WE ARE ON

OSA 100

Light & Shadows

with Judy & Nancy

#OpticsAtHome
#SeeTheLight

LET'S WONDER

Optics Magic with Judy & Nancy: LIGHT AND SHADOWS

HOW DOES LIGHT TRAVEL?
CAN YOU MAKE AN IMAGE (PICTURE) USING JUST A PINHOLE?
In this lesson, you will learn how light travels and how a pinhole image is formed.

MATERIALS:

Activity 1 - How Does Light Travel?

1. Cardboard square with triangle hole (see template on page 2)
2. Small light source like an LED key chain light or a bare flashlight bulb

Activity 2 - Two Light Sources (we will do this as a demonstration)

1. Same as Activity 1, but add a second LED bulb preferably of a different color. A very thin balloon can be wrapped tightly around a bulb to make a second color but the light will be much dimmer.

Activity 3 - Pinhole Image (we will do this as a demonstration)

1. Replace the small sources of light with a clear bulb with a long filament, like the kind used in fish tanks or display cases. You can use any bare filament bulb (like a clear appliance bulb), but the straight filament better represents the idea of a long line of tiny light sources.

Activity 4 – Make a Pinhole Image Viewer

1. Empty carton, size not important but at least 15 cm on a side
2. Waxed paper
3. Aluminum foil
4. Sharp pencil or ballpoint pen for poking a hole
5. Opaque tape (black electrical tape works well)

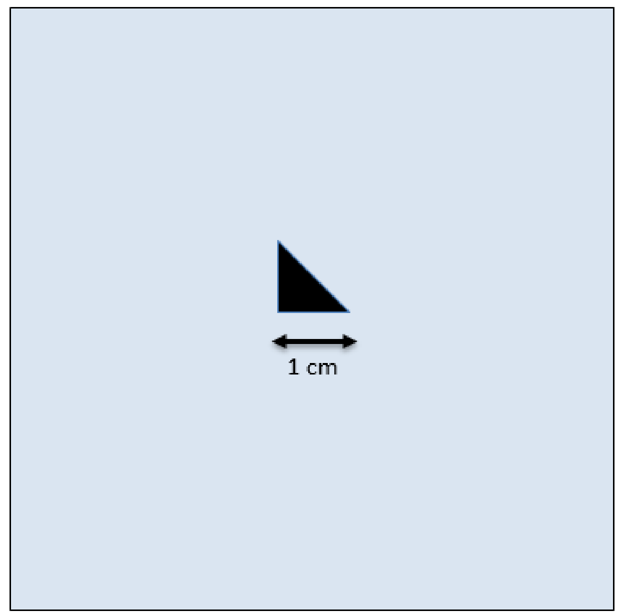
WHERE TO FIND MATERIALS:

1. The easiest point sources of light to use are key chain LED lights. LED finger lights work well too. They are very inexpensive, come in multiple colors and are available online and

in some dollar stores. The advantage of a set of finger LEDs is that you will have multiple colors- and can have a dance party afterward.
Before the availability of LEDs, we used flashlight bulbs. A Maglite® flashlight, if you have one, can be used in “candle mode”.

2. Long filament bulbs are sold in pet stores to light fish tanks. They’re also used in display cabinets. Clear appliance, candelabra or window candle bulbs work if a long filament bulb isn’t available.
3. Any small to medium size shipping carton should work. The larger the box, the larger (and dimmer) the image

PARENT AND TEACHER NOTES:
For the first activities you will need a piece of opaque paper or cardboard with a small triangular hole cut in the center. You can use as a template. Dimensions aren’t critical, but the triangle should be about 1 cm on the short sides. Dark construction paper or thin cardboard is fine for this activity. The piece should be large enough so light doesn’t “spill” around the edges but just goes through the hole. 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 small source of light about 30 cm to the other side. A painted wall makes a good screen. The room should be dark enough to clearly see the lighted patch on the wall.

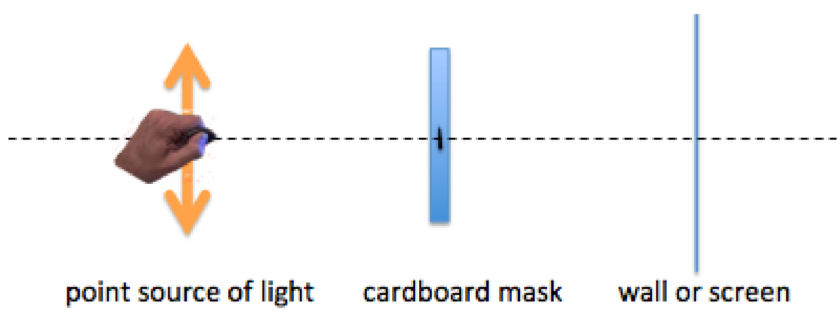


Figure 1 – Arrangement of mask, light and wall. The mask can be held by a second person or held by a stand made of Legos, or a binder clip, or a clip clothespin.

Children should predict what they expect to see before trying each step. If their predictions are incorrect, they should figure out why before proceeding to the next step.

The size of the triangle of light that appears 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 – 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. Explain that travels in a straight line from the light 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 don't contribute to the triangle of light seen on the screen.

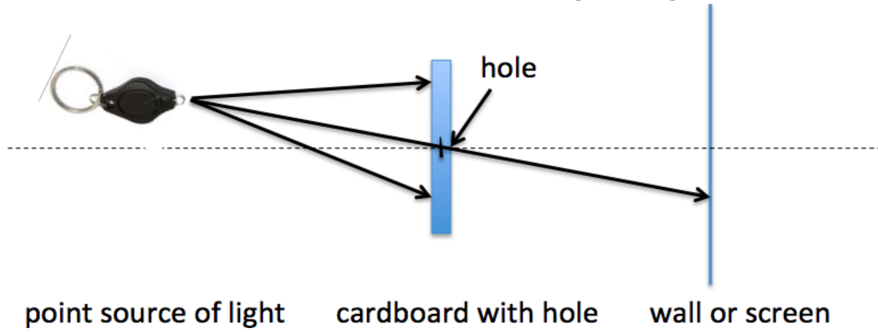


Figure 2 – Light travels in a straight line from the bulb through the hole to the screen. Some rays are blocked by the cardboard.

ACTIVITY 2 – TWO LIGHT SOURCES

Instead of holding one bulb (as in Figure 2), hold two bulbs close together, one above the other. Based on the previous activity, children should predict that they will see two triangular patches of light. If you have LEDs of two different colors you can see that the colors are reversed.

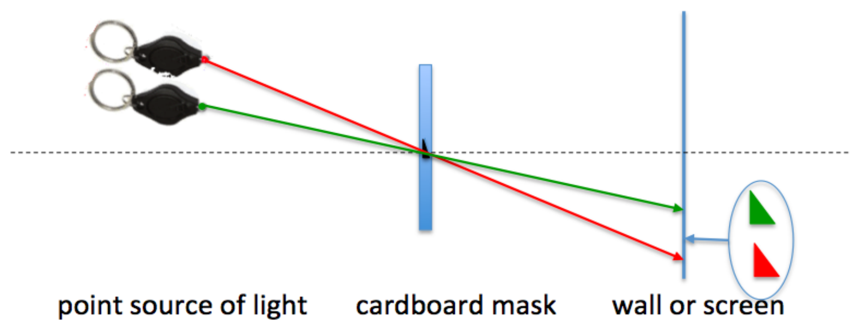


Figure 3 – The top LED makes the bottom triangle. The colors are reversed on the wall. Only one light ray is shown for each LED.

If you have a set of finger LEDs (and extra hands to help) you can try to see how many you can stack. Each added bulb produces its own triangular patch of light. 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. Ask what would happen if you put one bulb off to the left. (The triangle would appear on the right.)

ACTIVITY 3 – PINHOLE IMAGE

What would happen if you put 100 bulbs, one on top of the other? What would you see on the wall? (100 overlapping triangles – a kind of smudgy wide line that's flat on the bottom and pointed on the top.) Instead of trying to stack that many bulbs so closely, we can use a single straight-line source of light (a long filament bulb) that acts like a group of very small points of light all lined up. If you don't have a long filament bulb you can try any clear bulb where you can see the filament like an appliance bulb, a candelabra bulb or even a bulb from a window candle. Put the bulb in an appropriate light socket. It may require some rearranging of the mask and screen, if, say, the bulb is in a tall lamp.

A faint image of the filament will appear on the wall. Any "wiggles" in the filament will be visible. For a line filament, the bottom of the image on the screen should be flat and the top slightly pointed, but this may be difficult to see. Ask children if they can see these features. The image is upside down; the top of the filament is at the bottom of the image (where the image should be flat due to the triangle hole). Try to avoid looking at the bulb when it is turned on. SAFETY NOTE: The bulb is hot; be sure it doesn't touch anything flammable. Young children should not handle the bulb

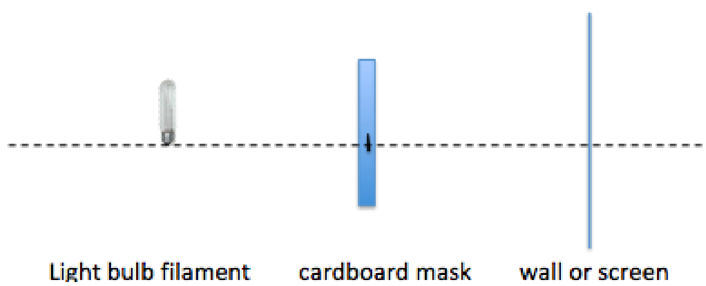


Figure 4 – A line filament is best (because it's easier to think of it as being a single line of tiny light sources) but any clear bulb will do.

ACTIVITY 4 – MAKE A PINHOLE IMAGE VIEWER

You can make a "camera" using just a pinhole. While actual pinhole photography requires a darkroom and developing chemicals this experiment shows how an image can be formed using just a pinhole. The resources section (below) has links to videos showing the process of making a pinhole viewer as well as pinhole photography and some pinhole photos.

The box that you choose should be fairly light-tight. Something like a small shipping box is fine. Cover any small holes (for example, in the box corners) with opaque tape. Electrical tape works well. Close up the box and seal it securely, blocking any possible light holes with tape. Cutting the holes in the carton is probably a job for adults. You can use scissors or a box cutter. In the middle of one side of the carton cut a square hole about 2-3 cm. On the opposite side cut a larger 10-15 cm hole. Tape a piece of wax paper over the large hole. This will be the "screen".

To make a pinhole, tape a piece of aluminum foil over the small hole. Be sure it's tight and smooth. Use a sharp pencil, pen, or even the end of a paper clip to poke a very small hole in the center. (You can always make it a bit bigger if the image is too dim.) The hole should be 2-3 mm across. If it's too big the image will be blurry. If it's too small the image will be too dim to see.

Figure 5
A pinhole viewer made from a cardboard carton.
The side opposite the pinhole is the viewing screen (See Figure 6.)

To use the "camera", point the pinhole toward a bright light source, like a bulb or lamp. You should see an image form (upside down) on the screen. It's best if the room is darkened except for the light you're using to image. In the evening, you might even be able to image the outside! Keep the room lights off and point the pinhole toward a window. The tops of trees should be visible against the bright sky.

Figure 6
A compact fluorescent bulb was made with a cardboard carton pinhole viewer.

An alternate pinhole viewer uses the *inside* wall of the box, opposite the pinhole, as the viewing screen. Don't cut the large square hole on the side, but tape a piece of white paper on the *inside* of the box 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.

ACTIVITY 5 – PINHOLE IMAGES IN NATURE
Walk around outside and look at the patches of light under leafy trees. Can you spot the overlapping round patches of sunlight? The small openings between leaves form pinhole images of the sun on the ground. A link in the resources section has several solar images "taken" by plants, including some during an eclipse when 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.

RESOURCES
1. The Dumpster Optics Power Point slides for classroom use for this lesson
2. Video on how to make a pinhole viewer including a video in Spanish
3. Pinhole photography with an oatmeal box camera
4. Pinhole images taken by trees and other plants