Surprises with Light

JoAnne Dombrowski

Topic

Behavior of lightwaves

Time

45 minutes to 1 hour

Safety

Please click on the safety icon to view the safety precautions. Do not look directly into the light source. Be careful using electricity, especially around liquids. Do not touch the hot lightbulb, and be careful not to spill water on it, as the bulb may explode. Always exercise caution when using glass; the jars can break, and the corners and the edges of the picture frame glass are sharp.

Materials

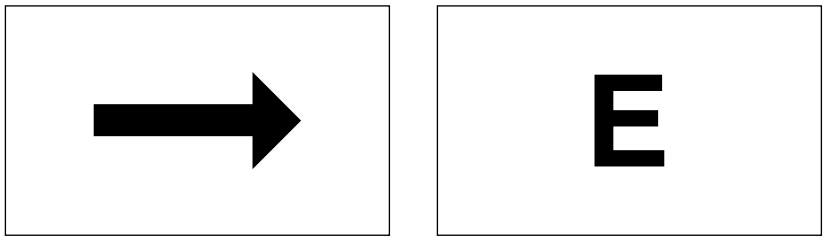
3 2 5 index cards
two plastic polarizing lenses (An old pair of polarized sunglasses will work.)
one small square of clear glass (from a picture frame)
one shoe box or other box (large enough to fit over your light source)
ruler
three identical glass jars, 1 qt or 1 L
three pencils
black marking pen
masking tape
bright light source (It needs to be able to fit under the shoe box.)
light corn syrup
scissors

Procedure

Part A

1. Take two index cards and draw a thick arrow on one and a thick letter E on the other with the black marker pen. Make sure both figures are centered (figure 1).
2. Set out three jars labeled 1, 2, and 3. Leave jar 1 empty (it is filled with air), fill jar 2 with water, and fill jar 3 with corn syrup. Put the jars on a table or counter, preferably at eye level and all at the same distance from you. Place a ruler alongside the jars for reference.

Figure 1



3. Hold the card with the arrow in front of you at the same distance as the far side of the jars. From this position, move the card away from you at 1-in. intervals, for a total of 5 in. Observe what, if anything, happens to the arrow, and record this on data table 1, in the first horizontal row labeled "Control."

DATA TABLE 1

	Jar No.	Observations					
		0 in.	1 in.	2 in.	3 in.	4 in.	5 in.
→	Control						
	1						
	2						
	3						
E	Control						
	1						
	2						
	3						

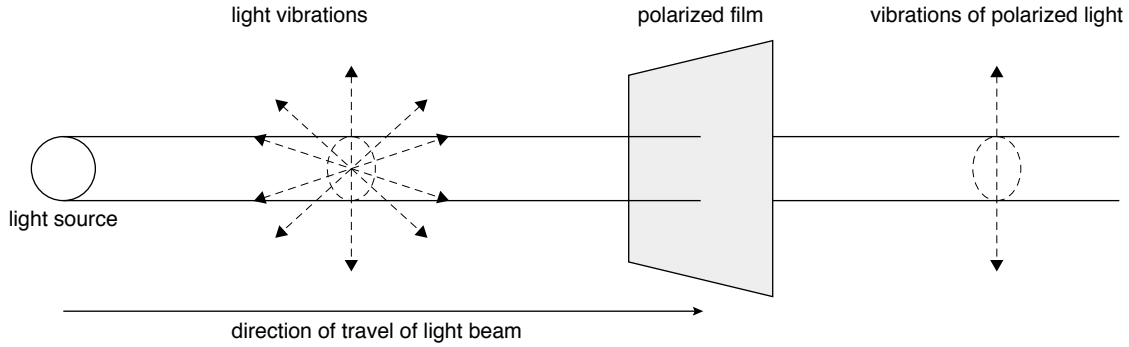
4. Hold the card with the arrow against the back of the jar filled with air (jar 1) so that you can see the arrow through the jar. Move the card away from the jar, 1 in. at a time, from 1 to 5 in. Observe what happens to the arrow at each point, and record your observations on data table 1.
5. Repeat step 4 for jars 2 and 3, and then repeat steps 3 and 4 with the other card (the letter E). Record all your observations on data table 1.

PART B

Lightwaves travel in straight lines, with the vibrations of the light taking place in every plane perpendicular to the direction of travel (figure 2). When light is sent through a sheet of polarizing film, the light becomes polarized. This means that the film will only allow through the passage of vibrations traveling in a single plane. The rest of the vibrations are blocked out by the polarizer. The light we see vibrates at all different *frequencies* and *wavelengths.* The color of a lightwave depends on its

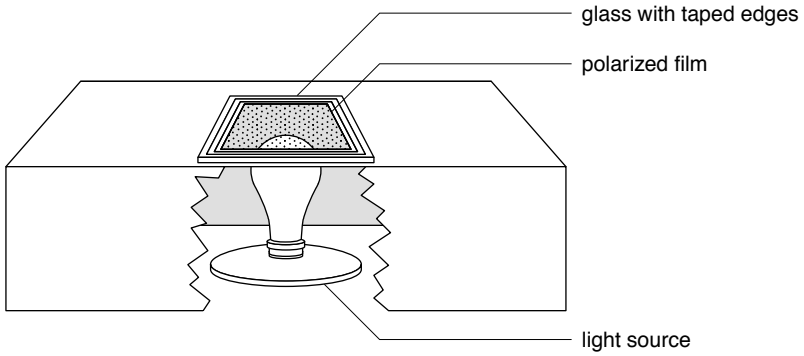
wavelength. Ordinary (unpolarized) "white" light is actually a combination of all the colors (wavelengths) seen at once. Passing light through certain kinds of materials can separate the light into the different wavelengths.

Figure 2



1. Carefully cut a hole in the top of the shoe box. Make the hole a little smaller than the polarized lens so that it can rest on top.
2. Place your light source underneath the hole so that the light shines up through it. Make sure you don't look directly into the light.
3. Being careful not to cut yourself on the sharp corners, tape the edges of the piece of glass so that light doesn't spill out the sides. Place the piece of glass over the hole in the box, and place one piece of polarized film over this (figure 3a). Turn on the light. Rotate the polarized lens slowly, one full turn clockwise, and observe what happens. Record your findings on data table 2. This is your control.

Figure 3a

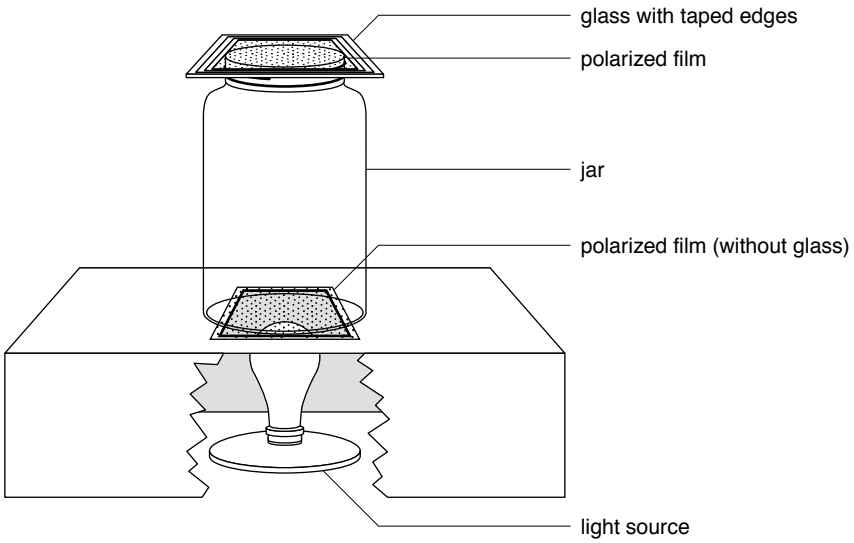


4. Hold the second piece of polarized film over the first. Rotate this slowly one full turn clockwise. Observe and record on data table 2.

DATA TABLE 2								
Substance	Appearance of light							
	Brightness	Red	Orange	Yellow	Green	Blue	Indigo	Violet
1 lens & glass (control)								
2 lenses & glass								
2 lenses glass & air								
2 lenses glass & water								
2 lenses glass & syrup								

5. Place jar 1 between the pieces of polarized film, with one piece beneath the jar and the other on top of the glass over the jar (figure 3b). Repeat step 4. Record all observations on data table 2.
6. Repeat steps 4 and 5 with jars 2 and 3.

Figure 3b



PART C

1. Empty enough liquid out of jars 2 and 3 so they are one-half full.
2. Put one pencil in each of the three jars.
3. As you observe each jar, hold the pencil upright and observe it from eye level and then from above and below. Record your observations on data table 3.
4. Repeat step 3, only this time let the pencil rest at an angle.

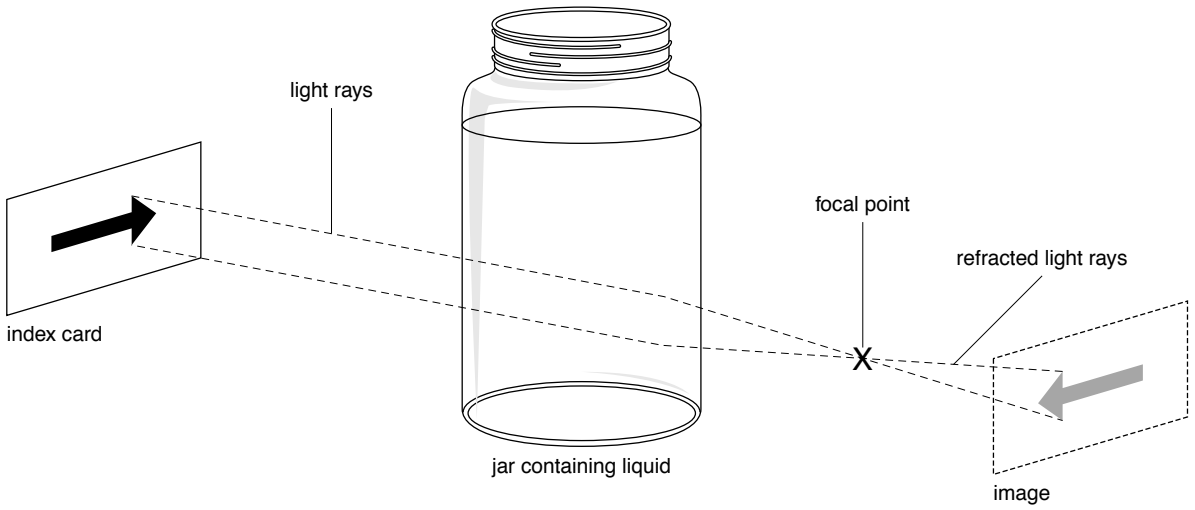
DATA TABLE 3		
Substance in jar	Appearance of pencil	
	Upright position	Angled position
air		
water		
syrup		

5. What phenomenon of light's interaction with matter allows us to see the index card?
6. What phenomenon of light's interaction with matter is responsible for the change you see when you view the index cards through the jar filled with water or corn syrup?
7. Describe what happened to the lightwaves coming from the index cards when they passed through the jars filled with water or corn syrup.
8. In Part B, how do you know that the light separated into waves with different wavelengths?
9. What were your results in Part B? Why do you think this happened?
10. What happened to the pencils? Why do you think this happened?

What's Going On

The answer to the question in step 5 is *reflection* and number 6 is *refraction.* The jars containing corn syrup and water reversed the images as they were moved further away from the jars. This is because the light reflected from the image is refracted (bent) by the liquid medium, and the lightwaves coming from the top of the image on the card come out of the jar at the bottom. Likewise the waves coming from the bottom of the image are refracted by the liquid medium and come out on top (figure 4). The bottle with no water distorts the image, but the combination of air and glass does not provide enough refraction to flip the image.

Figure 4



Different colors, resulting from different wavelengths, appear. In the jars containing air and water, you saw what happens when light is polarized. The first piece of film polarizes the light (admits only waves moving in one plane perpendicular to the direction in which the light travels). The second piece of film has the same property of polarizing the light, so when it is rotated to a 90-degree angle to the first film, no light can pass through it. The corn syrup takes the polarized light and scatters it, sending light of a similar color (same wavelength) in the same direction, separating the different colors. Since each wavelength (color) is vibrating in its own direction, the polarized film on top will only transmit the color that is traveling in the plane it is allowing to pass through. This is why you see the different colors. The pencils appear bent or broken when seen at an angle, and the part of the pencil in the liquid seems larger when the pencil is upright. Again the effect seen with air in the bottle is not as dramatic as the others. What you are seeing is the refraction caused by the liquid contained in the bottle as it acts upon the lightwaves entering the jar and reflecting off the pencil.

Connections

Light travels in straight lines in the form of waves (or under certain circumstances as particles, called *photons*). Most of the objects we see are visible because they reflect light. This means that when light shines on an object, it bounces off the surface as a ball bounces off a wall. When light encounters transparent matter, it is transmitted through it, but the matter slows down the speed at which light travels. This causes a change, or bending, in the direction of the light. This phenomenon is called *refraction.* In this experiment, you investigated what happens when light is transmitted through different types of transparent substances.

Safety Precautions

READ AND COPY BEFORE STARTING ANY EXPERIMENT

Experimental science can be dangerous. Events can happen very quickly while you are performing an experiment. Things can spill, break, even catch fire. Basic safety procedures help prevent serious accidents. Be sure to follow additional safety precautions and adult supervision requirements for each experiment. If you are working in a lab or in the field, do not work alone.

This book assumes that you will read the safety precautions that follow, as well as those at the start of each experiment you perform, and that you will *remember* them. These precautions will not always be repeated in the instructions for the procedures. It is up to you to use good judgment and pay attention when performing potentially dangerous procedures. Just because the book does not always say "be careful with hot liquids" or "don't cut yourself with the knife" does not mean that you should be careless when simmering water or stripping an electrical wire. It *does* mean that when you see a special note to be careful, it is extremely important that you pay attention to it. If you ever have a question about whether a procedure or material is dangerous, stop to find out for sure that it is safe before continuing the experiment. To avoid accidents, always pay close attention to your work, take your time, and practice the general safety procedures listed below.

PREPARE

- Clear all surfaces before beginning work.
- Read through the whole experiment before you start.
- Identify hazardous procedures and anticipate dangers.

PROTECT YOURSELF

- Follow all directions step by step; do only one procedure at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure that there is adequate ventilation.
- Do not horseplay.
- Wear an apron and goggles.
- Do not wear contact lenses, open shoes, and loose clothing; do not wear your hair loose.
- Keep floor and work space neat, clean, and dry.
- Clean up spills immediately.
- Never eat, drink, or smoke in the laboratory or near the work space.
- Do not taste any substances tested unless expressly permitted to do so by a science teacher in charge.

USE EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives and other sharp or pointed instruments with caution; always cut away from yourself and others.
- Pull plugs, not cords, when inserting and removing electrical plugs.
- Don't use your mouth to pipette; use a suction bulb.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Clean up broken glassware immediately.

- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use only low-voltage and low-current materials.
- Be careful when using stepstools, chairs, and ladders.

USING CHEMICALS

- Never taste or inhale chemicals.
- Label all bottles and apparatus containing chemicals.
- Read all labels carefully.
- Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING INSTRUCTIONS

- Use goggles, apron, and gloves when boiling liquids.
- Keep your face away from test tubes and beakers.
- Never leave heating apparatus unattended.
- Use safety tongs and heat-resistant mittens.
- Turn off hot plates, bunsen burners, and gas when you are done.
- Keep flammable substances away from heat.
- Have a fire extinguisher on hand.

WORKING WITH MICROORGANISMS

- Assume that all microorganisms are infectious; handle them with care.
- Sterilize all equipment being used to handle microorganisms.

GOING ON FIELD TRIPS

- Do not go on a field trip by yourself.
- Tell a responsible adult where you are going, and maintain that route.
- Know the area and its potential hazards, such as poisonous plants, deep water, and rapids.
- Dress for terrain and weather conditions (prepare for exposure to sun as well as to cold).
- Bring along a first-aid kit.
- Do not drink water or eat plants found in the wild.
- Use the buddy system; do not experiment outdoors alone.

FINISHING UP

- Thoroughly clean your work area and glassware.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Don't dispose of materials in the sink unless instructed to do so.
- Wash your hands thoroughly.
- Clean up all residue, and containerize it for proper disposal.
- Dispose of all chemicals according to local, state, and federal laws.

BE SAFETY-CONSCIOUS AT ALL TIMES