Dumpster Optics

LIGHT AND SHADOWS

(Adapted from K Wosilait, Heron P R L, Shaffer P S and McDermott L C, Development and assessment of a research-based tutorial on light and shadow, American Journal of Physics 66, 906-913 (1998) and the PHOTON Explorations in Optics, 2013)

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.

Activity 2, Two Light Sources

- Same as Activity 1, but add a second bulb preferably of a different 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, 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 or other opaque tape as needed)

OPTIONAL ACTIVITIES: Everyday Pinhole Images and Oatmeal Box Pinhole Camera (requires film development).

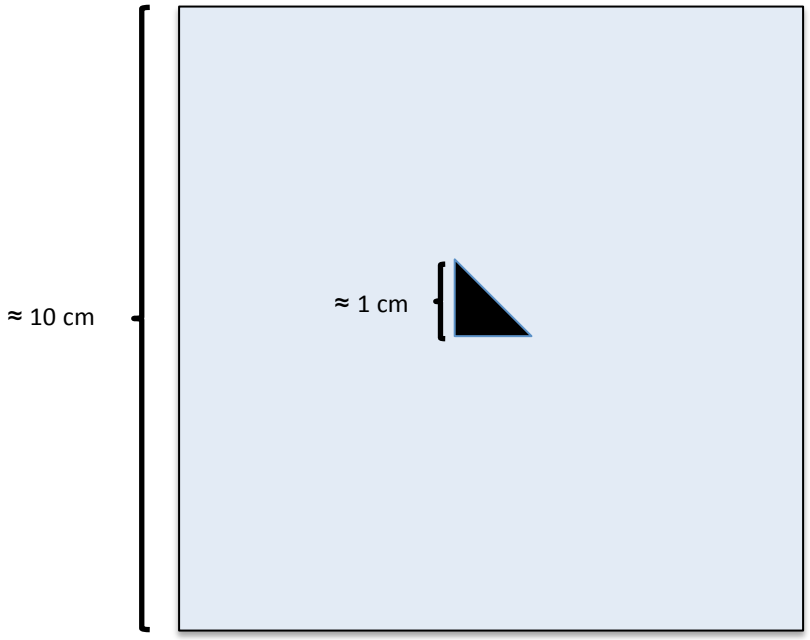
Where to find materials: The easiest point sources of light to use are key chain LED lights. LED finger lights work well too, and are very inexpensive (look for dealers selling lighting for dances such as Etekcity on Amazon.com. You can also use a bare flashlight bulb (no reflector), like a Maglite bulb. Long filament bulbs are sold at pet stores and most suppliers of lighting.

VOCABULARY:

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

TEACHER NOTES:

Each group of students needs a piece of opaque paper or cardboard (about 10 cm on a side) 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 no more than 1 cm on the short sides. Or try different size holes. (The image is sharper, but not as bright, with a smaller hole.) 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!



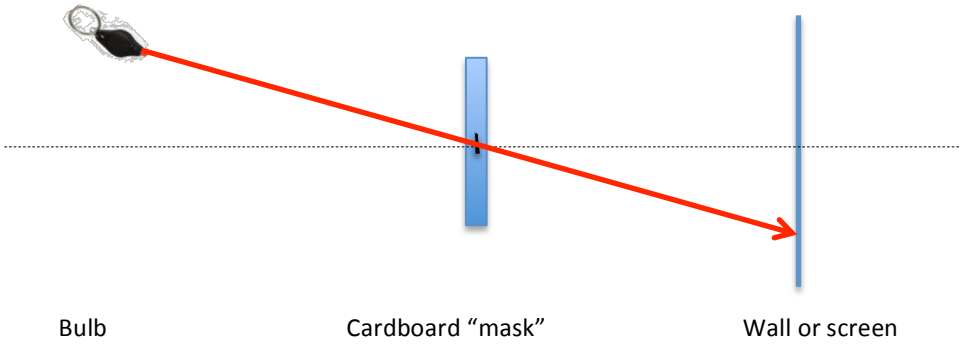
ACTIVITY 1 – HOW DOES LIGHT TRAVEL?

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 or tape a piece of white paper to a wall or large carton.

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 bulb 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.



ACTIVITY 2 – TWO LIGHT SOURCES

Repeat Activity 1 but with TWO 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. It's easier to see the effect if the bulbs are different colors. If two color LEDS are not available, wiggle the top one slightly so it's clear which bulb is producing which patch of light. You can also stretch a thin piece of color balloon over a white LED to create light of a different color, but it will be dimmer than the original 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. 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.

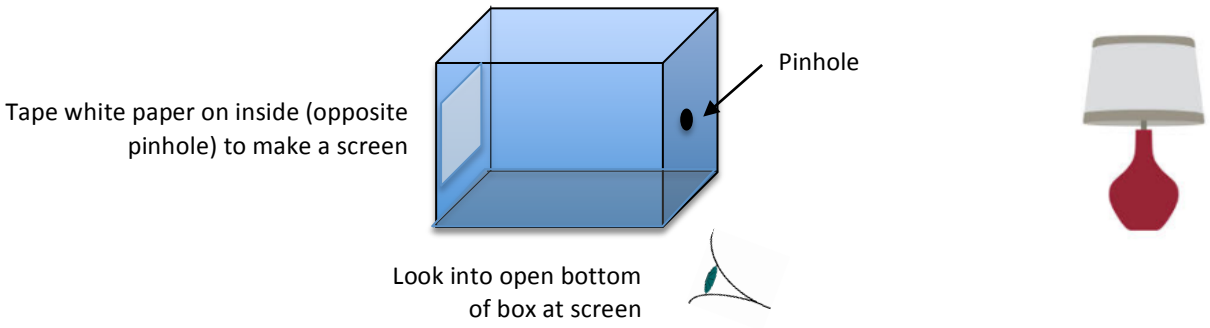
If you don't have access to a long filament bulb, use any bare filament bulb. You can also use a spiral compact fluorescent or even a large flashlight.

If you are able to darken the classroom, you can try making a clearer image of the bulb by using a mask with a different size 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. This short video shows the effects of different shape and size holes: https://www.youtube.com/watch?v=t4kkuf2fFcE

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 bottom of the box open. To see the image, hold the box 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. It works best with imaging something bright like a lamp.



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 of the sun. Some photos of images of the sun created by houseplants and leafy plants are in this list of photo links: http://www.lasertechonline.org/optics/optics_index.html

During a partial solar 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. Do not use 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. You can make an even better pinhole using a large needle or awl and a piece of aluminum cut from soft drink can. (Be careful of sharp edges!) 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 https://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 almost windowless 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 cut from a soft drink 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 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