Pinholes and Lenses

Many people know that lenses can produce sharp images on a screen. But there are some interesting properties of lenses that are quite surprising, both to youngsters and adults. Furthermore, a pinhole is in some ways very similar to a lens, in other ways quite different. Below we have some suggestions to help explore some of the similarities and differences between these two very simple devices. You will need the following materials:

- two square pieces of dark colored cardboard, each about 8 inches on a side;
- a square piece of waxpaper, about 7 inches on a side;
- a magnifying glass or some other converging lens (one that is thicker in its center than at its edges);
- a straight pin or safety pin;
- masking tape or transparent tape;
- scissors; and
- a frosted lightbulb in a socket (you can remove the lamp shade from a table lamp).

It would be best to perform the following experiments in a room that could be made fairly dark. The only major source of light should be that from the frosted bulb.

You first need to make a translucent screen. Use one of the pieces of cardboard and cut out a square in the middle of it, about 5-1/2 inches on a side. Then tape the waxpaper to the cardboard frame (see Fig. 1).

Exploring what a pinhole does

Make a pinhole device by using the pin to poke a tiny hole in the center of the other piece of cardboard. To experiment with the pinhole, you should turn on the light in an otherwise darkened (or nearly darkened) room. Hold the pinhole at arm's length between your eyes and the lightbulb. The pinhole should be about two feet from the bulb (or candle). With the other hand, hold the waxpaper screen between the pinhole and your eyes (see Fig. 2). Your eyes should be at least two feet behind the screen and at the same level as the pinhole.

With this arrangement, you should see a sharp upside down pattern of light on the screen that looks like the light bulb. While holding the cardboard with the pinhole steady, move the waxpaper screen right up to the pinhole and then back toward your eye. What you should observe is that the upside down reproduction of the bulb remains fairly sharp and only its size and brightness change. It gets smaller and brighter the closer the screen gets to the pinhole, and it gets larger and dimmer as the screen is moved further away from the pinhole.

Now, while you are holding the cardboard with the pinhole in one hand, take away the waxpaper screen with the other hand. Notice that the upside down reproduction of the bulb disappears and all you can see is some light coming through the pinhole. This is no surprise as the screen seems to be necessary to observe the bulb reproduction.

Now use your pin to poke a few more tiny holes in the cardboard, separated from each other by about

Fred Goldberg *is Professor of Natural Science and Physics at San Diego State University. He leads a research and development group that investigates how students learn physics and develops technology-based materials to facilitate learning. A major focus of this group's work has been in the domain of geometrical optics.*

Figure 1

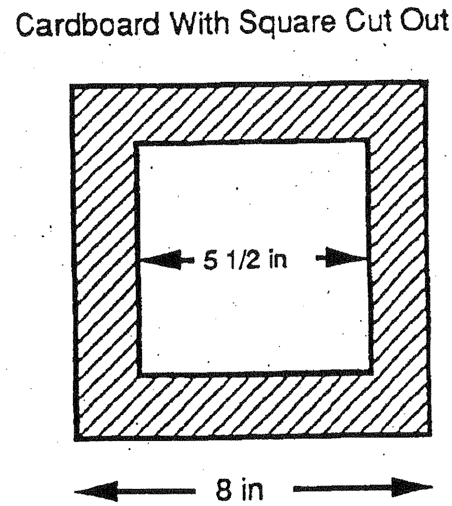
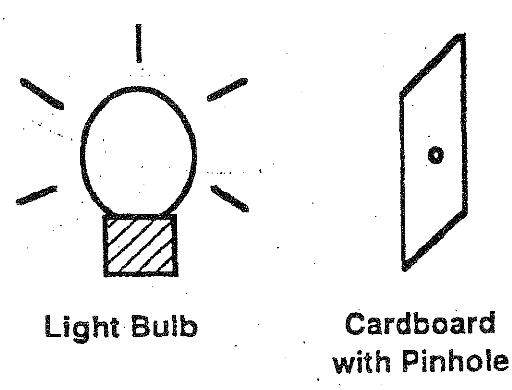
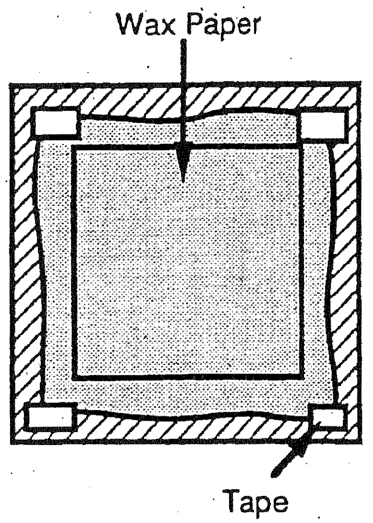
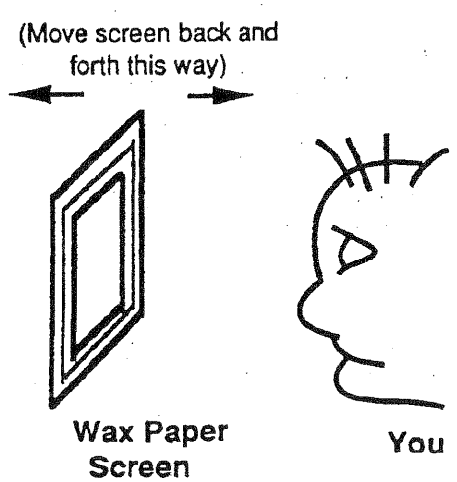


Figure 2







two inches. What do you think you will see on the waxpaper screen if you were to again arrange the cardboard with the pinholes, the waxpaper screen, and your eyes in the same position as in the figure? After you make a guess, try it. You might like to poke many more holes in the cardboard and observe what happens.

EXPLORING WHAT A LENS DOES

Now it's time to explore what the lens does and make comparisons with the pinhole. You will use the same bulb and waxpaper screen, but will replace the pinhole with the lens. You might want to start by holding the lens with one hand about three feet from the bulb. Hold the waxpaper screen with the other hand and look at the screen in the same way that you did with the pinhole. Move the screen back and forth between the lens and your eye until you find a position where you can see a sharp upside down image of the bulb on the screen. (If you cannot find such a position, you might need to start with the lens further away from the bulb.)

Notice that there is only *one* position for the screen where the image is sharp. If you move the screen away from this position—either closer to or further from the lens—the image becomes blurry. This is one difference between the pinhole and lens: with the pinhole, there are many positions for the screen where the reproduction is sharp; for the lens, there is only one position. Another difference you should note is that the reproduction formed with the lens is much brighter than the one formed with the pinhole.

The next difference is rather surprising. While holding the lens in one hand and looking at the sharp upside image on the screen held by the other hand, take away the screen. You should still see the same upside down image of the bulb! (By alternately replacing the screen and taking it away, you should note that you are really seeing the same image.) So, apparently, the lens can form the image even without the screen, and this is quite different from the behavior with the pinhole.

One other property of the lens is really amazing. Replace the screen so you can see a sharp upside down image of the bulb on it. What do you think would happen to the image if you were to cover up part of the lens? After guessing, you can try the experiment by using the piece of cardboard you had used with the pinholes. You'll need a partner to help you with this (unless you happen to own three pairs of hands). While looking at the image formed by the lens on the screen, have your partner touch the other piece of cardboard to the lens and slowly cover more and more of its surface. Notice that as more and more of the lens surface is covered, the entire upside down image of the bulb remains intact; it only becomes dimmer. So, *any* portion of the lens is sufficient to form the whole image.

In these activities you were able to explore some of the interesting properties of pinholes and lenses. If you would like to read a more detailed account of lenses and pinholes, with explanations for most of the behaviors you observed, we suggest you read "Lenses, Pinholes, Screens and the Eye," by Fred Goldberg, Sharon Bendall, and Igal Galili, which appeared in the April 1991 issue of *The Physics Teacher* (Vol. 29, pages 221-224).