

Polarized or Unpolarized

Purpose: An activity to explore the wave nature of light by testing the polarization properties of light sources including light bulbs, digital displays, lasers and others.

Student Info:

- 1) Designed for Physical Science (9/10) or Physics (11/12)
- 2) Prior Knowledge: Waves – Longitudinal vs. Transverse, EM Radiation, Electric & Magnetic Field Oscillation Perpendicular to Wave Propagation
- 3) Suggested Website(s)
<http://www.glenbrook.k12.il.us/GBSSCI/PHYS/CLASS/light/u1211e.html>

Teacher Info:

- 1) Prior Knowledge: EM wave description, vector components & LCD operation
- 2) Vocabulary: Propagation, Perpendicular, Vector, Component, Polarization
- 3) Suggested Website(s)
<http://www.polarization.com/sky/sky.html>

Time Required:

- 1) Setup \approx 20 min
- 2) Activity \approx 30 min
- 3) Data Analysis \approx 20 min
- 4) Discussion / Wrap Up \approx 10 min

Materials Needed:

- 1) Two 2" x 2" polarizers per group (1 per student if assigning as homework)
** Polaroid available in 10 piece kits from sciplus.com or elsewhere
- 2) Sunglasses – Polarized and Unpolarized
- 3) Light Sources - Fluorescent and Incandescent Bulbs, Flashlight, LEDs, ...
- 4) Television/CRT (Old Style Monitor) Screen and LCD (New Style Monitor)
- 5) Digital clocks, calculators, watch, stopwatches, cell phone, Ipod, ...
- 6) Lasers (Pointer Pen, Helium Neon, Green Astronomical, ...) – TEACHER ONLY!

*** Note: Sunglasses are Vertically Polarized (to eliminated Horizontal Glare) and can be used to determine the polarization direction for the plastic sheets ***

Procedure:

Part A: Understanding Properties of the Polarizers

- 1) Single Polarizer with Room Lights
Looking thru a polarizer, rotate it a full 360° and notice little variation in the brightness. This indicates that ordinary room lights are unpolarized as the random process which produces the unpolarized light has no preferred electric field direction.

- Note: The sky is slightly polarized, so some variation does occur.

2) Dual Polarizer with Room Lights

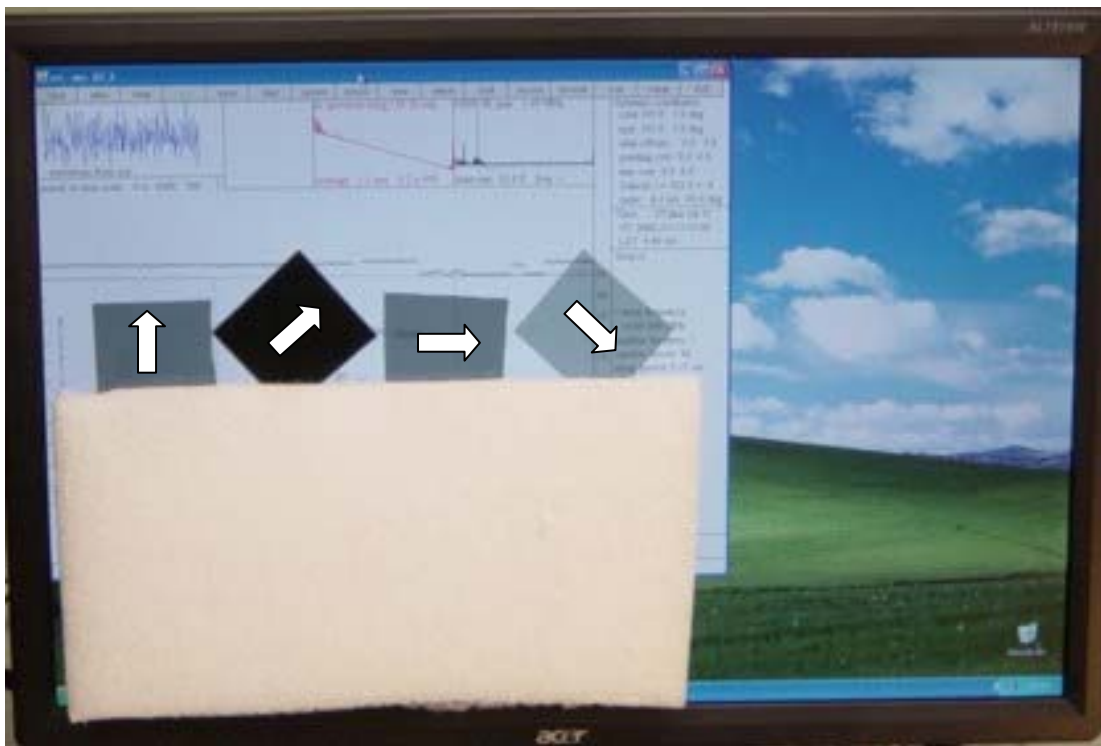
With the polarization direction aligned for two polarizers placed on top of each other, look through both to observe the room lights. The brightness should be dimmer than for the single polarizer (more absorption), but the light is still visible.

Now slowly rotate one polarizer relative to the second one until it is rotated 90° and the polarization directions are perpendicular (crossed). No (or very little) light should be seen in this combination of orientations.

Continue rotating the second polarizer until it has been rotated through a complete rotation of 360° . Describe your observations, including how many bright and dark locations are found while rotating the entire 360° .

Example – LCD Monitor:

The following is a picture of 4 polarizers placed in front of a LCD display with the polarization axis rotated by 45° for each slide from left to right. The second slide shows crossed polarization (darkest image at 45°) and the last slide shows the polarization directions aligned (brightest image at 90° to the darkest orientation).



Data Table:

Now that you are familiar with the way the polarizers behave, a single polarizer can be used to test the polarization characteristics of several different light sources including light bulbs, monitors, digital displays, lasers and others.

These sources can be categorized as polarized or unpolarized by using just a single polarizer by rotating it and observing any variations in the object being viewed. Use these following guidelines to complete the table below:

- A) If the view doesn't change (or only very little), then the light is unpolarized.
- B) If the view does change, note which direction the polarization arrow is pointing for the brightest view as this is the polarization direction. NOTE: Some sources are vertically or horizontally polarized while others can be oriented at 45° relative to their typical orientations. Examples of the results are shown at the end.

Source Type	Source	Unpolarized	Polarized		
			Horizontal	Vertical	45°
Light	Fluorescent Light				
	Light Bulb				
	Flashlight				
	LED				
Monitor	CRT Television				
	LCD Computer				
	Plasma TV				
Display	Microwave Oven				
	Coffee Maker				
	Calculator				
	Digital Watch				
	Car Odometer / Clock				
	Cell Phone				
	iPod				
Laser	Helium Neon (Gas)				
	Red Pointer Pen				
	Green Laser Pen				

Questions:

- 1) Were most sources unpolarized or polarized? Or equal amounts? EXPLAIN.

- 2) Which results did you expect? Which results surprised you? WHY?

- 3) Which displays wouldn't be visible (or dimmer) with polarized sunglasses? EXPLAIN.

- 4) Compare your results for the LED and the laser pointer pen? In what ways are these light sources similar / different?

- 5) Compare and contrast your results for the different displays? Do displays which use color (red, green, ...) tend to be unpolarized or polarized? EXPLAIN.

Conclusions:

- 1) Given your results, is polarization a wave-like or particle-like property of light?

- 2) Could this property of light be used to lighten / darken (heat / cool) a room or a building with windows made of polarized glass? Explain how this could be used?

** Note: EM waves actually transmit at 90° to the direction of the wire grid orientation, so the Mechanical Wave analogy is only a visual model to understand polarization.*

Mechanical Waves Analogy:

Additional Materials – Long (5-10 feet) Spring and Wooden Fence (~1 foot tall with 4 or more slots wide enough for spring to pass smoothly or grill grates with thin rope/cord)

- 1) Fix one end and pass through fence and vibrate in direction of slots. The rope will only pass if the vibration direction is aligned with slots of the fence.
- 2) Take a second fence and start with both aligned and rotate one fence until perpendicular to the first such that the wave doesn't pass through.

For more about this concept and to read a brief tutorial about polarization:

<http://www.olympusmicro.com/primer/lightandcolor/polarization.html>

Additional Notes on Polarization:

- Radio wave Transmitter and Receiver Antennas are oriented for the best matching of the polarization direction
- Atmospheric Effects of Polarization Rotation (Faraday Effect) are studied to understand in greater detail the properties of different atmospheric layers
- All CD Read/Write and DVD devices use polarized light properties
- Bees and octopi use polarization techniques for navigation and communication

Additional Activities:

- 1) Place two 6" x 6" (or larger) polarizers in a crossed orientation (90° between) on a overhead projector with space between to test different transparent items. Place clear protractor, ruler, ruffled transparent tape or other clear plastic items to show the birefringence due to stress in these objects. This effect can also be observed in rear windows of automobiles using polarized sunglasses.
- 2) The optical properties of Karo syrup and sugar (26g/100mL) solution can be studied for optical activity (polarization rotation) which is the optical analog to Faraday Rotation for EM waves such a radio waves in the atmosphere.
- 3) For Advanced Classes: Sketch Brightness vs. Angle (0° to 360°)
What kind of function has this behavior? (similar to $\cos\theta$, but actually $\sim \cos^2\theta$)
Is the brightness more sensitive to small rotations near a maximum (0° or 180°), a minimum (90° or 270°) or between (such as 45°)?

Follow-On Laboratory Experiment:

The radio wave VSRT version of Malus' Law allows students to quantitatively analyze the relationship between radio wave transmission and the angle between 2 polarizers. Graphing the data in EXCEL is completed as well as curve fitting using the $\cos^2(\theta)$ function.

Sample Results for Polarization Testing:

Source Type	Source	Unpolarized	Polarized		
			Horizontal	Vertical	45°
Light	Fluorescent Light	X			
	Light Bulb	X			
	Flashlight	X			
	LED *		X	X	X
Monitor	CRT Television	X			
	LCD Computer				X
	Plasma TV		X		
Display	Microwave Oven	X			
	Coffee Maker			X	
	Calculator		X		
	Digital Watch			X	
	Car Odometer / Clock				X
	Cell Phone	X			
	iPod			X	
Laser	Helium Neon (Gas)	X			
	Red Pointer Pen *		X	X	X
	Green Pointer Pen *		X	X	X

* Sources such as LEDs and Laser Pointer Pens have no standard orientation