Dumpster Optics

LIGHT AND SHADOWS

(Adapted in part from Tutorials in Introductory Physics, McDermott and Schaffer, 2002)

CAN YOU DESCRIBE HOW LIGHT TRAVELS AND USE THIS MODEL TO SHOW HOW A PINHOLE CAMERA WORKS?

In this lesson, you will predict what will be seen on a screen when light goes through a triangle shaped hole. You will learn how light travels and how a pinhole image is formed.

MATERIALS:

Activity 1, How Does Light Travel?

- Cardboard square with triangle hole about 1 cm on a side cut in the center
- Small light source like an LED key chain light or bare flashlight bulb (like a Maglight bulb), We'll call these "point" sources of light. The original directions for this type of experiment called for flashlight bulbs in tiny holders, common in science laboratories at the time. If you have these feel free to use them.

Activity 2, Two Light Sources

- Same as Activity 1, but add a second bulb preferably of a different color. Colored plastic or a very thin balloon can be wrapped tightly around a bulb to make a second color.

Activity 3, Pinhole Image:

- Replace the small point sources of light with a bulb with a long filament, like the kind used in fish tanks or display cases. If you can't find one, try a flashlight but cover the most of the front glass with tape so that it becomes a "line" source of light. You can use any bare filament bulb (like a candelabra bulb), but the straight filament best extends the idea of a straight line of sources.

Activity 4, Pinhole image viewer:

- Empty carton, size not important but at least 25 cm on a side,
- Transparency or waxed paper
- Aluminum foil
- Sharp pencil
- Tape (black electrical tape as needed)

Where to find materials: The easiest point sources of light to use are key chain LED lights. These can be purchased from Amazon sellers like LightsCastle (10 for about $4-$5). LED finger lights work well too, and are very inexpensive (look for dealers selling lighting for dances such as Etekcity on Amazon.com (100 for $18). Long filament bulbs are sold in pet stores and most suppliers of lighting. The best ones for this activity have clear glass so you can see the filament.

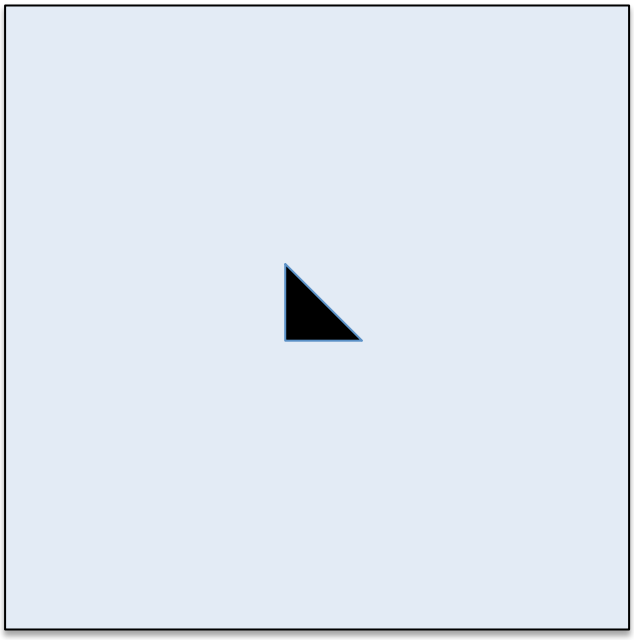
OPTIONAL ACTIVITIES: Everyday Pinhole Images and Oatmeal Box Pinhole Camera (requires film development). Slides for optional activities have a pink background.

VOCABULARY:

- Illuminate
- Ray
- Shadow
- Point source of light
- Pinhole image

TEACHER NOTES:

Each group of students needs a piece of opaque paper or cardboard with a small triangular hole cut in the center. You can use the drawing below as a template. Dimensions aren't critical, but the triangle should be less than 1 cm on the short sides. Dark construction paper or thin cardboard is fine for this activity. The cardboard with the triangular hole will be referred to as the *cardboard mask*. The room doesn't need to be exceptionally dark but for viewing dim images it's best not to have too much competing light. Experiment!



ACTIVITY 1 – HOW DOES LIGHT TRAVEL?

Place the cardboard with the hole about 30 cm from a plain wall or screen, and the point source of light about 30 cm to the other side. (See the PowerPoint slides for a diagram.) An LED key chain makes a good point source of light for this activity. What you need is a very small source of light that spreads in all (most) directions. A plain painted wall or whiteboard makes a good screen.

Be sure students make predictions by drawing what they expect to see before trying each step. If the predictions are incorrect, students should figure out why before proceeding to the next step.

The size of the triangle of light on the wall or screen depends on the exact distances to the light source and the wall. The orientation of the triangle on the wall should be the same as the mask, that is, the triangle of light points in the same direction as the cutout triangle.

Moving the bulb up (toward the ceiling) causes the triangle of light to move down (toward the floor). Moving the bulb down causes the triangle of light to move up. Students should observe that light travels in a straight line from the source (LED) through the hole in the mask to the wall. The path of the light is called a “ray”. Other rays leave the bulb traveling in different directions but they are blocked by the cardboard and do not contribute to the light seen on the screen. You might ask students what happens to light that is traveling toward the cardboard but not toward the hole.

The PowerPoint slide show animates the ray. Show the animated ray after students have made their drawings by viewing the slide as a "slide show".

ACTIVITY 2 – TWO LIGHT SOURCES

Repeat Activity 1 but with TWO different color point sources of light, one above the other. Based on the previous activity, students should understand that they will see two triangular patches of light. If two color LEDS are not available, wiggle the top ONE slightly so it’s clear which bulb is producing which patch of light.

Each added bulb produces its own triangular patch of light. It’s difficult to position more than two bulbs in front of the mask, but you can try. The bulbs need to be one above the other in a straight line- difficult to do with three people holding three bulbs. As more bulbs are added, more triangular spots appear stacked one upon the other, all in the same orientation. The bottom of the “stack” of spots is still flat and the top is triangular.

ACTIVITY 3 – PINHOLE IMAGE

It would be difficult to stack that many bulbs so closely, but we can use a single straight-line source of light (a long filament bulb) instead.

A faint image of the filament will appear on the wall. Any “wiggles” in the filament will be visible. The bottom of the image on the screen should be flat and the top slightly pointed- but this may be difficult to see. Have students look for these features. Note that the image is upside down; the top of the filament is imaged at the bottom of the screen (where the image should be flat due to the triangle hole). Since the bulb is very bright it might help to shield the back and sides (that don’t contribute to the image). Use heavy cardboard, or put the lamp in a box with one side left open. SAFETY NOTE: The bulb is hot; be sure it doesn't touch anything flammable. Young children should not handle the bulb.

If you don't have access to a long filament bulb, use a flashlight with black tape (or foil) masking all but a thin line of light. Because flashlights differ, try this first to be sure you have enough light to create an image. If not, cut a narrow line of foil or other opaque material and tape it over the center of the bulb. You will see an image of the line. If you cut an arrow into one end of the foil, you can verify that the image is inverted.

If you are able to darken the classroom, you can try making a clearer image of the bulb by using a mask with a smaller hole. Experiment with holes of different sizes. A large hole will make a bright image but it will be blurry. A small hole makes a clearer image but it will be very dim.

ACTIVITY 4 – MAKE A PINHOLE VIEWER

It is easiest to image bright sources like light bulbs, but you can try an outside scene viewed from a dark room. To keep the room dark, close all but one window shade and stand on the opposite side of the room, so the viewing screen is in dim light. Experiment! A video showing how to make and use the pinhole viewer can be found at https://www.youtube.com/watch?v=iF4qq39NsGY

An alternate pinhole viewer uses the inside wall of the box, opposite the pinhole, as the viewing screen. Do not cut the large square hole on this side, but tape a piece of white paper on the *inside* to use as a screen. In this case leave the top of the box open. To see the image, hold the box upside down over your head, point the pinhole at the light source and see the image on the inside white paper. It's awkward, but it makes a sharper image than waxed paper.

OPTIONAL ACTIVITY – PINHOLE IMAGES IN NATURE

Walk around outside and look at the patches of light under leafy trees. Can you spot the overlapping round shapes? The small openings between leaves form pinhole images of the sun on the ground. Inside, the sun shining through a grouping of leafy houseplants or the small holes of eyelet lace curtains can also create pinhole images. Some photos of images of the sun created by houseplants are here http://www.lasertechonline.org/optics/photos/assorted pinhole images/solar_images_by_houseplants.html

During an eclipse, the solar images are crescent shaped. In fact, one of the safe ways of viewing an eclipse of the sun is to create a pinhole image. (NEVER look directly at the sun without dark filters approved for solar viewing- not regular sunglasses.) You can purchase an "eclipse viewer" pinhole viewer but it's easy to make one yourself. Use the same method to create a pinhole in aluminum foil as in this lesson. Instead of a carton, place the pinhole over a hole in a large piece of cardboard. With the sun behind you, allow sunlight to fall on the pinhole. Allow the light passing through the pinhole to form an image on a piece of paper on the ground. NASA has complete instructions here http://www.jpl.nasa.gov/edu/learn/project/how-to-make-a-pinhole-camera/

OPTIONAL (ADVANCED) ACTIVITY – PINHOLE CAMERA

You really need a photographic darkroom for pinhole photography, both for loading and developing the film. (I use my basement at night.) There are a lot of instructions online for making oatmeal box cameras. Here are step-by-step instructions: http://users.rcn.com/stewoody/

The box must be light-tight so the ONLY way for light to enter is through the tiny pinhole. Spray paint the interior flat black and cover any cracks or holes with black electrical tape. For a small oatmeal box, the pinhole is about 0.5 mm diameter. (There are calculators online if you want to be particular but in our experience it isn't critical as long as the pinhole is less than 1 mm in diameter.) The pinhole is made with a needle, drilled into a piece of soda can. To make a drill, stick the eye end of the needle into the end of a pencil eraser so the pencil is the holder. Detailed instructions are in the rcn.com/stewoody web site.

Black and white film paper is loaded into the box in a darkroom. (Covering the top of an oatmeal box with foil before taking it out provides an extra measure of light block.) The exposures are several seconds outside in the bright sun to 20-30 minutes indoors. Liquid photographic developers (e.g. Ilford brand) are easiest to use in the darkroom. *Note that the used fixer is considered hazardous waste in some jurisdictions because it contains silver.* It must be disposed of properly.

For more on pinhole cameras and some amazing photos, see http://www.pinhole.org There are some less amazing photos made by high school and community college students at http://www.lasertechonline.org/Pinhole_Photos.html