light that lies in the same direction as the axis of the second polarizer, thus some light will be transmitted through the second polarizer (see the bottom figure).

The component,  $E$ , of the polarized electric field,  $E_0$ , is found by:

$$E = E_0 \cos \phi$$

Since the intensity of the light varies as the square of the electric field, the light intensity transmitted through the second filter is given by:

where  $I_0$  is the intensity of the light passing through the first filter and  $\theta$  is the angle between the polarization axes of the two filters.



**Figure 1.1: Polarization**

Consider the two extreme cases illustrated by this equation:

- If  $\theta$  is zero, the second polarizer is aligned with the first polarizer, and the value of  $\cos^2 \theta$  is one. Thus the intensity transmitted by the second filter is equal to the light intensity that passes through the first filter. This case will allow maximum intensity to pass through.
- If  $\theta$  is  $90^\circ$ , the second polarizer is oriented perpendicular to the plane of polarization of the first filter, and the  $\cos^2(90^\circ)$  gives zero. Thus no light is transmitted through the second filter. This case will allow minimum intensity to pass through.
- These results assume that the only absorption of light is due to polarizer effects. In fact most polarizing films are not clear and thus there is also some absorption of light due to the coloring of the Polaroid filters.

## Procedure

In this activity, the Light Sensor measures the relative intensity of light that passes through two polarizers. You will change the angle of the second polarizer relative to the first. The Rotary Motion Sensor measures the angle.

The DataStudio records and displays the light intensity and the angle between the axes of the polarizers. You can use the program's built-in calculator to compare the relative intensity to the *angle*, the *cosine of the angle*, and the *cosine<sup>2</sup> of the angle*.

## Equipment Setup

1. Mount the Basic Optics Light Source, Polarizer Holder, Polarizer Analyzer with Rotary Motion Sensor, and Aperture Bracket Holder with Light Sensor as shown. (Refer to the Introduction for more information.)
2. Connect the Light Sensor and Rotary Motion Sensor to the computer through a *ScienceWorkshop* or *PASport* interface (or interfaces), and start DataStudio.

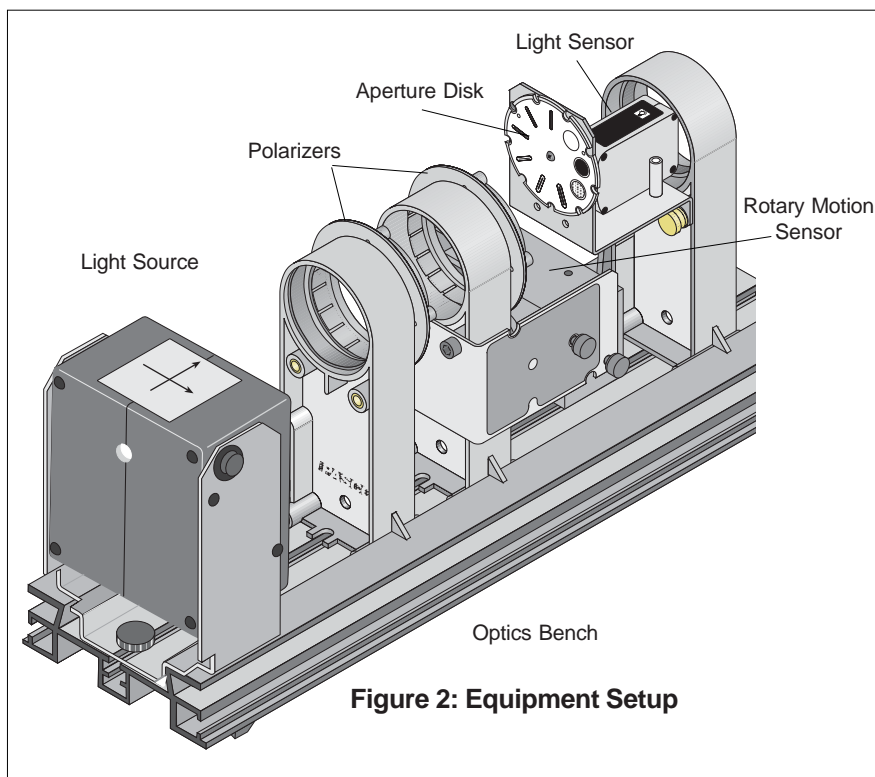


Figure 2: Equipment Setup

## Experiment Setup

### Select the Sensors and Set the Sample Rate

- Refer to DataStudio on-line help for detailed information on selecting sensors and changing the sample rate.
1. Set up the Rotary Motion Sensor for high resolution (for example, 1440 Divisions per Rotation). Select *Large Pulley (Groove)* for the linear calibration (if you are using a PASport Sensor, this step is unnecessary).
  2. Set the sample rate of both sensors to 20 Hz, or 20 measurements per second.

### Select the Display

- Refer to DataStudio on-line help for detailed information selecting and changing displays.
1. Select a Graph display.
  2. Set the axes of the Graph display so *light intensity* is on the *vertical* axis and *angular position* is on the *horizontal* axis.

### Prepare to Record Data

- Refer to DataStudio on-line help for detailed information on *monitoring* and *recording* data.
1. Turn both Polarizers so they are at the same beginning angle (e.g., zero degrees).
  2. Start *monitoring* data.
  3. Rotate one Polarizer back and forth until the transmitted light intensity is *maximum*.
  4. Stop monitoring data.

### Record Data

1. Start recording data.
2. Slowly rotate the Polarizer on the Polarization Analyzer in the clockwise direction. Continue to rotate the Polarizer until you have made one complete rotation (360 degrees).
3. After one complete rotation, stop recording data.

### Analyze the Data

- Refer to the on-line help for DataStudio detailed information on creating and displaying calculations and using DataStudio for data analysis.
1. Use the Experiment Calculator in DataStudio software to create a calculation of the *cosine* of the angle between the Polarizers.
  2. Repeat the procedure to create a calculation of the *cosine*<sup>2</sup> of the angle of the Polarizers.
  3. Use the Graph display to examine the plot of light intensity versus angle.
  4. Change the Graph display to show the plot of light intensity versus the cosine of the angle, and then change the Graph display to show the plot of light intensity versus the cosine<sup>2</sup> of the angle.
  5. Use Data Studio software to determine the relationship between the light intensity and the cosine<sup>2</sup> of the angle.

**Questions**

1. What is the shape of the plot of light intensity versus angle?
2. What is the shape of the plot of light intensity versus cosine of the angle?
3. What is the shape of the plot of light intensity versus  $\cos^2$  of the angle?
4. Theoretically, what percentage of incident plane polarized light would be transmitted through three Polarizers which have their axes rotated 17 degrees (0.29 radians) from each other? Assume ideal polarizers and assume that the second polarizer's axis is rotated 17 degrees (0.29 radians) from the first and that the third polarizer's axis is rotated 17 degrees (0.29 radians) from the second.
5. From your data, determine the answer to Question #4 for the real polarizers.