Optics Suitcase Presentation Guide

Table of Contents

1. List of Equipment and Supplies

Your Optics Suitcase contains two types of supplies: reusable and give-away.

Reusable Supplies

1 Black suitcase with room for other items that you may add to customize your presentation

1 Set of “Happy and Unhappy” balls

1 Slinky

1 silicon wafer

1 Fused Silica lens

2 high-quality sheet polarizers

1 Set of transparent plastic tableware: fork, spoon, knife

1 sheet of temperature-sensitive liquid crystal

Give-away Supplies

Take-home Packets:

25 Transmissive Diffraction Gratings

25 Polarization films

25 Liquid Crystals

2. Introduction and Objective

The Optics Suitcase is a hands-on educational tool designed to engage students in exploring the science of light and color. It contains reusable supplies and take-home packets for both in-class presentations and take-home demos. The primary goal is to inspire students to consider careers in technology by introducing them to the fascinating world of optics.

A typical presentation lasts about 45 minutes, assuming the presenter is familiar with the materials and activities. The suitcase is designed to be easy to use, enabling presenters to quickly set up in a classroom and spark students' interest in technology careers.

Presenters are encouraged to tailor their classroom visit by incorporating personal insights and experiences related to their own careers. Be prepared for questions about your job, such as your salary, education, and what you enjoy or find challenging in your work.

The following summarizes a few general observations and suggestions:

- Make arrangements with the teacher ahead of time to have access to a projector for visual displays, and table at the front of the room. The table will ensure that you have enough room to spread out.
- We have found that the presentation is most successful when given to the 6th through 10th grades. Younger children are excited by the gifts you bring, but the message seems to get lost.
- Ask the teacher for help in handing out the packets and for operating the room lights (more on this later).
- It takes a minimum of 40 minutes to do the presentation as described in this guide. With more time, you can slow the pace, add more personal information, and entertain more questions. With less time, you may want to cover only two activities. Adjusting the flow of your presentation is important. Read your audience and move on if their attention seems to be wandering.

3. Preparing for a Visit to the Classroom

1 to 2 weeks before a visit:

Obtain the following information from the classroom teacher to prepare your suitcase and make a take-home flyer:

- School name, school address, teacher's name, classroom location
- Ages of students
- Number of students
  - Take four extra sets of take-home packets (one for the teacher, one for you, and two spares)
- Length of presentation
- Number of presentations
  - Will you speak to one or two classes?
- The setting and teacher's expectations
  - Is your visit part of a career day at school where others are coming in to describe their occupations as well?
  - Is your visit being used to emphasize experiments that demonstrate fun with science?
  - Is your visit being used as part of a science unit on the topic of physics?
- Protocol for entering the school
  - You will probably report to the school office for a badge.
- Appropriate arrival time
  - 20 minutes before the target class time?
  - Will there be time available to setup in the classroom?
- Would the teacher like a short biography to introduce you to the class?

The day before your visit:

Check the contents of your suitcase. Print out the relevant instructions and graphics or create a powerpoint presentation to have on hand for visual demonstration purposes. Also, be sure to take some time to practice, even if you simply run through the presentation in your mind. If you have a laser pointer, you might bring it along, but be careful not to share it with anyone or leave it where it can be “borrowed.”

4. Getting Started (Breaking the Ice)

After the teacher or one of the students has introduced you, try the following:

- Thank the teacher for inviting you to school, restate who you are, where you work, what you do, and the types of people with whom you work.

Happy and Unhappy Balls (if time permits)

- Select a student to come forward.
- Hand them the two black spheres and ask the student to drop both onto the table. (The rubber in one ball is fully vulcanized, retains its shape, and bounces well. The rubber in the second ball is much more easily deformed and does not bounce.)
- Ask your helper continues to bounce the unhappy ball, ask which kind of rubber would be best suited for the tires of a racing car or the bottoms of a pair of sneakers. (Answer: a blend of both, for improved friction or gripping power and to absorb shocks, but not too "energy absorbing," because this is accompanied by high heat from friction and excessive wear.)
- Again, you might point out that technology and invention are the keys to improving our lives.
- Put the demo away.

5. Introduction to Optical Engineering

Now that you have their attention, you are ready to introduce a field of technology called "optical engineering."

- Hold up the silicon wafer (shiny side out) and the large silica glass lens. Ask if anyone can identify them. (The lens is usually easy. The students will likely refer to the wafer as a mirror.)
- Identify the wafer as single-crystal silicon, a pure elemental substance and the basis for all computers (the chips and microcircuits). Show them the reverse side of the wafer, which is dull, and explain that this side is ground and the other is polished to a mirror surface. Some optical engineers develop technologies for turning rough silicon wafers into integrated circuits for making computer chips. (You may want to elaborate on this.)
- Hand out copies of the periodic table of elements [useful for 8th and 9th grades and higher (Fig. 2)] and display the digital copy to help the students locate silicon (14) and oxygen (#8).
- State that the periodic table is a visual means for displaying all the elements known to man—every bit of matter in the universe is composed of one or more of these elements. Ceramic engineers, chemists, materials scientists, geologists, and optical engineers work with many of these elements and the compounds they form.
- Explain that the only difference between the silicon wafer and the silica lens is oxygen. Point out how a little oxygen turns a visibly opaque material into a visibly clear one. Suggest that if we were aliens whose vision was in the infrared, the silica lens would look opaque, and the silicon wafer would look transparent! Mention that optical engineers build lenses into systems that image light such as the Hubble Space Telescope, the Chandra X-Ray Telescope, or the digital cameras that record images on silicon.

You are now ready to do some experiments with the class that illustrate what optical engineering is all about.

- ***The following experiments explore several ways to "see" the colors in white light. I will be revealing certain "secrets" that might not be obvious to others when doing these experiments.*** (The "trick" aspect to these demos works well with 6th graders!)

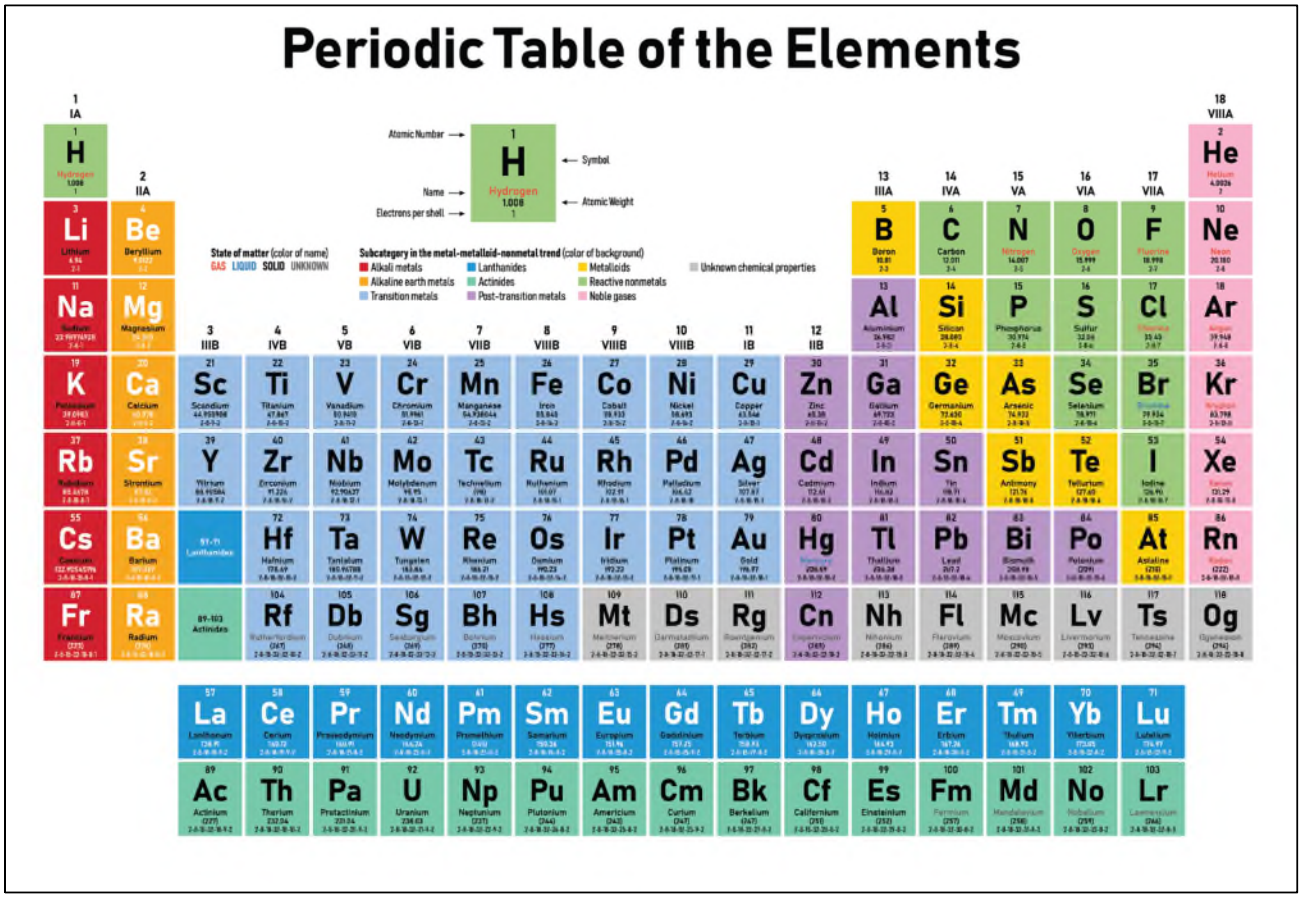

Figure 2. *The periodic table of elements*

6. Color by Redirection (Diffraction Demo)

Have the teacher pass out the **Diffraction Demo Take-home Packets**, but ask the students **not to open them yet**. When everyone has their own packet, proceed as follows:

- Remove the flashlight and the diffraction grating from your packet, hold them up, and identify them. Ask the students to remove theirs. Hold the diffraction grating up to your eye and from a distance, look at the flashlight through it. Be sure to avoid looking directly at the bright light from the flashlight. Have the students copy you.
- During the "oohs" and "ahs," ask the group, "Where does the color come from?" *(Many children will answer that the colors come from the optic. Tell them that the color comes from the white light in the flashlight.)*
- You can ask any or all of the following questions:
    - Do you see a regular pattern? Describe it.
    - Identify all of the colors. Are they the same in each spot?
    - Does the pattern change if the flashlight is close or far away? Do you see colors from other people's flashlights, even those far away from you? Do you see colors from the room lights?
- A highly magnified photograph of the surface of one side of the clear plastic in the diffraction grating would show an array of small bumps, only 2 microns high—too small to be seen or felt.
- The bumps are packed so closely together that about fifty could fit inside a human hair. These bumps are responsible for breaking up the light coming into the grating, depending on its color. This is called "diffraction." It occurs when light travels through small apertures (e.g., holes or slits).
- Ask for a show of hands by everyone who has/wants a cell phone. With the graphic *(Fig. 3)* explain how telecommunications uses fibers and lasers to divide light from one beam into many, each with a different color. This is the key to unlimited numbers of conversations all over the world at the same time. *(Optical engineers do this stuff.)*
- Ask everyone to seal the flashlights and gratings back into the packets. Tell them the packets are theirs to keep. Suggest that they can reveal to family members the secret of seeing colors in white light through diffraction.

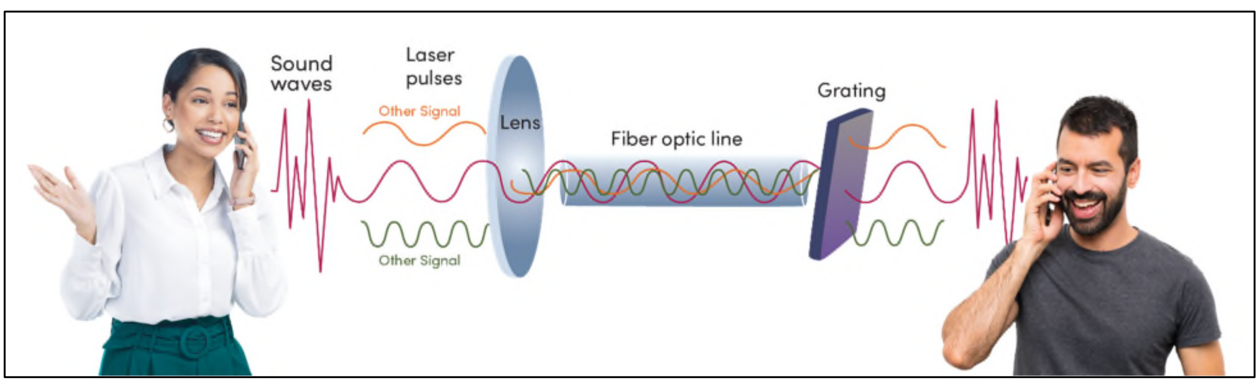

Figure 3. *The Diffraction Grating and TeleCom.*

7. Color by Polarization (Polarization Demo)

Remove the **slinky** from the suitcase and choose a volunteer to come up front.

- Give the student one end of the slinky and ask them to hold this end steady at mid-chest level. Stand 4 feet away and begin to vibrate your end up and down and in a circle. You should be able to create a standing wave with a few nodes, but the plane of vibration should not be well defined.
- State that, in addition to color, light has a wave nature. The slinky represents a light wave. This motion represents unpolarized light— light without a preferred vibration direction. *(For simplicity, we ignore circularly polarized light.)*
- Stop the circular motion and vibrate only vertically. State that light is “polarized” when it vibrates in one direction—vertical or (switch hand motion) horizontal. *(Horizontal motion is a bit harder to maintain while speaking and you might want to go back to the vertical motion.)*
- Define linearly polarized light as light whose vibration direction is in a plane. *[Here you might use the graphic (Fig. 4) that shows the spectrum from radio to gamma rays with low frequency, long-wavelength and high-frequency, short-wavelength radiation.]*
- Put the slinky away.

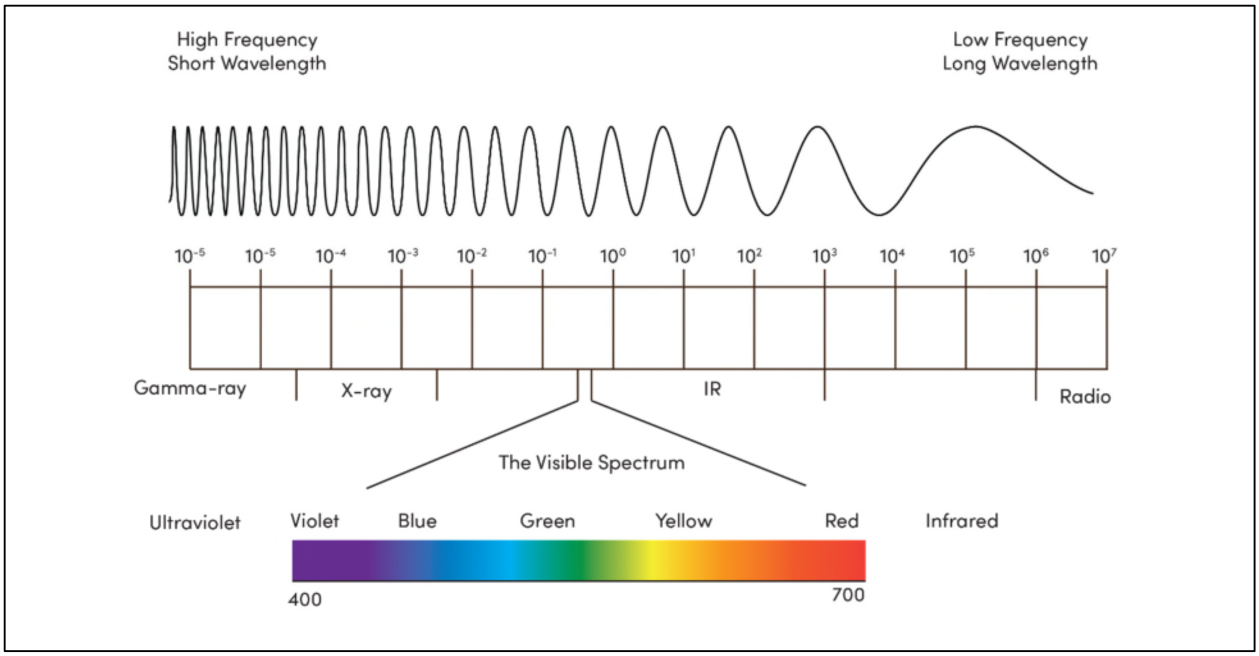

Figure 4. *The Electromagnetic Spectrum*

Have the teacher hand out the **Polarization Demo Take-home Packets** but ask the students **not to open them yet**. When everyone has their own packet, proceed as follows:

- Ask the students to remove everything from the packet and place the items from the polarization demo packet on their workspace. Have them check that they have two dark pieces of plastic, and one piece of plastic silverware.
- Take your **two large pieces of linear sheet polarizer** and hold them up, one in each hand. Combine them about one foot in front of your face with the transmission axes parallel. You should be able to see the students, and they should be able to see you. Ask them to make a

sandwich in the same way with their dark pieces of plastic. Show them what happens when you rotate one polarizer relative to the other.

- During the “oohs” and “ahs,” reveal that each piece of dark plastic has a secret code on its surface in the form of small lines. Combining the plastics so that the lines are parallel makes it possible to see through them. Combining them with lines that are perpendicular, or “crossed,” blocks the light. Identify the plastics as ***linear polarizers***. One piece of plastic held up to the room lights causes the unpolarized white light to become linearly polarized. Once the light is linearly polarized, it vibrates in one plane, and it is either transmitted or absorbed by the second plastic polarizer. Polarized sunglasses are made of this plastic.
- This demonstration works even better if you have a polarized light source (most LCD screens would work for this – laptops, phones, etc.). Have the teacher turn off the lights in the classroom. To show how light can be polarized, use a phone or laptop screen as a light source, and place one polarizing filter in front of it. Next, position a plastic fork between the light and filter. Rotate the filter and watch how the light changes in intensity and color as it interacts with the fork, helping you see how polarization affects light.
- Ask where the color comes from. *(You might get some correct answers.)*
- Explain that stresses inside transparent materials degrade the quality of linearly polarized light coming through the polariscope, causing various colors to show up. With a polariscope, geologists identify certain crystals and mineral structures. Civil engineers examine stresses inside structures made from transparent plastic to understand how to build them better. Photonics technicians evaluate the quality of laser glasses and laser crystals with polariscopes.
- Have the room lights turned back on. With the items from your packet, show the students how to make a polariscope in one hand. Ask them to find the colored stripes in the clear sheet of plastic from their packet. *(While looking through the crossed polarizer sandwich at the overhead lights, they must insert clear plastic between the polarizers.)*
- Ask the students to evaluate the internal stresses in the plastic vial and the fork. By squeezing the tines of the fork, the students may be able to induce and visualize additional stresses. *(See Fig. 5)*
- Have everyone put all items back in the packets. Suggest that the students demonstrate the Magic Stripes trick to their families, since they know the secret polarizer code and how to construct a polariscope.

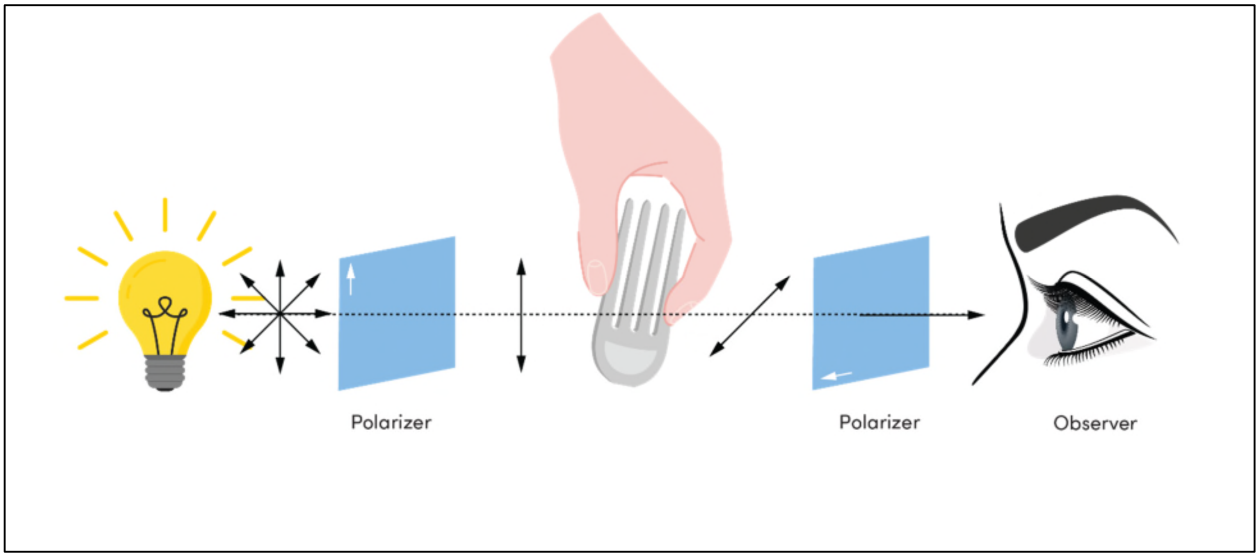

Figure 5. *Color chart for polariscopic observations of optical retardation induced by stress.*

8. Color by Selective Reflection (Selective Reflection Demo)

Remind the students that you have demonstrated how to see the colors in white light through diffraction and polarized transmission. Making sure that everyone is looking at you, take the **large sheet of microencapsulated liquid crystal** and place it against your face, shiny side out. *(If you wear glasses, remove them first.)*

- Wait a bit for the "oohs" and "ahs" to die out, then ask, "Where do the colors come from?" *(If some students say the heat from your face, answer no.)*
- Explain that the colors come from the white room lights reflecting off the black "paper."
- As the teacher passes out the **Selective Reflection Demo Take-home Packets**, explain that the paper has liquid crystal fluid trapped, or encapsulated, against the shiny side. *(Note: The patch material goes through a complete color change with a temperature change of 77°F to 86°F. If the room is warm, you may have to open an ice pack to enable students to cool their patches down. Ice cubes also work well.)*
- Suggest that each student determine if they are a vampire by placing the magic patch on the inside of their wrist. *(Vampires are the living dead and give off no heat.)*
- Ask if anyone can "see a vein." *(This would be characterized by a blue line.)* To explain selective reflection in liquid crystals and "mood rings," you may use the set of transparencies included as follows:

"Liquid Crystals in Education" Graphic

- Students are laying on the grass, disguised as liquid crystal molecules. In liquid crystals, the molecules show a high degree of organization and alignment in some regular order *(Fig. 6)*.

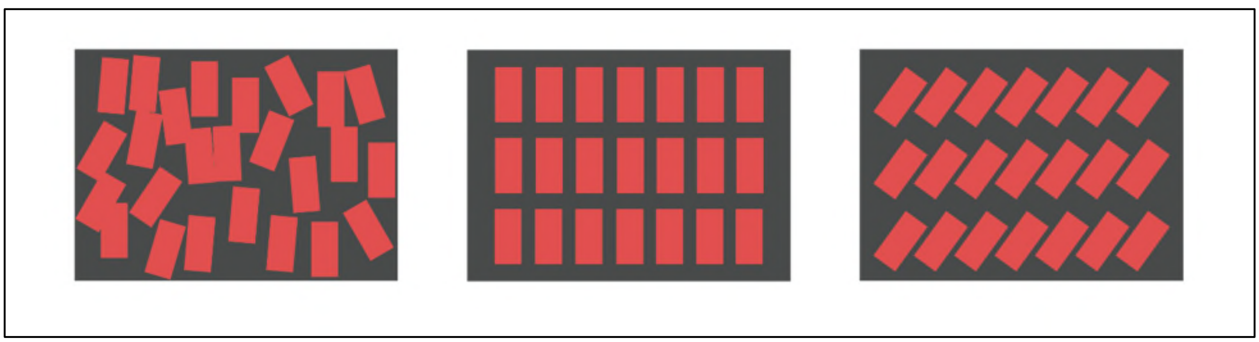

Figure 6. *"Liquid Crystals in Education" Graphic.*

“Selective Reflection in Cholesteric Liquid Crystals” Graphic

- If we try to stack students (or liquid crystal molecules) in a series of layers on top of each other, they tend to twist as shown on the left in Figure 7. The heads of the students point in a spiral direction as we move up through the structure, like a spring.
- Think of the liquid crystals in the black sheet as springs. When they are cool, the springs are relaxed with a long pitch (or twist). *(Refer to the right side of Fig. 7.)*
- Most of the colors in white light pass right through the cool liquid crystal film and are absorbed in the black paper. The patch appears black.
- As body temperature heats up the patch, the liquid crystal “springs” get tighter and they “selectively” reflect the red-light part of the white room lights. As the temperature climbs, yellow, then green, and finally blue-light are reflected. This is as tight as this liquid crystal gets *(Fig. 7).*
- The effect is reversible. Students may put their patches on an ice cube or under a mug of hot cocoa to see the effect of selective reflection. Give a warning that the sheet should not be folded or marked with a sharp object like a pencil.

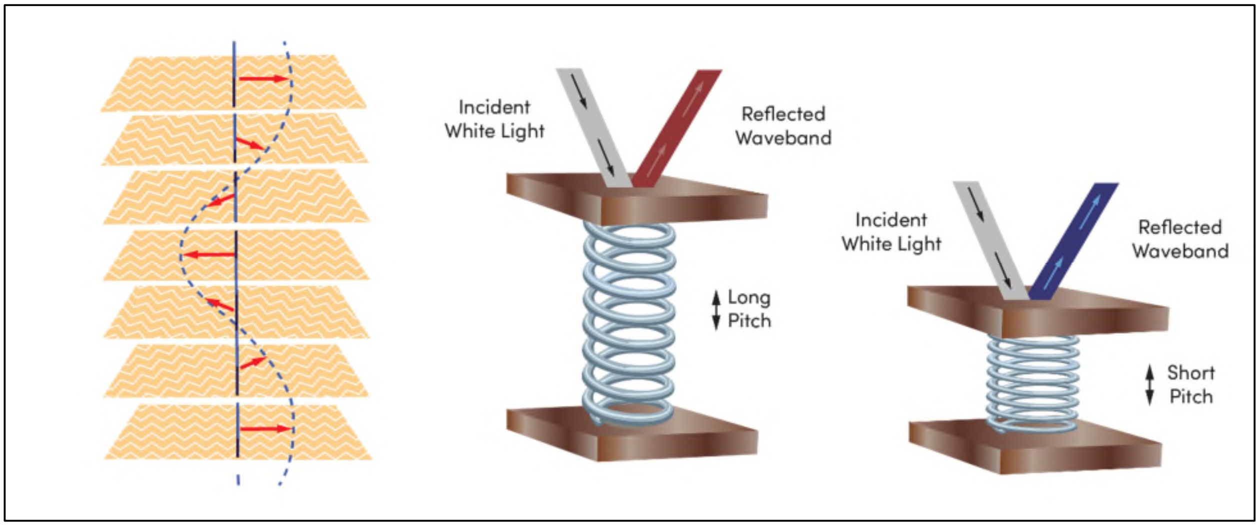

Figure 7*. “Selective Reflection in Cholesteric Liquid Crystals” Graphic*

9. Closing Notes

Thank the students for inviting you and ask if there are any more questions. Are there things that they want you to clarify or repeat?

The teacher may have to start up with another class five minutes after this one leaves, so be prepared to throw all of your props into your Optics Suitcase and make a hasty retreat.

10. Acknowledgements

This Optics Suitcase is dedicated to the memory of Dr. Stephen D. Jacobs.

Dr. Stephen D. Jacobs made lasting contributions to the fields of optical materials, liquid crystals, and optics manufacturing, but it is his passion for educational outreach which continues to impact countless young (and older) lives. He spent his entire career at the University of Rochester with appointments at the Laboratory for Laser Energetics (LLE), Institute of Optics, Materials Science, and Chemical Engineering departments. He volunteered as the educational outreach chair for the OSA-Rochester Section for over 15 years during which time he developed and organized the Optics Suitcase program that has been instrumental in introducing hundreds of thousands of young children to the fields of optics and materials science throughout the US and globally. Steve Jacobs touched many lives. His vision and desire to share optics continue with every use of the Optics Suitcase.

To purchase an Optics Suitcase or refill take-home packets, please visit us online at [EO link].

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