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

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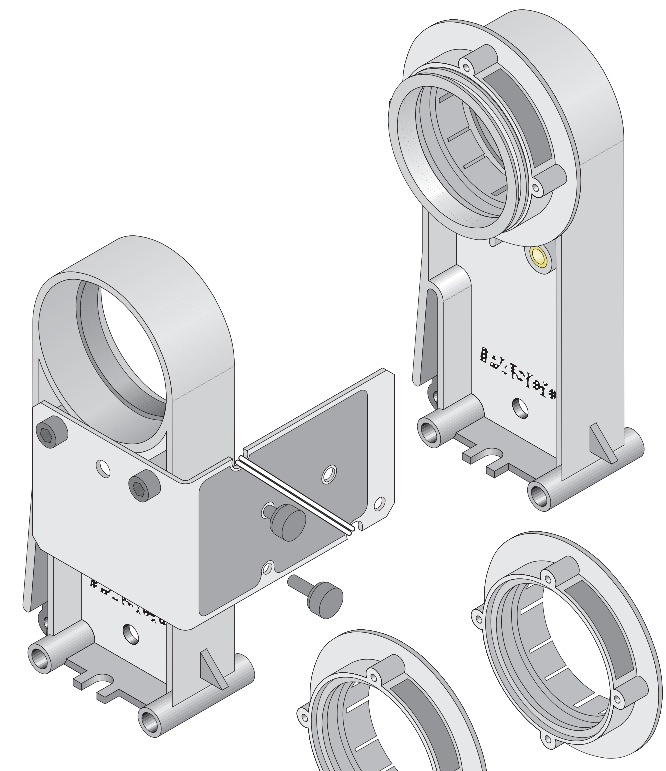
POLARIZATION ANALYZER



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This manual authored by: Dave Griffith

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③ Make certain that the packing material cannot shift in the box or become compressed, allowing the instrument come in contact with the packing carton.

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Introduction

The PASCO OS-8533 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 to explore polarization. When used with the PASCO CI-6538 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)
Aperture Bracket (OS-8534)	Rotary Motion Sensor (CI-6538)

Description

The Polarization Analyzer consists of a Polarizer Holder, an Accessory Holder with Mounting Bracket, two Polarizers, and a Retarder. 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.

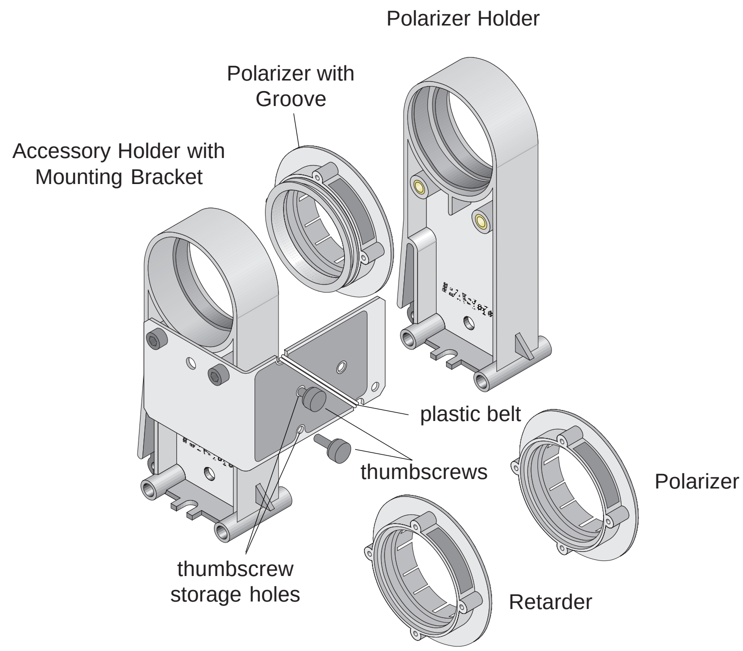


Figure 1: Polarization Analyzer Components

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 attached to one end. Use a Phillips head screwdriver to loosen the two screws that hold the rod clamp. Remove

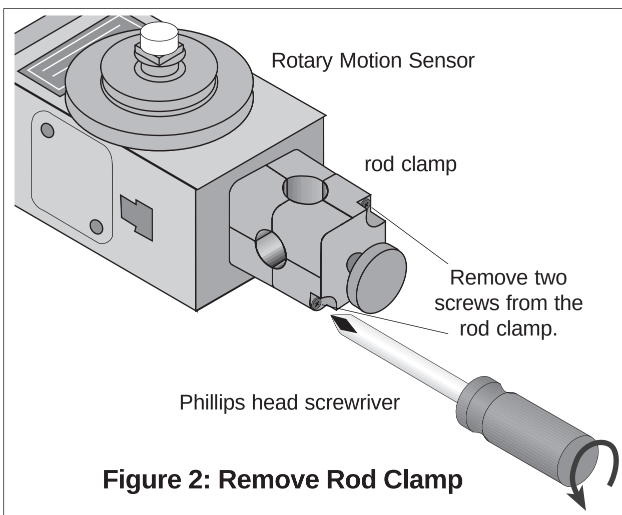


Figure 2: Remove Rod Clamp

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.

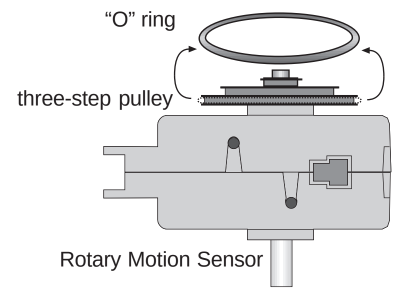


Figure 3: Remove "O" Ring

Prepare the Mounting 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.

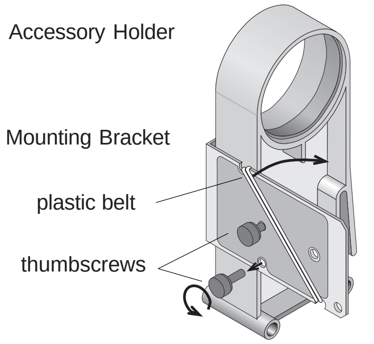


Figure 4: Prepare Bracket

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.

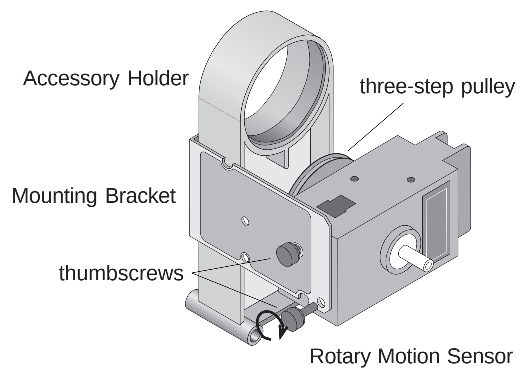


Figure 5: Attach Sensor to Bracket

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.

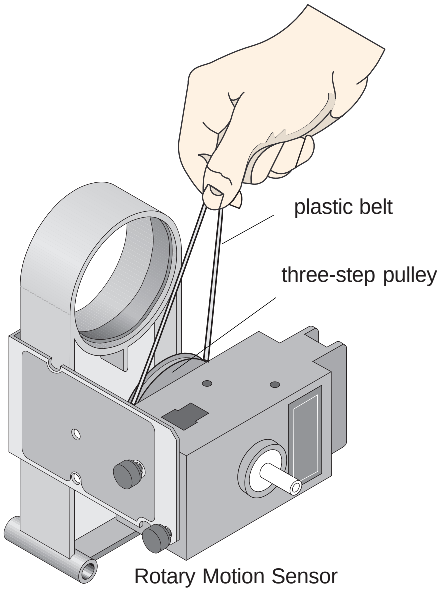


Figure 6: Put on Plastic Belt

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.

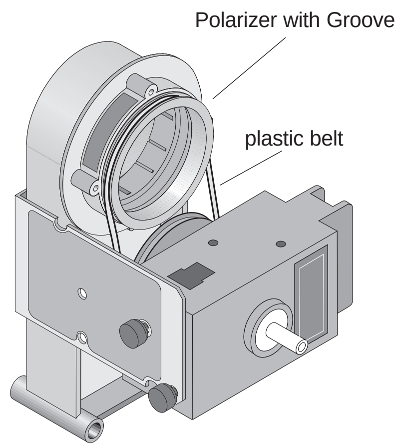


Figure 7: Attach Polarizer

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.

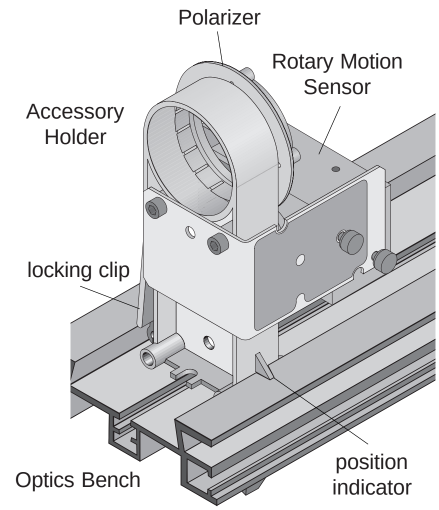


Figure 8: Holder on Bench

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 a *ScienceWorkshop* interface, you can measure the angular position of the Polarizer to within one-quarter degree.

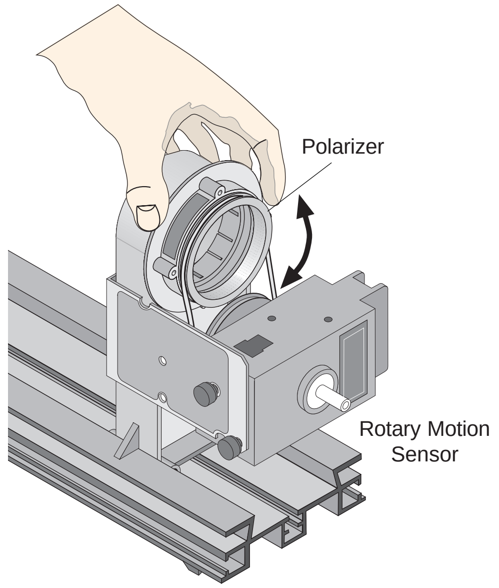


Figure 9: Rotate the Polarizer

Mounting a Light Sensor

You can use the OS-8534 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.

Attach the Light Sensor Mount to the Aperture Bracket Holder as shown in the instructions for the OS-8534 Aperture Bracket. Remove the Aperture Bracket Screen. Put the thumbscrew or the threaded post in the front hole of the Light Sensor Mount to attach the Light Sensor onto the Light Sensor Mount.

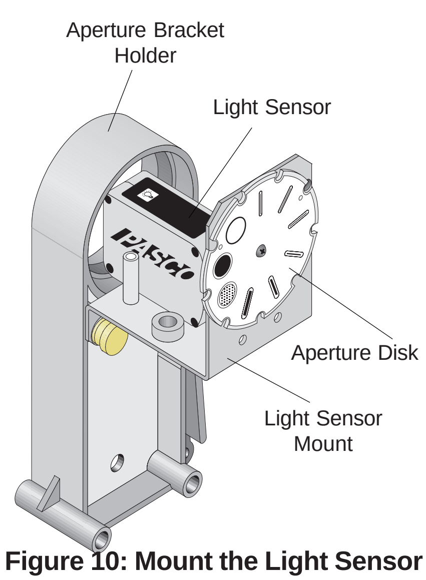


Figure 10: Mount the Light Sensor

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.

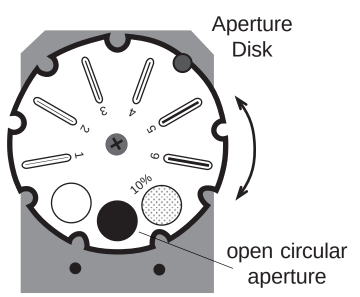


Figure 11: Rotate Aperture Disk

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.

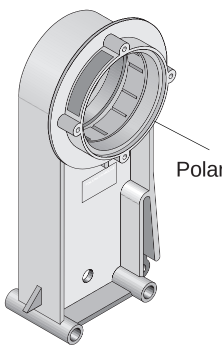


Figure 12: Prepare Polarizer

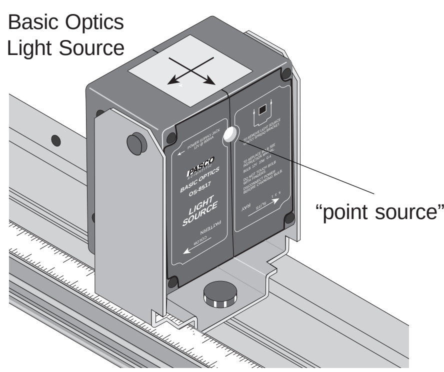


Figure 13: Light Source

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.

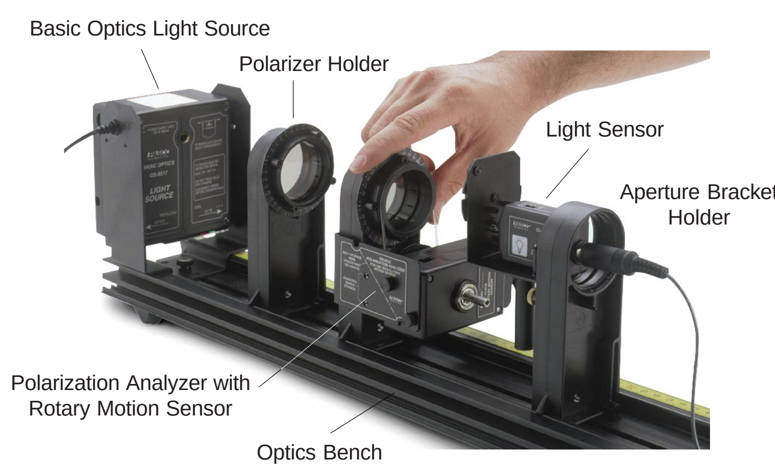


Figure 14: Setup for Measuring Light Intensity

Verify Malus' Law of Polarization

EQUIPMENT NEEDED

– Basic Optics Bench (part of OS-8515)
– Basic Optics Light Source (part of OS-8515)
– Aperture Bracket (OS-8534)
– Light Sensor (CI-6504A)
– Rotary Motion Sensor (CI-6538)

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, Ø, 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.

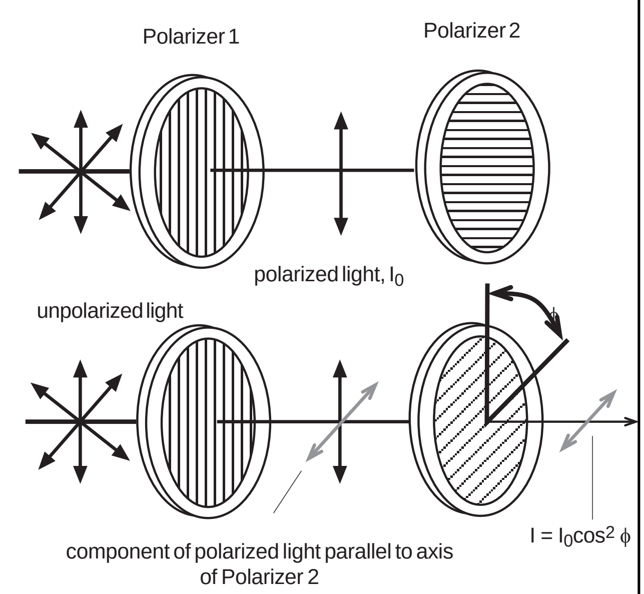


Figure 1.1: Polarization

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, $\boldsymbol{E}$, of the polarized electric field, $\boldsymbol{E_o}$, 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:

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

where $\boldsymbol{I_o}$ is the intensity of the light passing through the first filter and Ø is the angle between the polarization axes of the two filters.

Consider the two extreme cases illustrated by this equation:

- If **Ø** is zero, the second polarizer is aligned with the first polarizer, and the value of $\cos^2$**Ø** 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 **Ø** is 90º, the second polarizer is oriented perpendicular to the plane of polarization of the first filter, and the $\cos^2(90º)$ 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 *ScienceWorkshop* program 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*^{2} *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 *ScienceWorkshop* interface to the computer, turn on the interface. Start *Science Workshop*.
3. Connect the Light Sensor cable to Analog Channel A. Connect the Rotary Motion Sensor cable to Digital Channels 1 and 2.

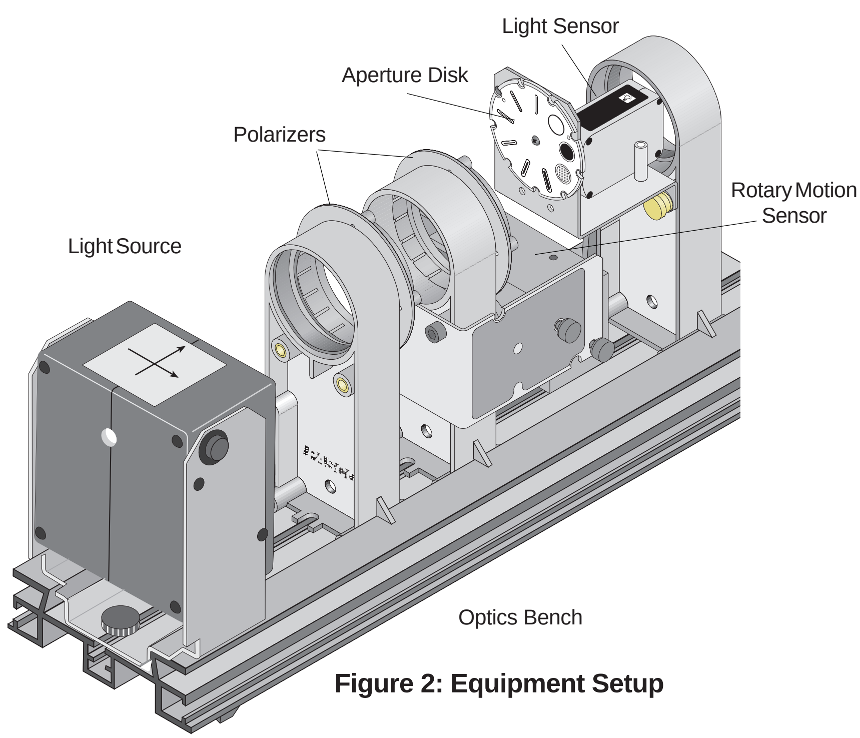


Figure 2: Equipment Setup

Experiment Setup

Select the Sensors and Set the Sample Rate

- Refer to the User's Guide for *your* version of *ScienceWorkshop* for detailed information on selecting sensors and changing the sample rate.

1. In the Experiment Setup window, select the Rotary Motion Sensor and connect it to Digital Channels 1 and 2.
2. Set up the Rotary Motion Sensor for high resolution (for example, 1440 Divisions per Rotation). Select *Large Pulley (Groove)* for the linear calibration.
3. In the Experiment Setup window, select the Light Sensor and connect it to Analog Channel A.
4. Set the sample rate to 20 Hz, or 20 measurements per second.

Select the Display

- Refer to the User's Guide for *your* version of *ScienceWorkshop* for detailed information on 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 the User's Guide for *your* version of *ScienceWorkshop* 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 User's Guide for *your* version of *ScienceWorkshop* for detailed information on creating and displaying calculations and using *ScienceWorkshop* for data analysis.

1. Use the Experiment Calculator in the *ScienceWorkshop* program to create a calculation of the *cosine* of the angle between the Polarizers.
2. Repeat the procedure to create a calculation of the *cosine*^{2} 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^2 of the angle.

5. Use the *ScienceWorkshop* program to determine the relationship between the light intensity and the $cosine^2$ 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 $cosine^2$ 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.

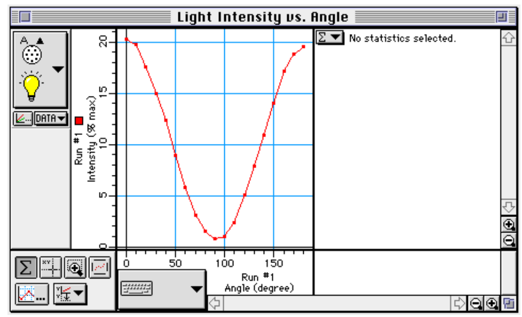
Teacher’s Guide

Data Analysis

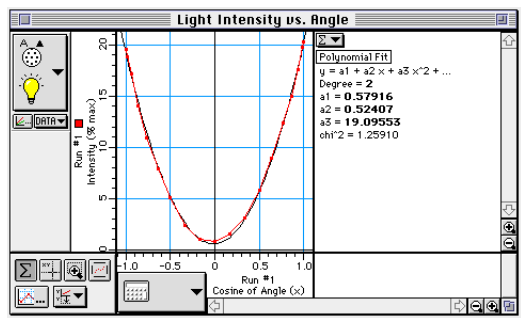
Sample Data

In the data analysis section, the curve fit for the polynomial function is <u>second</u> degree. This indicates that the light intensity varies as the square of the cosine of ϕ. This is confirmed by the curve fit for the linear function when light intensity is compared to the square of the cosine.

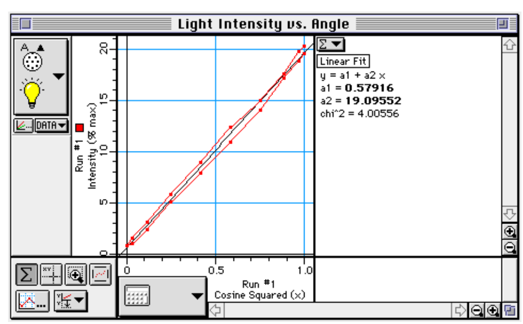
Answers to Questions



Sample Data: Light Intensity versus Angle



Sample Data: Light Intensity vs. Cosine Angle



Sample Data: Light Intensity vs. $Cosine^2$ Angle

1. What is the shape of the graph of the intensity versus the angle?

   Answers will vary. The shape of the graph of the intensity vs. the angle is approximately sinusoidal.

2. What is the shape of the graph of the intensity versus the cosine of the angle?

   The shape of the graph of the intensity vs. the cosine of the angle is a parabola.

3. What is the shape of the graph of the intensity versus the square of the cosine of the angle?

   The shape of the graph of the intensity vs. the square of the cosine of the angle is a straight line.

4. Theoretically, what percentage of incident plane polarized light would be transmitted through three polarizers which each have their axes rotated 17 degrees from each other? Assume ideal polarizers and assume that the first polarizer’s axis is 17 degrees from the axis of the second polarizer.

   Assuming ideal filters, the intensity passing through the first filter would be 50% of the initial intensity. The intensity after the second filter would be reduced by $\cos^2(17½) = 0.9145$ of the intensity passing through the first filter. Thus the intensity after passing through two filters would be 45.73%. The light passing through the third filter would be reduced by another 0.9145. So the three polarizers reduces the light intensity to $50\%*(0.9145)^2 = 41.82\%$.

5. From your graph, determine the answer to Question #4 for the real polarizers.

   Answers will vary. From the example, we see that the intensity at 17½ is 98%, so the final intensity should be $(.98)^2 = 96\%$ of the <u>intensity that passes through the first filter</u>. Using the sample data we see that only 33% passes through the first filter, thus the intensity of the light that passes through three filters is 96% of 33% or 31.68%.

Technical Support

Feedback

If you have any comments about the product or manual, please let us know. If you have any suggestions on alternate experiments or find a problem in the manual, please tell us. PASCO appreciates any customer feedback. Your input helps us evaluate and improve our product.

To Reach PASCO

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fax: (916) 786-3292

e-mail: techsupp@pasco.com

web: www.pasco.com

Contacting Technical Support

Before you call the PASCO Technical Support staff, it would be helpful to prepare the following information:

➤ If your problem is with the PASCO apparatus, note:

- Title and model number (usually listed on the label);
- Approximate age of apparatus;
- A detailed description of the problem/sequence of events (in case you can't call PASCO right away, you won't lose valuable data);
- If possible, have the apparatus within reach when calling to facilitate description of individual parts.

➤ If your problem relates to the instruction manual, note:

- Part number and revision (listed by month and year on the front cover);
- Have the manual at hand to discuss your questions.