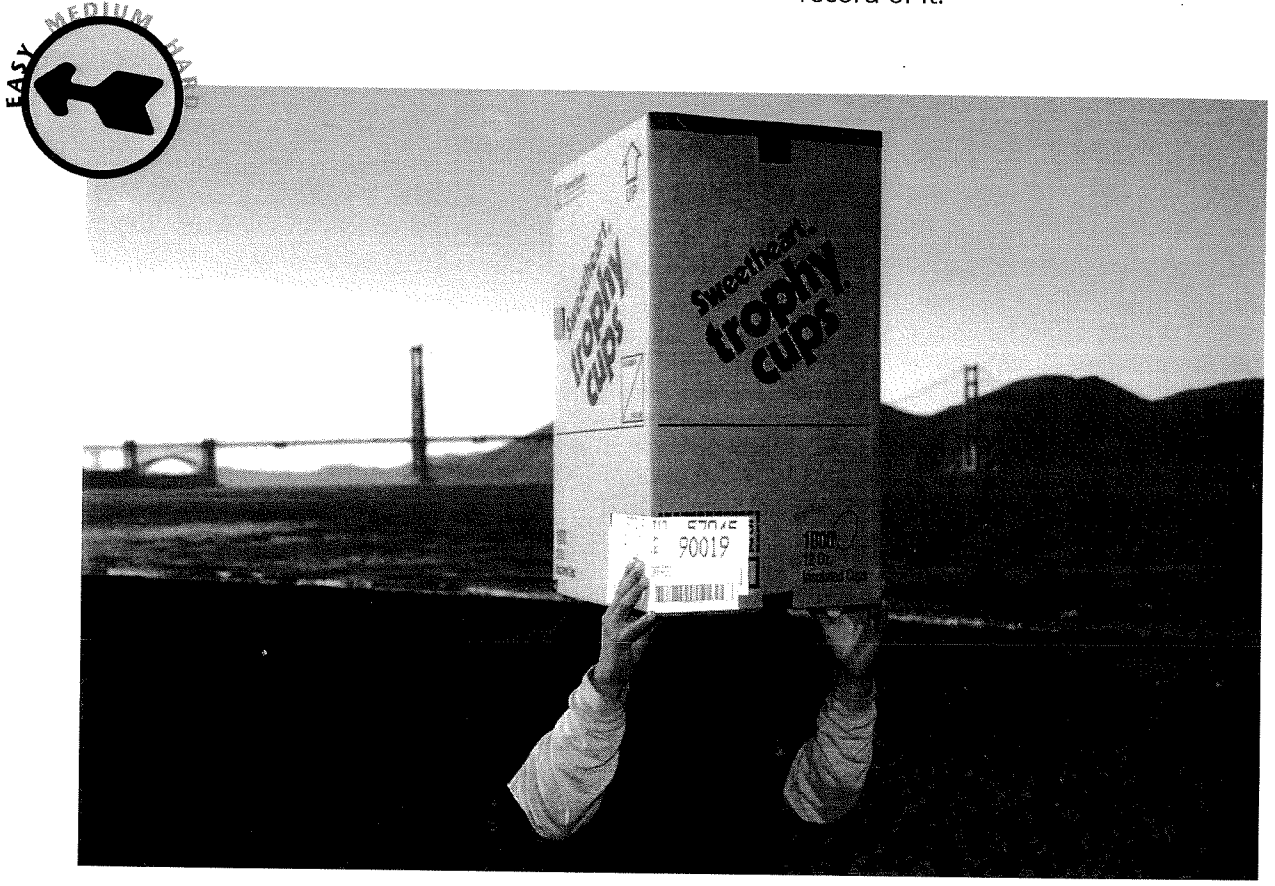
Personal Pinhole Theater

A pinhole camera you can really get into.

Have you ever heard of a camera without a lens? Or without film? In this snack you put your head in a large, dark box with a hole poked in the side. You view an image on the inside wall of the box that is essentially the same as the image formed on the film in a regular camera, except that there will be no permanent record of it.



Materials

- masking tape
- white paper, a few sheets
- large cardboard box (large enough to give you a foot of headroom inside when you rest it on your shoulders)
- utility knife
- scissors
- aluminum foil
- duct tape
- pushpin
- dark sweatshirt or towel
- pencil

ASSEMBLY

1 Before you read on, take a good look at figure 1 to get an idea of what you will be doing with the box.

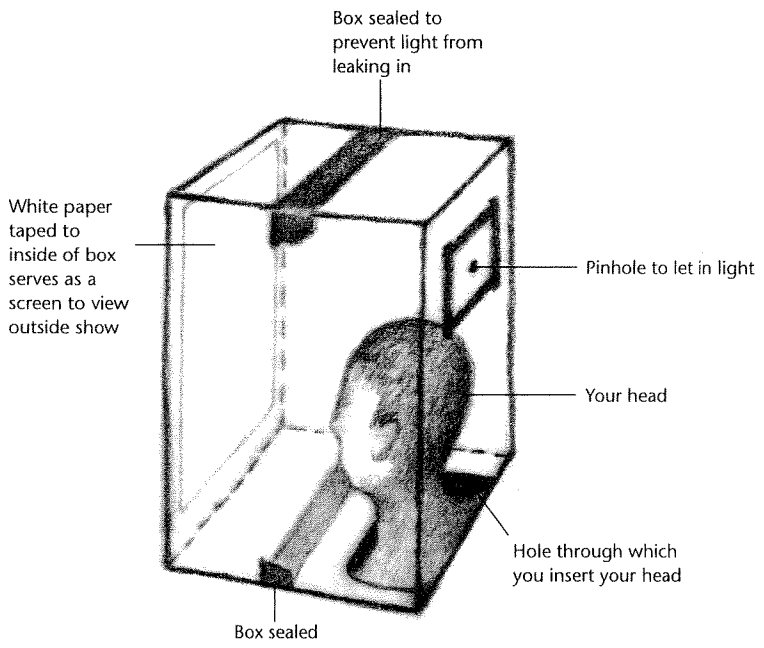
2 Tape sheets of white paper onto the inside wall of the box that you will be facing when your head is in the box. This will be the viewing screen.

3 Cut a small opening approximately 3 inches square (7.5 cm × 7.5 cm) in the side of the box opposite the screen, well above where your head will be (see figure 1). This is where the pinhole will be located.

4 Use the knife to cut a hole in the bottom of the box, through which you can put your head. Position this hole so that the back of your head will rest against the wall that is opposite the screen. The hole should be just big enough for your head to slip through, as shown in figure 1.

5 Cut a flat square of aluminum foil about 4 inches × 4 inches (10 cm × 10 cm). Make sure this piece of aluminum is large enough to cover the opening you cut in step 3. Use masking tape to tape the piece over the opening.

Figure 1



Here's what a completed Personal Pinhole Theater looks like.

6 Put the box on your head and check the corners and seams for light leaks. Use duct tape (or masking tape and aluminum foil) to seal any leaks you find. Don't worry for now if light is leaking in around your neck.

7 Use the pushpin to poke a pinhole in the center of the piece of aluminum foil. (A pushpin is best as it has a larger diameter than a straight pin.)

To Do and Notice

Find a well-lit area (outside on a bright day is great) and put your head into the box. Position your head so that you are facing the screen. Wrap the sweatshirt or towel around your neck to keep light from leaking into the box from the bottom. As your eyes adjust to the dim surroundings, notice if anything appears on the screen.

When images do appear, notice their orientation. Are they right-side up or upside down? Are they left-right reversed or normal?

Move around and notice how the images on the screen change. Try to position yourself so that two similar objects at different distances away (for example, two cars) cast their images on the screen at the same time. Which image is larger? Are both images in focus at the same time?

After you have had a chance to use your Personal Pinhole Theater for a while, try enlarging the pinhole significantly by carefully poking a pencil through it until it is about half to two-thirds the diameter of the pencil. What happens to the image on the screen as a result? (If you want to go back to the small hole, you can tape foil over the large hole and poke a new small hole with the pushpin.)

What's Going On?

You have made a *camera obscura* ("dark room"), or pinhole camera. Any images on the screen are upside down and left-right reversed. The drawing in figure 2 shows how the up-down part of this reversal takes place.

Light rays are coming from every point on the tree and hitting the outside of the box (light rays from only

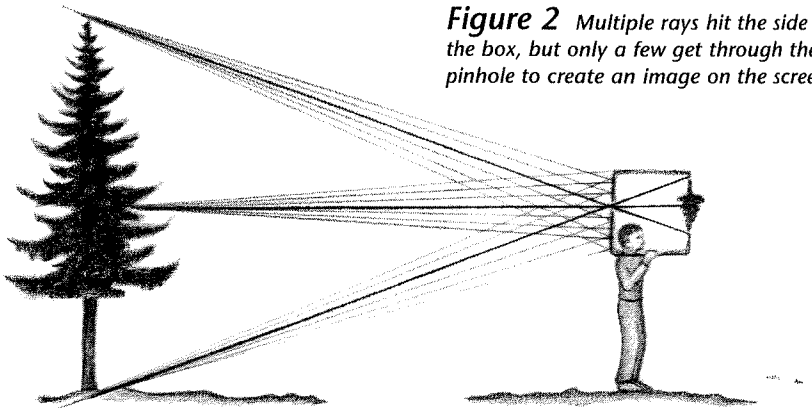
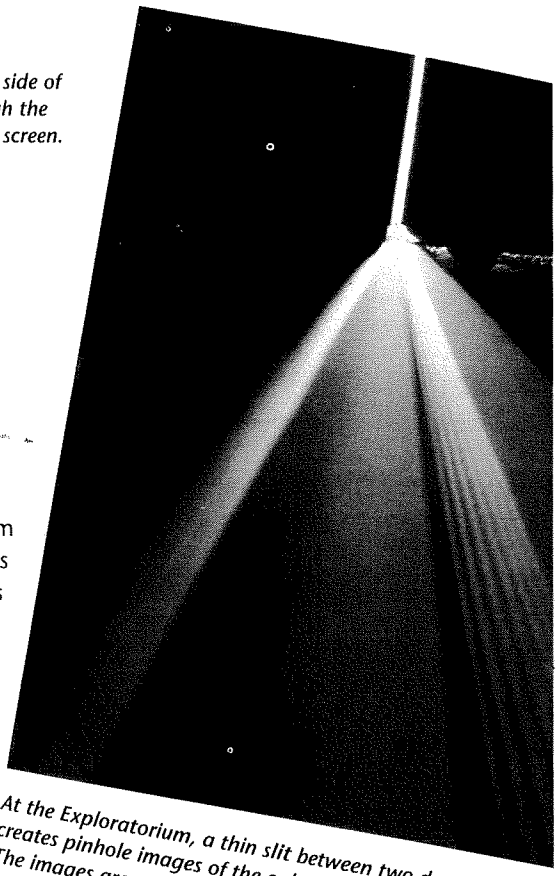


Figure 2 *Multiple rays hit the side of the box, but only a few get through the pinhole to create an image on the screen.*



At the Exploratorium, a thin slit between two doors creates pinhole images of the columns outside the door. The images are on the floor of the museum.

three points are shown on the drawing because it would be impossible to show all of them). Each light ray in effect carries an image of the point on the tree where it originated, and so the entire side of the box is covered with images of all points on the tree. The result is an unintelligible overlapping of images.

The pinhole, however, lets only a small number of rays from each point pass through, and the rays from each point are projected on a small area of the white screen, without significant overlap from the images of the other points. The result is a clear image of the tree. As you can see, however, the ray from the top of the tree hits the lower portion of the screen, and the ray from the bottom of the tree hits the upper portion. This geometry results in the image of the tree appearing upside down on the screen (and left-right reversed, as well).

The farther an object is from the pinhole, the smaller its image will be on the screen, as shown in figure 3. Focus (sharpness of the image) is not affected by distance.

Using a larger pinhole gives you a brighter image, since it lets in more light rays. But this increases the overlapping of images, causing the image to lose sharpness and become blurry.

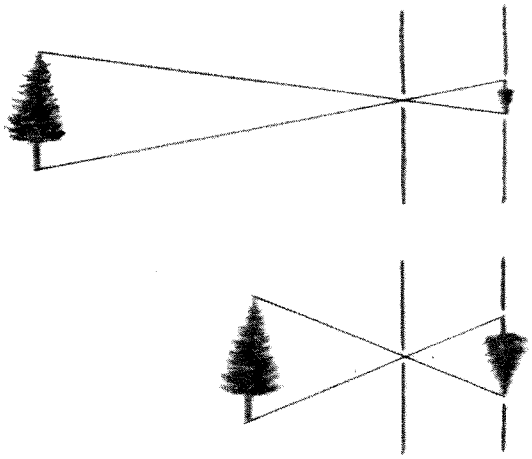


Figure 3 *This ray-tracing diagram shows why the image on the screen is bigger when an object is closer to the pinhole.*

So What?

The Personal Pinhole Theater demonstrates a classic principle of optics, one that photographers must take into account in every shot: There's a trade-off between brightness and sharpness.

In photography, the zone in which objects will be in sharp focus is known as *depth of field*. The smaller the lens aperture, or opening, of a camera, the greater the depth of field. In other words, the more the lens opening is like a pinhole, the greater the ability to have objects at different distances from the camera in focus simultaneously. As the opening is made smaller, however, less light is allowed through, and you have to use a longer exposure time to compensate. To take a picture in dim light, you open the lens wider to let in more light, but in so doing you sacrifice depth of field.

Going Further

Pinhole Variations

Systematically vary the size or shape of the pinhole you use and note how the image changes. You might also experiment with using two pinholes.

Walk Right In!

Make another Personal Pinhole Theater out of a refrigerator box so that it is big enough for your whole body.

Real Photographs

You can build a pinhole camera that will actually capture photographic images on film. One source for this activity is Jim Shull's book in the Credits & References section, and others can be readily located.

Did You Know?

Artist's Tool

Renaissance painters used portable camera obscuras very much like your Personal Pinhole Theater, except that they were smaller and handheld, and the screen side had only a piece of translucent paper, rather than a solid opaque wall. The image projected on the translucent paper could be seen from outside the box and could be traced directly onto the paper. (Sometimes a black cloth was draped over the screen and the user's head, to prevent the image from getting washed out by normal daylight.) The traced drawings of objects helped the artist represent perspective realistically. Johannes Vermeer (1632–1675) is one artist of note who is thought to have used a camera obscura in his work (see figure 4).

Popularly known as the Giant Camera, a room-sized camera obscura can be found near the Cliff House in San Francisco (see figure 5). Double convex lenses in the ceiling of the camera-shaped building rotate 360 degrees every six minutes, reflecting external images of the surrounding cliffs and Pacific Ocean onto a large concave bowl wherein visitors can easily discern seagulls in the sky, seals on the rocks, and tourists walking by outside.

Figure 4 View of Delft, *by the Dutch painter Johannes Vermeer, may have been created using a camera obscura to trace the outlines of the scene, enabling Vermeer to create a painting that is almost photographically precise.*

Figure 5 *Near San Francisco's Cliff House restaurant at Land's End is a room-sized camera obscura open to the public on clear days.*

Credits & References

This snack was developed by Eric Muller of the Exploratorium Teacher Institute. It's related to the Exploratorium exhibits Holes in a Wall and Cracks in a Door.

Chevalier, Tracy. *Girl with a Pearl Earring.* New York: Plume, 2001. A novel centered around Vermeer's painting "Girl with a Pearl Earring," which mentions Vermeer's use of a camera obscura loaned to him by his friend, Antonie van Leeuwenhoek, an early developer of the microscope.

Shull, Jim. *The Beginner's Guide to Pinhole Photography.* Buffalo, N.Y.: Amherst Media, Inc., 1999.

Steadman, Philip. *Vermeer's Camera: Uncovering the Truth Behind the Masterpieces.* Oxford: Oxford University Press, 2001.

Also see the Pinhole Magnifier snack in the *Exploratorium Science Snackbook,* 1991.