National Aeronautics and Space Administration

NASA eClips™

Educator Guide

NASA LAUNCHPAD

The Colors of Ice

Educational Product	
Educators & Students	Grades 9-12

EG-2010-05-007-LaRC

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EDUCATOR GUIDE

NASA eClips™

The Colors of Ice

National Standards:

National Science Education Standards (NSES)
Science as Inquiry

Understanding about scientific inquiry

Physical Science

Interactions of energy and matter

Science and Technology

Understanding about science and technology

Essential Questions:

- What happens when light passes through polarizing film?
- What can be learned about ice using light and polarizers?
- What is the scientific importance of studying ice?

Instructional Objectives:

Students will:

- investigate the mechanics of cross-polarizers;
- observe birefringence;
- explore the importance of studying ice; and
- investigate ice structures to analyze and deduce ice formation.

Lesson Overview:

Students are introduced to the topics of polarized light and birefringence. Working in groups, students use polarizing films to examine the crystal structure of ice. They document their results using digital images and organize their work by creating a multimedia presentation. Students apply what they have learned by

NASA LAUNCHPAD

Grade Level:
9-12

Subjects:
Physical Science, Physics

A workshop that includes this activity is offered as part of the History of Winter Program sponsored by NASA Goddard Space-flight Center. More information can be found at *http://education.gsfc.nasa.gov/how/*

Teacher Preparation Time:
One hour total. The samples used by students in the EXPLAIN section should be prepared two days before the lesson.

Lesson Duration:
Four 55-minute class meetings if all components are completed in class

Time Management:
Class time can be reduced to two 55-minute time blocks if students complete the EXTEND and EVALUATE sections at home.

creating 3-D sculptures to be viewed through cross-polarizers. Students analyze cross sections of natural and manmade ice to transfer learning to a real world application. This lesson is developed using a 5E model of learning.

Prior Knowledge:

To be successful in this activity students need a working knowledge of electromagnetic radiation and refraction.

Icons flag five areas of interest or opportunities for teachers.

Technology highlights opportunities to use technology to enhance the lesson.

Modification denotes opportunities to differentiate the lesson.

Resources relate this lesson to other NASA educator resources that may supplement or extend the lesson.

Connections identify opportunities to relate the lesson to historical references and other topics or disciplines.

Check for Understanding suggests quick, formative assessment opportunities.

Materials List:

ENGAGE (per student)

- Student Guide

(**MODIFICATION**) The Student Guide is organized so the teacher can select the sections to be used. NASA background information and vocabulary are found on pages 1-3; student data sheets are on pages 7 and 8; the multimedia rubric is on page 9. To conserve paper, directions could be given orally or provided to each group while pages relevant to individuals could be duplicated.

(**MODIFICATION**) You may choose to have students answer all questions and complete all work in a science notebook, eliminating the need to reproduce Tables 1, 2, and 3 of the Student Guide.

EXPLORE

- Class demonstration
  - clear jar or beaker
  - water to fill the jar about ¾ capacity
  - two single-use plastic glow sticks
- Per group of three or four
  - two 7.5 cm x 7.5 cm pieces of polarizing film (polarizing film is available from science material supply companies)

- one clear plastic CD case
- light source such as a light table, overhead projector, or a large lantern flashlight (light source must have a flat surface on which to lay the polarizing film)
- thin piece of mica (optional) (mica is available from science material supply companies)
- one12.5 cm x 15 cm piece of polyethylene (optional) (sheets of polyethylene may be purchased from home improvement stores)

EXPLAIN

Per group of three or four

- ice (*prepared by freezing water in shallow lids or dishes*)
- hot plate

  (**MODIFICATION**) Buffet warmers may be substituted for low-temperature hot plates. If you do not have access to several hot plates, some students may need to begin conducting the activity using thin ice sections prepared by the teacher in advance. Alternate turns using the hot plate so all students experience making their own thin ice sections.
- aluminum pie tin
- glass microscope slide that has been stored in a freezer (*glass is necessary for proper adherence of the ice to the slide*)
- light source such as a light table, overhead projector, or a large lantern
- two 7.5 cm x 7.5 pieces of polarizing film
- paper towels for blotting as needed
- (**TECHNOLOGY**) digital camera (*optional*)
- (**TECHNOLOGY**) laptops or desk top computers (*optional*)

5E Inquiry Lesson Development

ENGAGE (25 minutes)

1. Divide the class into teams of three or four. Ask students to examine and compare the six colorful images on page 3 of the Student Guide.

   (**MODIFICATION**) If teacher does not have access to a color printer, polarized ice images may be projected or teacher may download the page for student access on classroom computers. The images must be viewed in color to accurately analyze them.

   (**TECHNOLOGY**) Images may be displayed on an interactive whiteboard. Students may sort the six images and identify similarities and differences directly on the whiteboard.

2. Discuss the similarities and differences observed by each team. Ask students to brainstorm what they think the images might be and give reasons for their deductions. *(The images of ice, provided by Dr. Peter Wasilewski, Frizion, www.frizion.com, were taken using polarizing film. This process is discussed in the NASA eClips™ video segment in the EXPLAIN section.)*

   (**TECHNOLOGY**) Students may record their ideas on an interactive whiteboard.

3. Tell students that they will be using polarizers to study some properties of materials.

   (**MODIFICATION**) If students have no prior experience with polarizers, allow them to explore the concept of polarized light by using polarized sunglasses to observe materials such as LED displays and safety glass. Safety glass has a coating that appears as a checkerboard pattern.

4. (**RESOURCE**) For more information about the images used in this section, go to

   http://www.nasa.gov/centers/goddard/news/topstory/2003/0508ice_photo.html

EXPLORE (25 minutes)

In this activity, students learn how polarizers alter light waves to produce birefringence. Polarizing filters, like those found in sunglasses, are used to reduce glare. Polarizing filters in photography are used to make lighted background objects, like the sky, appear darker. Double refraction, or birefringence, is an interesting, colorful phenomenon related to polarized light as it passes through certain types of crystalline structures.

Birefringence is a process in which light moving in different directions, or polarizations, travels at different speeds within a material. The light waves are split into unequally reflected or transmitted waves. When light is emitted from a source, the waves of light vibrate in all directions and orientations. When this same light passes through a piece of polarizing film, only light waves moving in one direction can pass through the filter. All other waves are blocked.

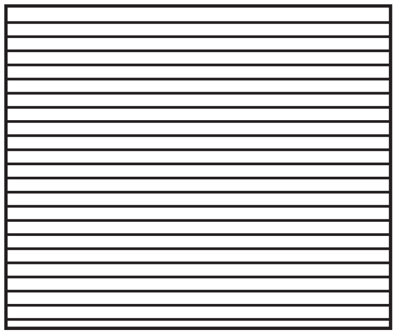


Figure 1: Only horizontally-oriented light can pass through this film.

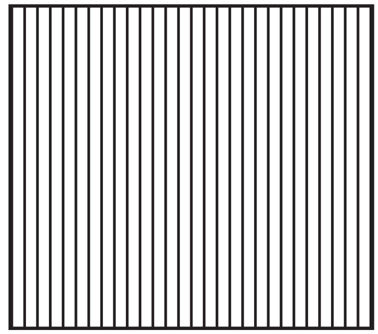


Figure 2: Only vertically-oriented light can pass through this film.

When one piece of polarizing film is placed on top of another, the films will be either transparent or opaque to light depending on whether the films are parallel or perpendicular to each other. By rotating one film while leaving the other stationary the light will be blocked or travel through both films. When the light is blocked, the filters are described as being cross-polarizers.

All crystalline substances are made up of atoms and molecules arranged in orderly, repetitive patterns. These patterns vary in different materials. If the spacing of the atoms is the same along each axis, the crystal structure is isotropic. Because crystals line up the same way along each axis, ordinary rules about refraction, or light bending, apply. Table salt is an example of an isotropic crystal. If the spacing or arrangement of atoms along one axis is different than that of another axis, the crystal structure is classified as anisotropic. Certain materials, such as calcite or snowflakes, are anisotropic. These materials have a crystalline structure that is the same in two directions, along the lattice or axis of the crystal, but is different along the third axis. Light traveling through anisotropic crystals is split into two waves. Each wave travels at a different speed. The light from each wave is refracted or bent as it passes through the crystal, creating a double image of anything viewed through the transparent medium.   This phenomenon is called birefringence. When anisotropic materials are placed between cross-polarizers they display a multitude of colors. These colorful displays can be analyzed to help scientists understand the crystalline structure of the material.

To describe the growth of crystals in three dimensions, crystallographers have defined crystallographic axes which are similar to the xyz coordinate plane. The crystallographic axes are labeled a, b, and c. The c axis is the primary axis along which the crystal grows. In simple cubic crystals, the a, b, and c axes look exactly like the xyz coordinate plane as shown in Figure 3.

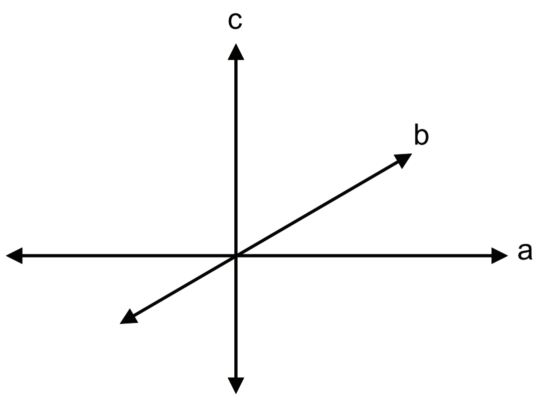


Figure 3: The crystallographic axes for a simple cubic crystal.

Although the polymer structure of plastics is not crystalline, stressing plastic by compressing or stretching it often produces birefringence. Exposing materials such as clear cellophane tape or molded clear plastic to a pair of polarizing filters produces the same birefringence as seen in crystals. Engineers can use this process to analyze a structure by building a plastic scale model and applying force to the structure. Polarized filters are then used to see where the stress is greatest. The colored bands indicate places where stress fractures are likely to occur. This same process is often used to identify the crystal structure of gemstones, such as diamonds, before they are cut and polished.

In this activity, students explore the properties of birefringence using cross-polarizers and plastic CD cases.

1. Gather the materials for the class demonstration and each group of three or four students:
2. As a class demonstration, place one activated glow stick in a clear jar of water. Ask students to describe what they see. Explain that the water refracts or bends the light waves as they pass through the water. Add a second activated glow stick to the water. Students should be able to see two light stick refractions. This double image can be used to introduce the process of birefringence. As light passes through a crystalline structure, the light is split into two paths, creating double refraction. Ask students to write their own definition for birefringence.
3. (**MODIFICATION**) Ask the students to do a "Think-Pair-Share" activity. Based on what they have observed in the demonstration, each student

should first write his or her own definition of birefringence. Students then turn to a partner and discuss their definitions. Together the pair comes to consensus about the best definition for birefringence. Then student pairs are invited to share with the class. A class definition is created from the sharing. Students may record this process using the journal page in the Student Guide, page 7.

4. Demonstrate how cross-polarizers work by placing one piece of polarizing film on the light source and the second piece on top of the first piece of film. Keep the bottom piece stationary and rotate the top piece until no light passes through the films.

5. Allow students to examine the plastic CD case through the cross-polarizers, following the directions in the Student Guide.

   (CHECK FOR UNDERSTANDING) Once students have examined the plastic case through the cross-polarizers, ask them to explain why they think the colors are changing as the film is rotated. *(The various colors indicate the stress applied to the material as it was molded into its current shape. Light is doubly refracting as it travels through the material.)*

6. (**MODIFICATION**) Ask students to examine a thin piece of mica with the cross-polarizers. Students can also examine a piece of polyethylene between the cross-polarizers. While one student holds the cross-polarizers over the light source, another student should stretch the polyethylene. As the polyethylene is stretched, areas of color indicate areas under stress. Challenge students to find other materials that display this property.

7. **(CHECK FOR UNDERSTANDING)** Use the following question to help students summarize their learning.

   (**MODIFICATION**) Question may be discussed orally or students may be asked to record their answers.

   What happens when light passes through polarizing film? (*When light is emitted from a source, the waves of light vibrate in all directions and orientations. A polarizer, or polarizing filter, is like a screen with narrow bands in one direction. The filter blocks some of the light waves.*)

EXPLAIN (One 55-minute class meeting; two 55-minute class meetings if the optional multimedia activity is completed in class)

Scientists use polarized filters to study thin ice sections. Interpreting the colorful patterns is complex, but basically two types of ice form in a lake or pond. The kind of ice depends on the weather conditions. On very cold, calm nights, large ice crystals spread rapidly across the surface. Individual crystals may be a meter wide. The “c” axis of the crystals is vertical, or up and down. When lake conditions are cold and winds blow across the surface, ice crystals form around particles of dust, snow, or ice blown by the wind. These ice crystals grow on a horizontal “c” axis. The polarizing filters allow scientists to analyze the three-dimensional structure of the lake ice. In this activity, students make thin sections of ice, examine them with cross-polarizers, and document their results using digital cameras.

1. BEFORE ASSIGNING THIS ACTIVITY
   a. Freeze water in shallow lids or dishes, like a Petri dish, to make the ice for the thin ice sections (at least two-three per group). Lids should be filled with about 5 mm of water. These thin samples may be broken into smaller pieces for the students to use.
   b. Place glass microscope slides in the freezer overnight.
   c. Using the directions found on pages 4 and 5 in the Student Guide, prepare several slides with thin ice sections ahead of time to be used to model this activity for students.
   d. Gather and test the hot plates. Hot plates must have a temperature control and a low setting cool enough to be touched.
2. (**TECHNOLOGY**) As an introduction to this portion of the lesson show the NASA eClips™ video segment *Launchpad: Thin Ice – Looking at Birefringence*. This segment can be found at

   http://www.nasa.gov/audience/foreducators/nasaeclips/search.html?terms=”thin%20 ice”&category=0010

   or *http://www.youtube.com/watch?v=VVQJak_TkTI*
   The video may be streamed from either web site. The video may be downloaded from the *nasa.gov* web site. A captioned version is also available at the *nasa.gov* site.
3. Tell students they will study some thin ice sections in a similar fashion to the way the scientists in the video studied them.
4. Organize students into teams based on available supplies. Three or four students working as a team is the optimum group size.
5. Gather the materials for each team.
6. Model the procedure for creating the thin ice sections.
   a. Turn the hot plate on low and place the aluminum pie tin on the hot plate.
      SAFETY NOTE: The hot plate must be set at its lowest temperature

and should be cool enough to touch AT ALL TIMES. DO NOT ask students to test the temperature of the hot plate. Emphasize that students should NEVER touch working hot plates.

   b. Demonstrate placing an ice sample in the pie tin and sliding the ice around to flatten it. Point out that to form a thin ice section only a few millimeters thick the students must continually move the ice around and should flip the ice over every minute or so.

   c. Model how to place the thin section of ice on the glass slide and return it to the freezer for a few minutes. Use already prepared thin ice slides to model the lab set-up.

7. Have students practice making thin sections before they use the slides from the freezer. If a freezer is not available, slides can be stored in a cooler with ice.

8. Review how to use the cross-polarizers to observe light traveling through the thin ice sections.

9. **(TECHNOLOGY)** Students may use digital cameras to document the way light travels through thin ice sections and capture the colorful birefringence process.

10. **(CHECK FOR UNDERSTANDING**) Discuss how this activity compares to the EXPLORE activity. Ask students to brainstorm what is producing the birefringence in the ice samples. Guide the students to understand that the crystalline structure of the ice produces birefringence. The conditions under which the ice formed determine the size, shape and orientation of the crystals.

11. **(TECHNOLOGY) (RESOURCE)** Show students a video documenting how scientists study natural ice samples

    http://learners.gsfc.nasa.gov/HOWmedia/IceCoreThinSectioning/

12. Ask students to discuss similarities and differences to the procedure modeled by the scientists and the work they have just completed. (*Answers will vary*).

13. **(MODIFICATION)** Allow students to make their own thin sections with materials of their own choosing to compare to those provided by the teacher.

14. **(RESOURCES)** Have students look at the protocol forms for collecting ice core samples found at: *http://education.gsfc.nasa.gov/how/pdf/lakeicecores.pdf*

15. **(CHECK FOR UNDERSTANDING)** Use these questions to help students summarize their learning.

(MODIFICATION) Questions may be discussed orally or students may be asked to record their answers for homework or as exit slips.

a. What can be learned about ice using light polarizers? *(By examining ice under polarized light, scientists can examine crystal structure, crystal size, and crystal orientation.*)

b. What is the scientific importance of studying ice? *(Ice crystals provide clues of past weather patterns. By drilling core samples of ice, scientists not only can observe ice structures under polarized light but they can also use the bubble patterns to help scientists determine past weather patterns.)*

c. This activity modeled the way scientists study ice core samples from lake ice. Compare the protocol you used to the one used by scientists in the field. How was your experiment different? Suggest ways to improve the classroom lab procedure. *(Using natural ice samples would more closely model the work of cryospheric scientists.*)

16. (**TECHNOLOGY**) (*OPTIONAL*) Students may use presentation software or video production software to document their results in a multimedia presentation. Students may choose to create a collage of their digital images. Presentations should demonstrate a clear understanding of the science concepts involved. A rubric to evaluate student presentations can be found on page 9 of the Student Guide.

(**MODIFICATION**) To save class time, students may create the multimedia presentation at home.

EXTEND (One 55 minute class period; class time may be reduced by assigning only one of the EXTEND activities, or by asking students to complete the activities at home.)

1. Dr. Peter Wasilewski, scientist at NASA Goddard Space Flight Center, uses polarized light to study the size, structure, and orientation of ice crystals. He uses polarized light to create a unique art form he calls Frizion.

   (RESOURCE) The images in the ENGAGE section are examples of Dr. Wasilewski's Frozen Visions. Students can learn more about his art by researching his web site at: *www.frizion.com*.

2. Ask students to create their own unique, colorful artwork using polarized filters. Students can create wire sculptures that are covered with strips of cellophane tape. Be sure to test the tape beforehand. Some types of tape, such as "invisible tape" will not work. Have the students place their sculptures in front of one piece of polarizing film. Rotate a second piece

of film in front of the sculpture while shining a bright light through the film from behind the stationary piece. Document the brilliant colors using digital photography.

(TECHNOLOGY) Students may want to display pictures or create a multimedia art show.

3. **(CHECK FOR UNDERSTANDING)** Use these questions to help students summarize their learning.

   (MODIFICATION) Questions may be discussed orally or students may be asked to record their answers.

   (CONNECTIONS) How do scientists and engineers use polarized light or birefringence? What applications for this technology do you see in your everyday life? (*Answers will vary, but may include: polarized filters are used in sunglasses, skylights, tinted windows, and camera lenses to decrease glare. Jewelers and engineers use birefringence to identify areas where stress fractures are likely to occur. Birefringence is used in televisions and electronic cameras. Frizion (Frozen Vision) is an art form based on the birefringence color patterns seen in ice when photographed with polarizing filters.*)

EVALUATE (30 minutes)

1. Use questions, discussions, and work in the Student Guide to assess students' understanding.
2. Ask students to examine the thin ice sections they photographed in the EXPLAIN section. Using the criteria established by scientists for evaluating ice crystals found in Table 4 on page 8 of the Student Guide, discuss what conclusions students can draw from the crystal sizes and orientations in their pictures. Record thoughts and observations.
3. Use the rubric on page 9 in the Student Guide to assess the multimedia presentation from the EXPLAIN investigation.
4. Show students pictures of the horizontal sections of natural and manmade ice found on page 6 of the Student Guide. The natural ice section is from a lake and the manmade ice section is from a hockey rink. Explain that the scale of the pictures is the same. The size of the picture is different because the thin section of lake ice was larger than that of the rink ice. (*Full size image available in Student Guide.*)

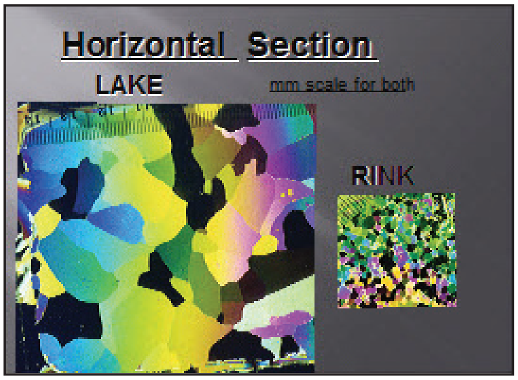


Figure 4. Horizontal Ice Sections.
Image credit: Peter Wasilewski,
NASA Goddard Space Flight Center

5. Ask students to brainstorm possible reasons for the differences in the crystal sizes and record their responses. *(Answers will vary, but should include information about conditions under which the ice was formed and crystal size, structure, and orientation. Lake ice is formed under different conditions than ice in an ice rink. The differences in crystal sizes are due to the speed at which the ice crystals form. The more slowly the ice freezes, the larger the crystals. Ice formed in an indoor rink would not be exposed to wind blowing across the surface.)*
6. Have students draw pictures of what they observe and present them to the class.
7. **(MODIFICATION)** Have advanced students synthesize their learning by creating a display based on the lesson.

STUDENT GUIDE

The Colors of Ice

Essential Questions:

- What happens when light passes through polarizing film?
- What can be learned about ice using light and polarizers?
- What is the scientific importance of studying ice?

Background

NASA's Cryospheric Sciences Program studies water in its frozen state. Derived from the term kryos, meaning frost or ice cold, Earth's **cryosphere** includes snow, sea ice, lake ice, glaciers, permafrost, ice caps, and ice sheets.

Understanding Earth's cryosphere offers insight into the past, present, and future behavior of the Earth as a whole. Polar and sub-polar regions are most sensitive to changes in **climate**. These areas are remote and therefore difficult to study. Areas of the cryosphere shrink and expand over time. NASA satellite observations help scientists monitor changes in global and regional climate by observing these changes. Scientists use the satellite data to better understand **weather** and climate patterns over the last several decades. NASA data and analyses will ultimately enable more accurate climate models and prediction.

Ground study of ice and snow helps confirm satellite observations. Since 2000, NASA Goddard Space Flight Center's History of Winter (HOW) program has immersed teachers in the role of scientists to study ice and snow. One focus of the program is the study of thin ice sections taken from lakes. To make thin ice sections, core samples of lake ice are removed. These cores are sliced into very thin pieces called thin ice sections. The sections are studied using **polarized light.**

Ordinary white light vibrates in many directions. This light can be polarized using a polarizing filter, like ones used in sunglasses. The filter blocks all light except that which is vibrating or moving in one direction. When thin ice sections are viewed using polarized light, unique colors and patterns are produced. The colors and patterns allow scientists to examine the crystal structure, size, and orientation in the section.

This study of natural ice can also be applied to the science of man-made ice. Core samples from an ice rink can be analyzed using the same polarization techniques. Different types of ice are important to various sports. Figure skaters, for example, require softer ice than the kind needed for hockey players. Using the color patterns refracted in the samples, scientists can determine if the snow or ice is appropriate for each sport.

Resources:

NASA's History of Winter

http://education.gsfc.nasa.gov/how/

Olympic Ice Is Different in a 'Frozen Light'

http://www.nasa.gov/vision/earth/lookingatearth/olympic_ice.html

Climate Variability and Change

http://nasascience.nasa.gov/earth-science/climate-variability-and-change

Vocabulary

anisotropic – Anisotropic materials have a crystalline structure where the arrangement of atoms along one axis is different than that of another axis. Optically anisotropic materials rotate polarized light as it passes through them.

birefringence – Birefringence is a process where light of different polarizations travels at different speeds in different directions through a transparent medium. Birefringence is also called double refraction.

climate – Climate is the long term or average weather in a specific area over a long period of time.

cross-polarizers – Cross-polarizers are created when two pieces of polarizing film are placed at 90 angles to each other.

cryosphere – The cryosphere is the area of Earth's surface where water is in solid form.

crystal lattice – A crystal lattice is the structure of an ionic solid in which orderly three-dimensional patterns of atoms are repeated over and over on one or more axes.

ionic – Ionic compounds are compounds in which the atoms are held together by ionic bonds. An ionic bond is a chemical bond in which one atom loses one or more electrons to form a positive ion and another atom gains one or more electrons to form a negative ion. The force of attraction between the positive and negative ions forms the bond.

isotropic – Isotropic materials have a crystalline structure where atoms are arranged in the same way along each axis.

polarized light – Polarized light waves are vibrating in one direction as they pass through or are reflected by certain media.

polymer – A polymer is a large molecule made of a chain of many smaller units connected by bonds where the atoms share electrons.

weather – Weather is the current state of the atmosphere, measured in terms of temperature, pressure, humidity, wind speed and direction, cloudiness and precipitation.

A. ENGAGE

Examine the six images below. Identify similarities and differences between the images. How do you think these images were created?

Figure 1. Credit: Peter Wasilewski, Frizion

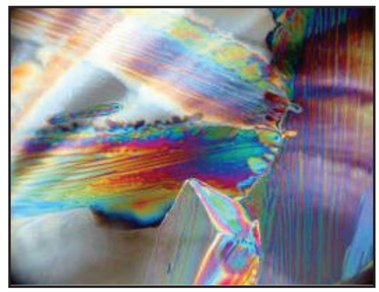


Figure 2. Credit: Peter Wasilewski, Frizion

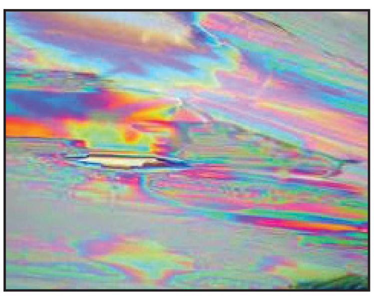


Figure 3. Credit: Peter Wasilewski, Frizion

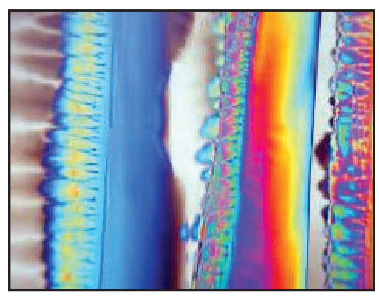


Figure 4. Credit: Peter Wasilewski, Frizion

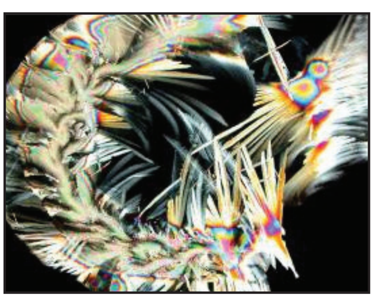


Figure 5. Credit: Peter Wasilewski, Frizion

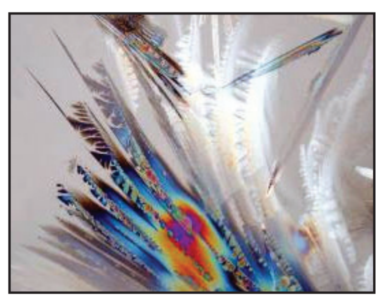


Figure 6. Credit: Peter Wasilewski, Frizion

EXPLORE

Explore how light travels through polarized films in this activity. Then, discover how different materials look through polarized light.

Procedure

1. Your teacher demonstrated light refraction and double refraction, also known as birefringence, using glow sticks and a beaker of water. Based on what you have seen in this demonstration, write a definition for birefringence. You may record your response in Table 1 on page 7 of your Student Guide.
2. Your teacher also demonstrated how cross-polarizers work by placing one piece of polarizing film on a light source and the second piece on top of the first. The bottom piece will be kept stationary while the top piece is rotated. Discuss with your group what you see.
3. Gather these materials for your group:
   - two 7.5 cm x 7.5 cm pieces of polarizing film
   - clear plastic CD case
   - light source such as a light table, overhead projector, or a large lantern flashlight
   - thin piece of mica (optional)
   - one 12.5 cm x 15 cm piece of polyethylene (optional)
4. Place one piece of polarizing film on the flat surface of the light source. Place the CD case on top of the polarizing film. Now lay the second piece of film over the top of the case. Rotate the top piece of film slowly, as demonstrated by your teacher. What do you see? Record your findings in Table 2 on page 7 of your Student Guide.
5. (Optional) Examine other materials your teacher has provided. Record what you see when these materials are viewed through a pair of polarizing filters in Table 2 on page 7 of your Student Guide.

EXPLAIN

The images you looked at during the ENGAGE portion of the lesson were all created by making very thin sections of ice, placing the ice between cross-polarizers, and taking a picture of the results. In this activity you will create your own images.

Procedure

Work together as a team to make your thin ice sections. Document your findings in Table 3 on page 7 in your Student Guide. Use a digital camera to take digital images of the ice sections.

STUDENT GUIDE

1. Gather the following materials from your teacher:
    - ice
    - hot plate
    - aluminum pie tin
    - glass slide that has been stored in a freezer (glass is necessary for proper adherence of the ice to the slide)
    - light source
    - two 7.5 cm x 7.5 cm pieces of polarizing film
    - paper towels for blotting as needed
2. Turn the hot plate on low and place the aluminum pie tin on it.

    NOTE: the hot plate should remain on this setting AT ALL TIMES. DO NOT touch the surface of the hot plate once it has been turned on.
3. Place an ice sample in the pie tin. Slide the ice around to flatten it. Flip the ice over and continue to slide the ice around until it forms into a thin section only a few millimeters thick.
4. Place the thin section of ice on the glass microscope slide and return it to the freezer for a few minutes.
5. While the ice sample is in the freezer, set one piece of polarizing film on the light source.
6. Retrieve the ice sample and place it on the film on the light source. Place the second piece of film on top of the ice sample and rotate it to obtain the best color definition. Document your results by taking a digital image.
7. To analyze your sample examine the pattern formed by the light. Large areas of a single color indicate that the ice crystals grew in a direction parallel to the plane of the ice section. Many small areas of color indicate that the ice crystals grew perpendicular to the plane of the ice section.
8. Describe what you observe. Characterize the crystal growth in Table 3 on page 8 in your Student Guide.
9. Repeat this process several times with different samples of ice. Be patient as it may take a few trials to perfect your technique.
10. Once you have completed four samples, clean up all materials and return them to their designated area.
11. If directed by your teacher, create a sequence of pictures that you think best illustrates the beauty and complexity of the ice samples you examined. Download the digital images you took to a computer or flash drive. Then,

using either presentation or digital video software, create a multimedia presentation with your images. Specific requirements for this presentation can be found in the Student Rubric on page 9 of your Student Guide.

EXTEND

1. Dr. Peter Wasilewski, NASA scientist, uses polarized light to create unique art forms he calls Frozen Visions or Frizion. You can find out more about his art at *www.frizion.com*
2. Create your own colorful artwork using polarized filters.
   a. Use sculpting or florist wire to create a wire sculpture.
   b. Cover the sculpture with layers of cellophane tape. Use the tape like you would strips of paper Mache to make the sculpture three-dimensional.
   c. Place the sculpture in front of a stationary polarized filter. Ask someone to shine a bright light through the filter from behind. Rotate a second filter in front of the sculpture until the brightest color patterns are visible.
   d. Ask someone to document your dazzling display using a digital camera.
   e. Display the pictures or create a multimedia art show of the different sculptures.
3. How else do scientists and engineers use polarized light or birefringence? What applications for this technology do you see in your everyday life?

EVALUATE

Examine the cross sections of lake ice vs. rink ice below. Why do you think the crystal sizes are different?

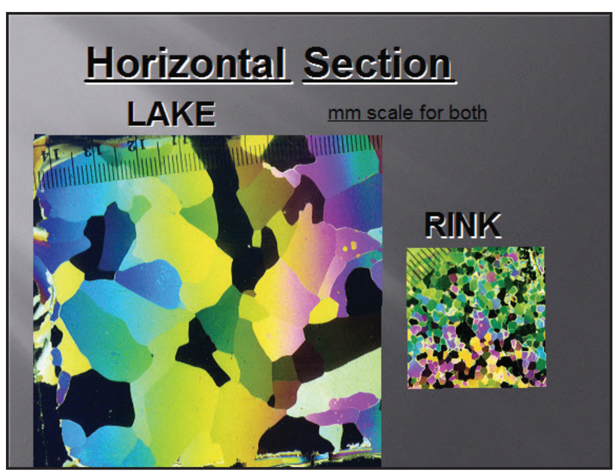


Figure 7: Horizontal Ice Sections,
Image credit: Dr. Peter Wasilewski, NASA Goddard Space Flight Center

STUDENT GUIDE

Table 1. Explore Journal

THINK, PAIR, SHARE
My definition of birefringence:
My partner's definition of birefringence:
Our final definition of birefringence:

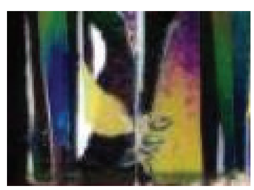
Table 2. Polarized Light Observations

CD Case	**Observations/Characteristics/Sketches**
Other Materials	

Table 3. Ice Observations

Ice Sample	Observations/Characteristics/Sketches
Sample #1	
Sample #2	
Sample #3	
Sample #4	

Table 4. Criteria for evaluating ice samples

Color	Orientation	Conditions
Large areas of a single color	Growth along the horizontal "c" axis 	Cold lake conditions with winds causing crystals to form around particles of dust, snow or ice
Many small areas of different colors	Growth along the vertical "c" axis 	Very cold, calm conditions allowing large crystals to form and spread rapidly across the surface

STUDENT GUIDE

Colors of Ice - Student Rubric

Tasks may be modified to fit individual class assignments.

Criteria / Task List	Score
1. Descriptions of birefringence Figures 1 - 6	
2. Birefringence definitions and cross-polarizer activity completed	
3. Thin section 1 made and four digital images taken	
4. Thin section 2 made and four digital images taken	
5. Thin section 3 made and four digital images taken	
6. Thin section 4 made and four digital images taken	
7. Descriptions of thin section 1 images included	
8. Descriptions of thin section 2 images included	
9. Descriptions of thin section 3 images included	
10. Descriptions of thin section 4 images included	
11. (Optional) Images, descriptions, and music or audio track included in multimedia presentation	
12. (Optional) Images, information, audio for multimedia presentation combined in a creative manner	
13. (Optional) Copyright and complete references for music and other resources used in multimedia presentation included	
14. Demonstrated appropriate activity procedures	
15. Effectively used class time to accomplish tasks	
16. Used teamwork skills during assignments	
17. Used lab materials appropriately	
Total Score – 56 pts maximum (68 pts if steps 11-13 done + up to 17 bonus pts)	

Scoring

5* Presented material, procedures, and understanding BEYOND the requirements

4 Tasks accomplished completely; well-polished/attractive presentation

3 75% complete; usually neat and organized presentation

2 50% complete; somewhat disorganized presentation

1 Only 25% of work finished; disorganized presentation

0 No evidence of criteria; off task behaviors during project time

*Bonus points - above maximum score