January 2017

Dumpster Optics

POLARIZED LIGHT ART

WHAT IS POLARIZED LIGHT? HOW DO POLARIZED SUNGLASSES WORK? CAN YOU USE POLARIZED LIGHT TO MAKE COLORFUL ART OUT OF TRANSPARENT MATERIAL?
This STEAM lesson includes both science and art activities.

MATERIALS

Activity 1 – Bright and Dark

- A polarizing filter (polarizer). This can be the lens of polarized sunglasses or a piece of polarizing film (available from science supply houses),
- An LCD screen such as a laptop monitor or television screen

Activity 2 – Where Else is Polarized Light?

- Polarizer
- Small bowl of water

Activity 3 – Make a Prediction

- Two polarizers (done with a partner)

Activity 4 – Colors from Polarization

- Polarizer
- Piece of cellophane tape (like Scotch® brand tape) or food wrapper. Cellophane is a thin wood-based transparent film often used for food packaging or wrapping gift baskets. Some types of clear plastic will also work for this experiment – try them first.

Activity 5 – Polarized Light Art

- Polarizer
- Cellophane tape
- Square of transparency film or other thin plastic to protect the monitor and polarizer from adhesive damage. You can tape directly to the film or, if you use cellophane/plastic that isn't adhesive, use a small amount of glue stick.

Where to find materials:
Polarized sunglasses can sometimes be found in a dollar store. Carefully remove the lenses and you have two polarizers to work with. Sometimes sunglasses are labeled polarized when they are not. To check, take two pair of sunglasses and rotate the lens of one in front of a lens of the other. The light coming through the pair of lenses should dim as you rotate. Some Amazon.com sellers advertise polarized sunglasses for a few dollars. Be sure to read the comments to see if they are really polarized; if they aren't people usually note it.

The online merchant at http://www.polarization.com has inexpensive sheet (thin plastic) polarizer as well as a thicker laminated version but there is a minimum order size (one foot). It can easily be cut with scissors to provide a classroom's worth of polarizers. Finally, some 3D theaters will donate used cardboard glasses, which have polarizing plastic for the "lenses". Be sure they use linear polarizers, not circular polarizers. (Sunglasses will be linear polarizers).

VOCABULARY:

- Wave
- Vibration
- Polarized light
- Polarizer
- Liquid Crystal Display (LCD)
- Cellophane

TEACHER NOTES:

The lesson begins by observing polarization before explaining it. Three videos of the lesson's activities are available at http://bit.ly/1ZMQ0rg, including one showing the construction of a "magic polarizing box":

- Exploring Polarization
- Polarized Light Art
- The Magic Box

ACTIVITY 1 – BRIGHT AND DARK

Light from an LCD screen is polarized. I had good results using a laptop screen as well as an LCD TV. Other types of screens (tablets, calculators, etc.) may work as well- experiment!

The light from the laptop display should alternately dim and brighten twice as the polarizer is rotated in front of it through one complete turn (360°).

ACTIVITY 2 – WHAT ELSE MAKES POLARIZED LIGHT?

The reflection of room lights from the water surface should alternately dim and then brighten as the polarizer is rotated. In a complete 360° rotation it should dim twice. The effect is more pronounced at certain angles so if it is hard to see, try looking at a closer or more distant reflection. The geometry shown in the diagram is about right for a reflection from water or glass.

The reflection from glass windows, a waxed floor or a whiteboard is also partly polarized and should show some dimming and brightening as the polarizer is rotated. If it's a sunny day, go outside and look at the blue sky, again rotating the polarizer. Look at the sky in different directions. DO NOT LOOK AT THE SUN! The blue sky is polarized in different directions at different times of the day. Bees can sense this polarization and use it to navigate! (There is much more about animal vision and polarized light at http://www.polarization.com.)

WHAT IS POLARIZED LIGHT?

Like all analogies, this one is not an exact description of how light behaves. But it helps explain the concept of waves that vibrate in only one direction. You can make rope waves as an additional activity. I once saw this demonstrated with a rope tied to a reciprocating saw (or an electric knife- anything that vibrates quickly up and down). The rope was passed through the wires of an oven rack to illustrate polarization. A classroom exercise with a piece of picket fence is described and illustrated at http://galileo.phys.virginia.edu/outreach/8thGradeSOL/PolarizedLight.htm

Application: Although sunlight is not polarized, reflections of the sun from snow or water are polarized, that is, the light waves vibrate in only one direction. The polarizing filters (lenses) in sunglasses block the reflected light. The glare from sunlight reflected from a lake is polarized horizontally (waves parallel to the water surface). The polarizers in the glasses must be in the vertical direction to block horizontal waves – or they won't work.

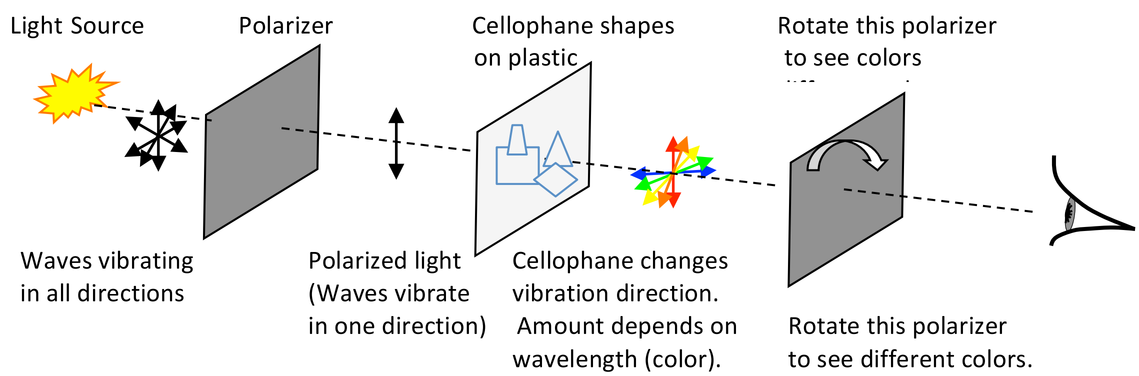
ACTIVITY 3 – MAKE A PREDICTION!

When the polarizers are aligned in the same direction (more precisely, their *transmission axes are aligned*), light passes through. When they are perpendicular, no light passes through. In the analogy that is like having two picket fences; with the pickets in the same direction (parallel) waves pass through but when the pickets are at 90° (perpendicular) the waves are stopped.

Because polarizers can either transmit or block polarized light, they can be used as "light switches". In this case, the polarizers are made of crystals that can be turned off and on very quickly by an electrical signal.

ACTIVITY 4 – COLORS FROM POLARIZATION!

The colors come from the interaction of polarized light with the cellophane. The LCD screen produces polarized light, that is, light waves vibrating in one direction. The direction of the light wave's vibration is changed (rotated) by the cellophane, and the amount of rotation depends on the wavelength (color). Thus, different colors are seen as the top polarizer rotates and allows them to pass.



Making colors using two polarizers and cellophane (described below)

What is labeled "cellophane" in many stores is plastic film that may not work well in this experiment. (True cellophane is made from cellulose.) Some of the best colors come from clear packing tape, the clear wrappers of supermarket vegetables, and the clear sleeves florists use for floral stems. Even though the directions specify cellophane, some plastics will work as well. Tape is easy to use but hard to cut into shapes. If you use cellophane or plastic (tested to make sure it produces colors), use a bit of glue stick to hold it to the transparency film. Rubber cement works even better but is not considered appropriate for children in some places. They should be closely supervised.

Instead of an LCD screen, this activity can also be done with two polarizers. The "sandwich" is polarizer, cellophane, polarizer. Some back light is needed so hold the "sandwich" up to a light or window and look into the top polarizer through all the three layers. Rotate the top polarizer to change colors.

Real (expensive!) art is produced by this technique. Austine Wood Comarow creates Polarized Light Art, (she calls it Polage® art, a term coined *from polarized light collage*). Her work sells for thousands of dollars, and some pieces are wall-sized collages on display in museums. See http://www.austine.com for videos and examples of her work.

Application: This property of materials, called *birefringence,* is used in microscopy, for studying crystal formations, and in medical diagnostics.

OPTIONAL ACTIVITY – ARE YOU STRESSED?

When plastic or glass is mechanically stressed (a force is applied) it becomes birefringent. In some cases, it returns to its normal state when the stress is released. If the stress is applied when the piece is heated during manufacture, it can remain "frozen in" when the piece cools.

This technique can be used to see if there is any stress remaining when glass is manufactured especially for precision uses like gas laser tubes. Residual stress in glass can result in it shattering when tapped or bumped.

You can see stress birefringence in transparent plastics like protractors or clear plastic flatware, also eyeglass lenses. Put the piece to be examined between two polarizers and rotate the top one to look for color lines or areas.