

Pinhole Viewers

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Constructing the pinhole viewers engages the students in a memorable design technology activity to learn how light travels.

Grade Level: 3rd grade (2nd – 4th grade)

Time Required: 60 minutes

Group Size: Whole class will work together, but students can pair up during viewer construction.

Summary:

Light is something that we encounter in everyday life, allowing us to see images, colors and shapes. This lesson will focus on solidifying the concept that light travels in a straight path, and students will first learn how light bouncing off objects actually travels in straight lines. The lesson will then go on to demonstrate that if these beams of light pass through a small aperture, a coherent image can be produced. This is in fact how our eyes work, as our pupils act as the small holes allowing us to see our surroundings. Each student will construct their own simple pinhole viewer that will give a hands-on example of how this property of light works, and will then have the opportunity to create their own images. Using hands-on investigating skills students will learn that the pinhole viewer, like their eye, is a light detector, and that light reflects off objects in straight lines in order for the object to be seen.

Keywords/Vocabulary

Reflection: The process by which light bounces off a surface, returning to the side of the surface from which it came

Image: An optically formed duplicate or representative reproduction of an object. This is created by manipulating light using mirrors, lenses, or pinholes, so that the light falling on an observer's eye or on a screen appears to be originating from a copy of the object, often displaced from its true position and altered in size (magnified) or orientation (inverted).

Magnify: Make the image appear larger.

Inverted: Flipped upside-down or upside-down as well as left-to-right.

Aperture: A small opening limiting the passage of light.

Educational Standards

- Science: 3.1 Observe that light travels in a straight line until it strikes an object and is reflected and/or absorbed
- Math: 3.01 Use appropriate vocabulary to compare, describe and classify two and three-dimensional figures.

Pre-Requisite Knowledge

Students should have a general understanding of what exactly light is. They do not need to understand its exact properties, but they should already know from previous lessons that it is created from a light source, can travel to an object and bounce off of it into their eye so that they can see it. Many of these ideas will have been discussed in Activity 2, “Light in Space,” and will be reinforced here.

Learning Objectives

After this lesson, students should be able to:

- Explain how light travels in a straight line and is able to bounce off reflective objects.
- Understand that images are produced by light that passes through a small hole (aperture).
- Demonstrate how their pinhole viewer is able to produce an inverted image.
- Show how they can change the size of the pinhole viewer image by moving the screen closer or further from the pinhole.
- Use their viewers to view various objects, and enjoy!

Expendable Cost per Group ~5 dollars per class

Materials List

Each student needs:

- 1 Pinhole Viewer lab sheet (Appendix A)
- 1 Styrofoam cup (8 oz.) with bottom
- 1 Styrofoam cup (8 oz.) without bottom

- 1 black construction paper circle cutout (see Appendix B, Shape A)
- 1 black construction paper crescent cutout (see Appendix B, Shape B)
- 1 4" x 4" wax paper cutout

Each group needs:

- 1 sharpened pencil to make pinhole (a thumbtack, paperclip, or other thin object will work)
- 1 roll of scotch tape

Activity Background:

The simple pinhole viewer students construct creates an image of objects in front of the viewer on a screen of translucent wax paper. If we hold a sheet of wax paper up we can see through it, but the outlines of objects are fuzzy, because light penetrating through the paper is often deflected from its original straight-line path. More importantly for us, if we shine a flashlight at the paper, we can observe the bright spot on the paper even if we are not looking at the light, but at an oblique angle. If the light is colored, the bright spot will have the same color. Looking at the paper, we see at each point on it the color of the light hitting that spot.

If we hold the paper up and look at it, absent a flashlight, it appears uniformly white. Essentially, light from every direction, and hence essentially of all colors, is hitting each point on the paper, causing the light diffusing through the paper to be uniformly white.

To form an image on the paper, we need to set things up so that the light hitting a particular point on the paper will be light from a particular direction only. Then this point on the paper will take on the color of whatever object lies in that direction. Observing the paper we will then see an image of objects in front of it, different points on the paper corresponding to different directions.

In our viewer, this is achieved by passing light through a pinhole. As the figure below shows, when light is forced to pass through the pinhole to reach the paper, only light from the top of the object can reach the bottom of the paper, and only light from the top of the object can reach the bottom of the paper. The same is true for left and right, not represented in the figure. Altogether, this creates an inverted image of the object on the paper. As the figure also shows, moving the paper farther from the pinhole creates a larger image.

Images can also be produced using a lens or a mirror to bend the paths of light beams. The advantage of using a lens is that one can form an image using light passing through a larger aperture and hence obtain brighter images. The Additional Activities "Mirror Mazes" and "Jello Lenses" contain suggestions for more work in this direction.

Another interesting extension is to note that our eye works by creating images as well. The lens forms an (inverted) image of the world in front of us on the retina. Instead of wax paper, this image forms on a bed of light-sensitive cells which respond to the brightness and color of light hitting them. The information from each individual cell is processed by the brain to form our mental image of the world.

Finally, in a camera the wax paper is replaced by film which, when exposed briefly to light, responds by “freezing” the pattern of light and colors, preserving the image for later use. There are a few more details here, the extension activities include more detail.

Preparation: Getting Ready

- Copies of the worksheet Appendix A are required for each student
- Cut-outs of a crescent and circle from black construction paper need to be made – 1 each for every student. The template for each of these shapes is available as Appendix B, or tracings could be drawn onto the construction paper as well. The crescent will be rolled to cover the inside of one cup, and the circle will cover the inner bottom of the same cup.
- Cut out the bottom of one Styrofoam cup for every student. A sharp, unserrated blade works best to get a clean cut

Make your own pinhole viewer before hand to understand what possible problems your students may encounter, and to have an example to display. When looking through a viewer for the first time, the bright spot of light formed where light from the pinhole hits the paper, is distracting. It is important to look *at* the wax paper and not *through* it. Having some familiarity with this will be helpful in getting students to see the images.

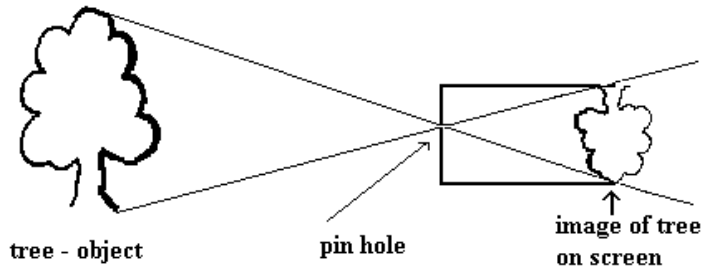
Activity Procedure: Part 1. Science Notebook Intro

Before beginning, jog the students’ memory by helping them recall what was discovered about light and shadows during the last lesson. As an introduction, ask the students to briefly respond to at least one of the following questions in their science notebook:

- 1) Draw a picture or explain how the light from a lightbulb can let you see what it is pointing at (try to identify what is making the light, where the light is going, and how the light is moving)
- 2) How do you think a camera works?

After the students have written their responses down, ask for students to volunteer answers. Try to guide the students in their responses to the first question to cover the facts that the light bulb creates the light, the light bounces off the object, and that the light bouncing off then enters your eye.

To help explain the second question, draw a picture similar to the following on the board. Begin with just the tree on the left and the screen on the right:



Source: www.uq.edu.au/_School_Science_Lessons/28.9.0.GIF

To explain how a camera works, start first by drawing various lines from one spot on the tree to the screen where the image is supposed to be while pretending there is no pinhole for the light to pass through (the lines can go everywhere). Stress that all the light coming from the tree has to travel in a straight line, that is, the lines coming from the tree need to be straight. If this was not true, then light from behind a wall could curve around it to allow us to see what is behind it! After demonstrating that no image is produced without a pinhole, add the middle component above to your picture. Drawing lines only through the pinhole, show how light lines coming from spots at the top of the tree have to go to the bottom of the screen and vice-versa. Have students come up and draw their own straight light rays from the tree through the pinhole to the screen, and finally complete the image on the screen by drawing an upside-down tree. As students will probably wonder why the tree is upside-down, explain that they will see for themselves that the images they will observe with the pinhole viewers will actually be upside-down, and begin to introduce the activity.

Up until now, an explanation of the mechanisms through which a pinhole viewer works has been given, but what exactly the viewer is still is somewhat of a mystery. Before construction, briefly tell the students exactly what type of viewer they will be working on. A pinhole camera is the simplest type of camera, as it only needs an aperture to work. The pinhole viewers the class is about to make are essentially pinhole cameras without any film to record an image. Film has the ability to “freeze” whatever light hits it in a short period of time, so that light is visible for a long time. Here, the screen just displays the light that is hitting it in real time.

Activity Procedure: Part 2. Viewer Construction

1. Distribute the materials to the students.
2. Following along with the worksheet, proceed step-by-step with the class. Try to make sure no one gets too far ahead, **and that no one attempts the last step alone** (poking the hole).
3. Have the students work with a partner when attaching the wax paper to the cup without a bottom. One student can hold the wax paper in place while the other tapes it to the outside of the cup. **Try to keep the wax paper as flat and unwrinkled as possible.** The less wrinkles there are, the easier it will be to see an image.



Partners assist one another to tape down the wax paper keeping it as flat and unwrinkled as possible. Teacher monitors taping and supports teamwork.

4. When it is time to poke the pinhole in the bottom of the cup it is recommended that each group waits until you can help them. **The hole should be small,** allowing just a point of light to be visible through. Additionally, the hole needs to be poked all the way through both the Styrofoam and the circle of construction paper on the bottom.
5. After the viewers are made, have the students look at bright objects that are around 10 feet away:
 - Fluorescent lights and windows in the classroom are easily visible
 - Movement is easily seen, so waving a hand in front of a light works
 - Turning on an overhead projector and having someone move in front of the light creates a shadow that is usually visible
 - If it is sunny outside, looking at bright color contrasts outdoors from inside the classroom is probably the best source of images.



As each student finishes and before heading outside check their pinhole viewer construction. Inform your students that they may need to adjust their pinhole's design as they use it.

Attachments

Appendix A, B contain step-by-step instructions for making viewers and templates for the construction paper cutouts.

Safety Issues

- Use caution while using a sharp object to poke a hole in the cup
- Make sure the students do not look at the sun with their viewers. It is a bright object, but its intensity is damaging for the eyes.

Assessment

Pre-Activity Assessment

Two general questions about light travel and how a camera works for science notebook.

Activity Embedded Assessment

- *Can you recognize what you are looking at? Is it upside down or right-side up?*
- *What happens to the picture when you move the screen farther back from the hole by pulling the cup out?*
- *Draw a tree with light rays from the top and bottom going through an aperture. Draw the picture of the tree on the screen as we would see it.*
- *Draw the picture again when the screen is moved further back.*

Post-Activity Assessment

- *Who noticed that their images were upside-down? How did you know they were upside-down?*
- *When was it easiest to see an image on the screen (wax-paper)? Why do you think that is?*
- *Did moving the cup with the screen change the image at all?*
- *Was anyone able to make the images they saw bigger or smaller with their viewer?*

Homework

- *None. However, the students should be encouraged to hang onto their pinhole viewers so that they can play with them later.*

Activity Scaling

- For lower grades, less background information about light and the way the viewer works.
- For upper grades, more background. A pinhole camera with actual film could be created with students a bit older, but another construction method is necessary as the film needs to be completely sealed from light before and after a picture is taken.

Lesson Extension Activities

The Exploratorium, an amazing science Museum in San Francisco, provides an easy to construct family project or classroom centers project with a volunteer to make a **Pringles Can Pinhole Viewer**. Check it out at

http://www.exploratorium.edu/science_explorer/pringles_pinhole.html

For more light activities check out the science Snacks Section of the Exploratorium's website. Science Snacks are very engaging easy to prepare one-time lessons for your class. Try out the activity, **Blind Spot**, to discover where the part of your eye's retina that doesn't give you visual information is located:

http://www.exploratorium.edu/snacks/blind_spot.html

Additional information and research about the Sun to help both you and your students can be found using a virtual tour at the Yokoh Outreach Project, a partnership of NASA, Lockheed Martin and Montana State University

<http://www.lmsal.com/YPOP/Spotlight/Tour/index.html>

Additional Multimedia Support/ Relevant Websites

If you or your students are really interested they can be encouraged to create an actual pinhole camera with film. More information can be found at:

http://www.exploratorium.edu/light_walk/camera_todo.html

- A gallery of pinhole camera pictures on film is viewable at: www.pinhole.org
- A brief history of pinhole cameras: <http://www.photo.net/learn/pinhole/pinhole>
- More general and technical information on pinhole cameras:
http://en.wikipedia.org/wiki/Pinhole_camera
- Materials to build an actual pinhole camera available at:
<http://www.pinholeresource.com/>

References

Tomas Charles Edison Fund Example Experiments at

<http://www.charlesedisonfund.org/Experiments/HTMLexperiments/Chapter5/5-Expt6/p1.html>

Arizona Collaborative for Excellence in the Preparation of Teachers Pinhole Camera Activity at <http://accept.la.asu.edu/PiN/rdg/lightpath/lightpath.shtml>