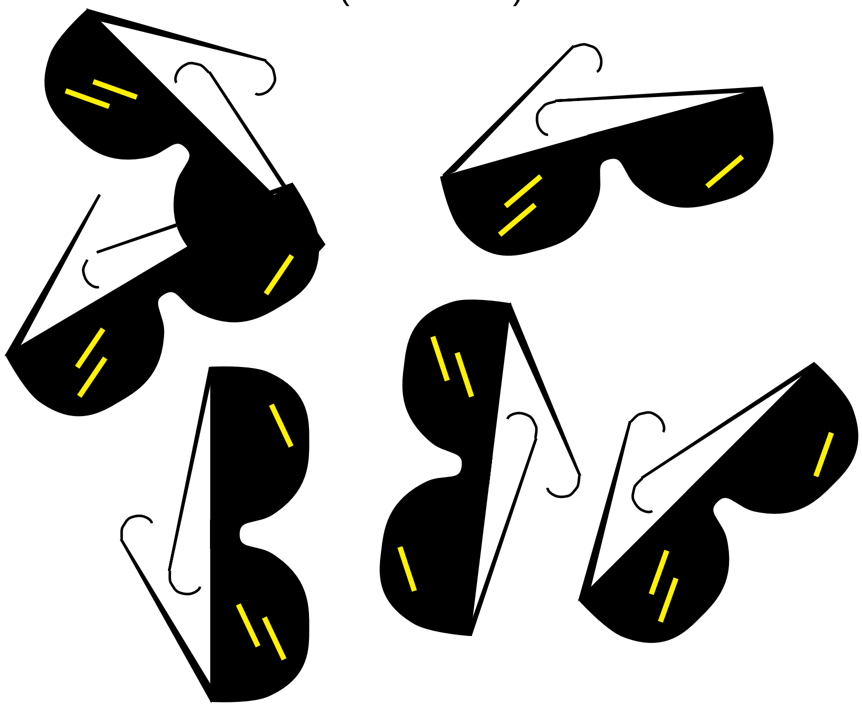
Puzzling Polarizers

(Grades 4-12)



Question: What do the Vikings, honeybees, and you have in common?

Answer: The Vikings are said to have used the polarization of the sky and special "sun stones" to navigate. Honeybees do a "waggle dance," oriented to the polarized light of the sky, to communicate the location of a food source to other bees in the hive. You benefit from many technological applications of polarized light and polarizing filters; one example is the liquid-crystal displays (LCDs) on digital watches and calculators.

When we apply the scientific method to real-world problems, often we can invent applications for the effects we observe even without understanding the origins of those effects. This process is commonly used in the development of new technologies; one example is the discovery of x rays. This curriculum unit is designed to encourage this investigative process through inquiry-based learning involving exploring, observing, and then applying the information gained. Light and its interactions with matter form the main focus for this activity, because light is the chief product of the Advanced Light Source (ALS). One property of light (polarization) is highlighted as a tool for exploration. This activity can be used in lessons on the scientific method, how advances in technology occur, the properties of light, how we observe things, or other related topics.

The Advanced Light Source is a national user facility funded by the Department of Energy and located at Lawrence Berkeley National Laboratory, University of California. Scientists from around the world use the ALS to do a variety of scientific experiments that take advantage of the unique qualities of the light it produces.

This curriculum unit is part of a presentation package created for a teacher workshop given by the Advanced Light Source in March 1996. Other materials available include:

- Moving Electrons - a hands-on activity unit
- "Inside the ALS" poster - a resource for teachers and students with a handout on suggestions for using it in the classroom
- "The Electromagnetic Spectrum" poster - a great classroom resource for exploring the range of electromagnetic radiation from radio waves to gamma rays
- Top Ten Questions People Ask about the ALS (a fun trivia sheet of cool facts)
- Mass, Energy, The Speed of Light—It's Not Intuitive!
- A Day in the Life of an ALS Electron - a lighter look at what an electron does at the ALS

For copies of "Inside the ALS" and "The Electromagnetic Spectrum" posters , contact the ALS User Office [(510) 486-7745]. All other curriculum materials are available on the web at: http://www.lbl.gov/MicroWorlds/

For more information about the ALS, contact Elizabeth Moxon [(510) 486-5760 or ejmoxon@lbl.gov].

Comments Welcome!

We welcome your criticisms, suggestions, helpful hints, and any other information that will help us improve these curriculum ideas. Please send your comments to:
Elizabeth Moxon, Berkeley Lab, MS 4-230, Berkeley, CA 94720
Tel: (510) 486-5760, Email: ejmoxon@lbl.gov.

Developers

These curriculum materials were developed by the Advanced Light Source and Kirsten Daehler, a science educator, in cooperation with local teachers.

About...

Those Polarizers on Your Face

What you need

A collection of sunglasses, including at least one pair with polarizing lenses.

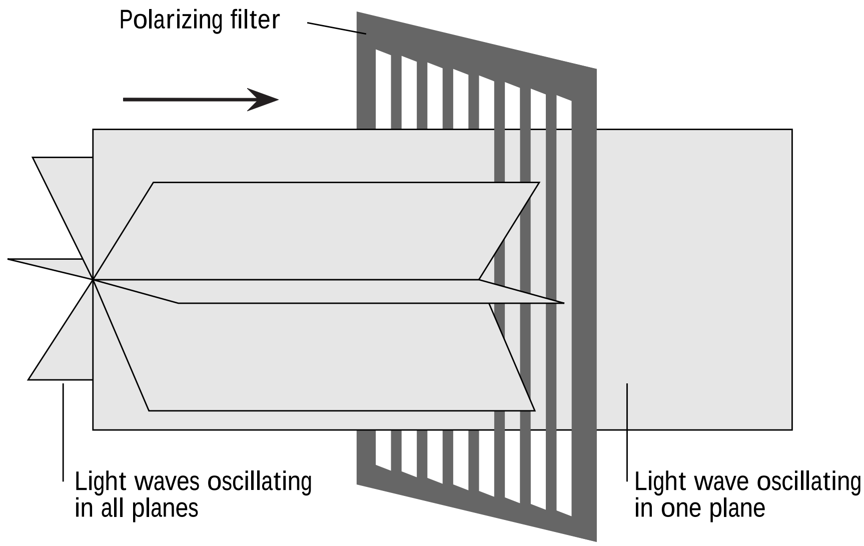
Try it and see

Compare a variety of sunglasses and find out which sunglasses reduce the glare of light reflecting off surfaces. Can you figure out which sunglasses contain polarizing lenses? Look through the sunglasses at a surface reflecting glare and see what happens when you rotate the glasses around. Try to find to find glare reflecting off a horizontal surface such as a table top, water, or a shiny floor, as well as glare from a vertical surface, such as a white board, windows, or other shiny, flat surfaces. How do the sunglasses (or polarizing filters) have to be oriented to reduce the glare from a horizontal surface? From a vertical surface? Why does it make sense for the polarizing lenses in sunglasses to be oriented to reduce the glare from horizontal surfaces?

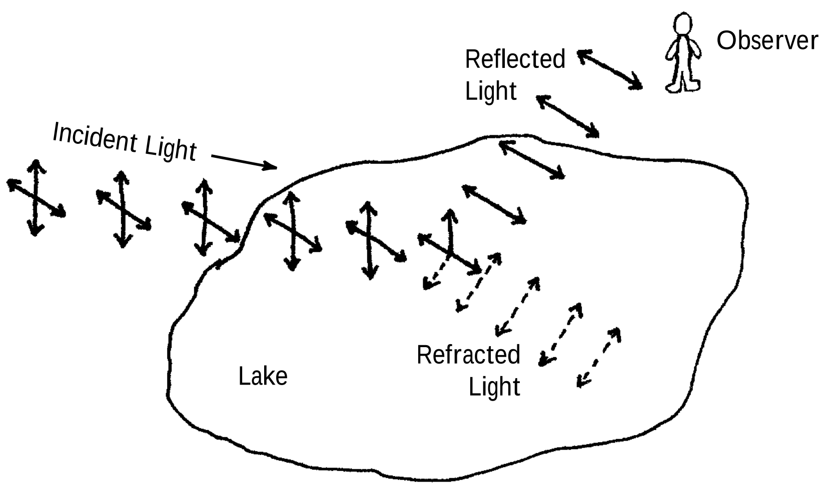
What is going on?

Most light, including that from the sun, from incandescent light bulbs, and from candles, is not polarized. This means that the electrons that wiggle to produce the electromagnetic waves (light) are oscillating in many different planes. To make the light, some electrons might have been vibrating up and down, while others were vibrating from side to side or at any different angle diagonally. Polarized light is produced by electrons that are all vibrating or accelerating in the same plane. Imagine having two people hold the ends of a rope, while one shakes her end from side to side. The wave this would produce in the rope would be horizontally polarized, like the light generated by electrons all wiggling from side to side. If the rope were shaken up and down instead, the resulting wave would be vertically polarized.

Polarized light can be produced from some light sources, such as the Advanced Light Source, but it is more commonly obtained using a polarizing filter (also called a polarizer). Polarizers only transmit light that is oscillating in one plane, called the axis of polarization, while absorbing all other light. If you align two polarizers so their axes of polarization are at right angles to each other, they will not transmit any light. Polarizing filters are made by uniformly aligning tiny crystals or large polymer molecules that preferentially absorb light oscillating in certain planes.



Light reflected from water, glass, and most other nonmetallic surfaces is polarized. These materials reflect light waves that are vibrating mostly parallel to the material's surface, while absorbing or refracting light vibrating in other planes.



Make your best guess

If you were driving a car on a bright day, which of the following pairs of sunglasses would you choose to wear? Why? (The lines indicate the axes of polarization.)

Suppose you want to look through a window to see the people inside. Even though you are wearing polarizing sunglasses, you may still see glare from the window. Why is this? What could you do to eliminate the glare?

Going further

Your medical insurance may pay the extra money for a pair of polarizing sunglasses is they are important to your job. In what kinds of jobs might it be more important to wear polarizing sunglasses, and why?

Photographers can use special polarizing filters over a regular camera lens to improve the quality of photographs. How would this affect the photograph? In what photography situations would a polarizing filter be most useful?

Investigating Materials With Polarized Light

What you need

(It is not necessary to have all of the following items. Rather, it is important to provide a variety of different things for comparison.)

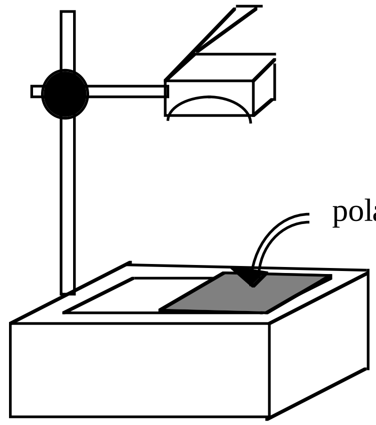
- Several polarizing filters
- An unpolarized white light source, such as an overhead projector, a light table, or an incandescent lamp
- Identical glass jars containing a variety of substances, such as:
    - Three different concentrations of corn syrup in water (recommended labeling: full strength, 1/2 dilution, and 1/4 dilution, plus one jar containing an “unknown” dilution)
    - Saccharine and water
    - Soapy water
    - Plain water
    - Table sugar and water or glucose (dextrose) and water
- Glass jars of different widths containing solutions of corn syrup at the same concentration
- Chunks of different crystals, such as calcite, mica, tourmaline, herapathite, quartz, table sugar crystals or rock candy, rock salt, etc.
- Clear plastic items that can be flexed or stretched, such as a hard plastic box, a ruler, a sandwich bag, etc.
- Other fun things such as ice cubes, clear unsweetened gelatin (cut in cubes that jiggle), cellophane tape layered on a transparency for different thicknesses, etc.

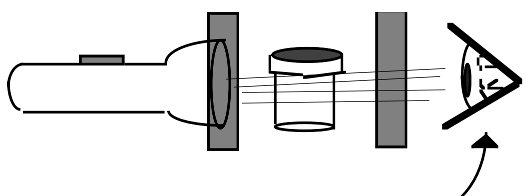
Where to get all this

Most materials are readily available at a grocery store or general purpose store. Baby food jars work well as identical jars for different solutions. Rocks and minerals can be found at most “nature” stores, including The Nature Company (be sure to ask for their educators’ discount). Polarizing filters can be purchased through Edmund Scientific for approximately $17 per square foot for a large sheet (14”x24”; unit prices go up if you buy smaller pieces).

Setting it up

There are at least two ways to do this activity. One is to use an overhead projector or light table, placing a polarizing filter over part of the surface and leaving part uncovered. You can then use the polarized and unpolarized light to compare what happens when you look through polarizers at various objects sitting on the plain overhead projector or light table surface (unpolarized light) versus the polarizing filter (polarized light).





Another possibility is to place a polarizing filter over the end of a flashlight or slide projector. By shining the beam through various objects and viewing them through a second polarizing filter, you can see different effects.

Try it and see

Look through a polarizing filter at several different solutions and materials (see the list of materials above). Compare what happens when polarized light passes through the material to what happens if you use unpolarized light. Find out as much as you can about what happens when polarized light interacts with these different materials. What creates the effects you see is an interesting question, but for this activity, think about how polarization effects can be useful. Make a list of everything you discover about polarized light and what it does. Be as specific as possible in the conclusions you draw from your experiments. For example, here are some things you might write down while looking at plastics:

We observed:	**We concluded:**
(When looking through a polarizer using polarized light —) • There are colored bands at different places in the plastic ruler. Bending the ruler makes more colored bands at the "stress places" where the ruler is	• Polarized light can be used to "see" or detect where there is "stress" or stretch in some kinds of plastic.

bent.

- Stretching a plastic bag leaves colorful bands where stretched. Where the bag is not stretched, the plastic remains clear.

As a place to start with the different solutions, see if you can answer these questions: Does polarized light produce the same effect when passing through different concentrations of a solution? Can you figure out the concentration of the unknown corn syrup solution? Do all solutions turn colors when viewed through a polarizer as polarized light passes through each?

Now you're ready to think as inventors and technological entrepreneurs do—you've explored and observed what you can do with polarized light and polarizing filters, and now you can look for applications of the effects you've seen. Imagine you are starting a business that will make use of the effects of polarized light and/or of polarizing filters. What will your company do using polarized light and/or polarizers? What services or products can your company offer that make use of polarized light and/or polarizers? How will your company benefit society? What possible hazards or problems might arise as a result of your business?

What is going on?

For a description of polarized light, see Activity I (Those Polarizers on Your Face). The polarized light interacting with materials in this activity produces a number of optical effects; exactly what is going on depends on the particular material. Some effects involve chiral (asymmetric) molecules that twist the polarization axis of some of the incoming light. Other effects involve the alignment of large polymer molecules. Still others involve materials with different indices of refraction depending on the polarization of the incoming light. This should be enough to get some interesting independent research going!

Going further

Have you ever seen dark round spots in the back window of another car while wearing polarizing sunglasses? Try it. These dark spots are stress patterns from uneven cooling during the manufacture of the glass. How could this effect be useful in manufacturing other glass products? How would it help to know where there are weaknesses in the glass?

Using a pair of polarizing sunglasses or a single polarizer, look at the blue sky at a 90° angle from the sun. Is light from this part of the sky polarized? Try other parts of the sky and see if you can find where the polarization is greatest. As you rotate the polarizer, where is the difference greatest between dark and light?

Unlike humans, some insects and animals can “see” polarized light and use this to their benefit. Find out who some of these polarized-light-detecting critters are and how they use polarized light.

Shine a bright beam of light, such as the beam from a slide projector, through a glass jar filled with water with a little bit of milk added. Look through a polarizer at the blue light that is reflected out of the sides of the container. What happens when you add more milk?
Some calculators, watches, and laptop computers use polarized light in the liquid crystal display. See if you can build a model to simulate how numbers or letters can be created using only some polarizing filters, an unpolarized white light source, and a mirror. *The Way Things Work*, a book by David Macaulay, is a helpful resource for this activity.

The light generated by some sources, including the Advanced Light Source (ALS), is polarized. Based on what you know about wiggling electrons and how they generate light, why do you think light from the ALS comes out polarized? Why would this be useful to the scientists doing experiments there? Find out about some scientific experiments best performed using polarized light.

Resources

Burnie, David. Eyewitness Science: Light. Dorling Kindersley, Inc., New York, 1992. A strongly graphical presentation of the physics of light in historical context. Explains concepts and their development over time in nontechnical terms.

Erhlich, Robert. Turning the World Inside Out and 174 Other Simple Physics Demonstrations. Princeton University Press, Princeton, 1990. Wide range of experiments covering everything from optics to magnetism and mechanics. Excellent chart at beginning of the book details cost, excitement level (really), time and construction commitment for each experiment. Geared to middle and high school students.

The Exploratorium Science Snackbook. The Exploratorium, 3601 Lyon Street, San Francisco, California, 94123 (Tel: 800-359-9899 or 415-561-0393), 1991. Lists a dazzling variety of science demonstrations, with full descriptions of how to make them and brief explanations of what is going on in each.

Falk, David, Dieter Brill, and David Stork. Seeing the Light: Optics in Nature, Photography, Color, Vision, and Holography. John Wiley and Sons, New York, 1986. An excellent and thorough reference source for light, its properties, and how we use it written at the high school or college level. Lots of good diagrams and pictures.

Gamow, George. Mr. Tompkins in Paperback. (Containing "Mr. Tompkins in Wonderland" and "Mr. Tompkins Explores the Atom.") Cambridge University Press, New York, 1965. An excellent, enjoyable presentation of quantum physics in the form of extended metaphors, as seen through the eyes of the curious everyman, Mr. Tompkins.

Gonick, Larry and Arthur Huffman. The Cartoon Guide to Physics. HarperCollins, New York, 1991. A humorous (and accurate) comic-book approach to basic physics concepts, this book brings abstractions down to earth. Helpful for beginning students.

Hewitt, Paul G. Conceptual Physics, 7th ed. Scott, Foresman and Company; Glenview, Illinois; 1993. This college physics text (also available in a high-school version) uses mathematics chiefly as a supplement to accessible, intuitive explanations,
keeping the everyday world at center stage.

Morrison, Philip, Phylis Morrison, and the Office of Charles and Ray Eames. Powers of Ten: A Book About the Relative Size of Things in the Universe and the Effect of Adding Another Zero. Scientific American Library, New York, 1982.

Macaulay, David. The Way Things Work. Houghton Mifflin, Boston, 1988. A pictorial book for a lay audience brimming with details about the machinery of our world.

Nye, Bill. Bill Nye The Science Guy's Big Blast of Science. Addison-Wesley Publishing Company, New York, 1993. A fun and slightly irreverent approach to exploring science from "molecules to the Milky Way." A wide variety of easy-to-do activities and experiments with explanations that everyone can understand.

Walker, Jearl. The Flying Circus of Physics with Answers. John Wiley and Sons, New York, 1977. A book full of provocative questions, addressing virtually everything you ever wondered about that relates to physics in everyday life. A valuable section of brief answers has been added to this edition.

Observations and Conclusions Worksheet
Polarized Light

We observed:	**We concluded:**
(When looking through a polarizer using polarized light —) • There are colored bands at different places in the plastic ruler. Bending the ruler makes more colored bands at the “stress places” where the ruler is bent. • Stretching a plastic bag leaves colorful bands where stretched. Where the bag is not stretched, the plastic remains clear.	• Polarized light can be used to “see” or detect where there is “stress” or stretch in some kinds of plastic.