Bibliography

Some of the following publications are out of print but are usually available in any good library.

Elementary Photography, Neblette, Brehm, and Priest, MacMillan Co., pp. 1-6, 8-49.

Encyclopedia of Photography, Vol. 8, National Education Alliance, Inc., pp. 2906-2913.

Lenses in Photography, Rudolph Kingslake, Garden City Books, Garden City, New York, 1951, pp. 56-58.

Photography, August 1954, 35: No. 2, Make a Pinhole Camera," p. 46.

The Photographic Process, J. E. Mack and M. J. Martin, McGraw-Hill Book Co. Inc., pp. 33-38, 88, 524-526.

Pinhole camera kits mentioned in some of these references are no longer available from Eastman Kodak Company.

Consumer Markets Division

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How to Make and Use a Pinhole Camera
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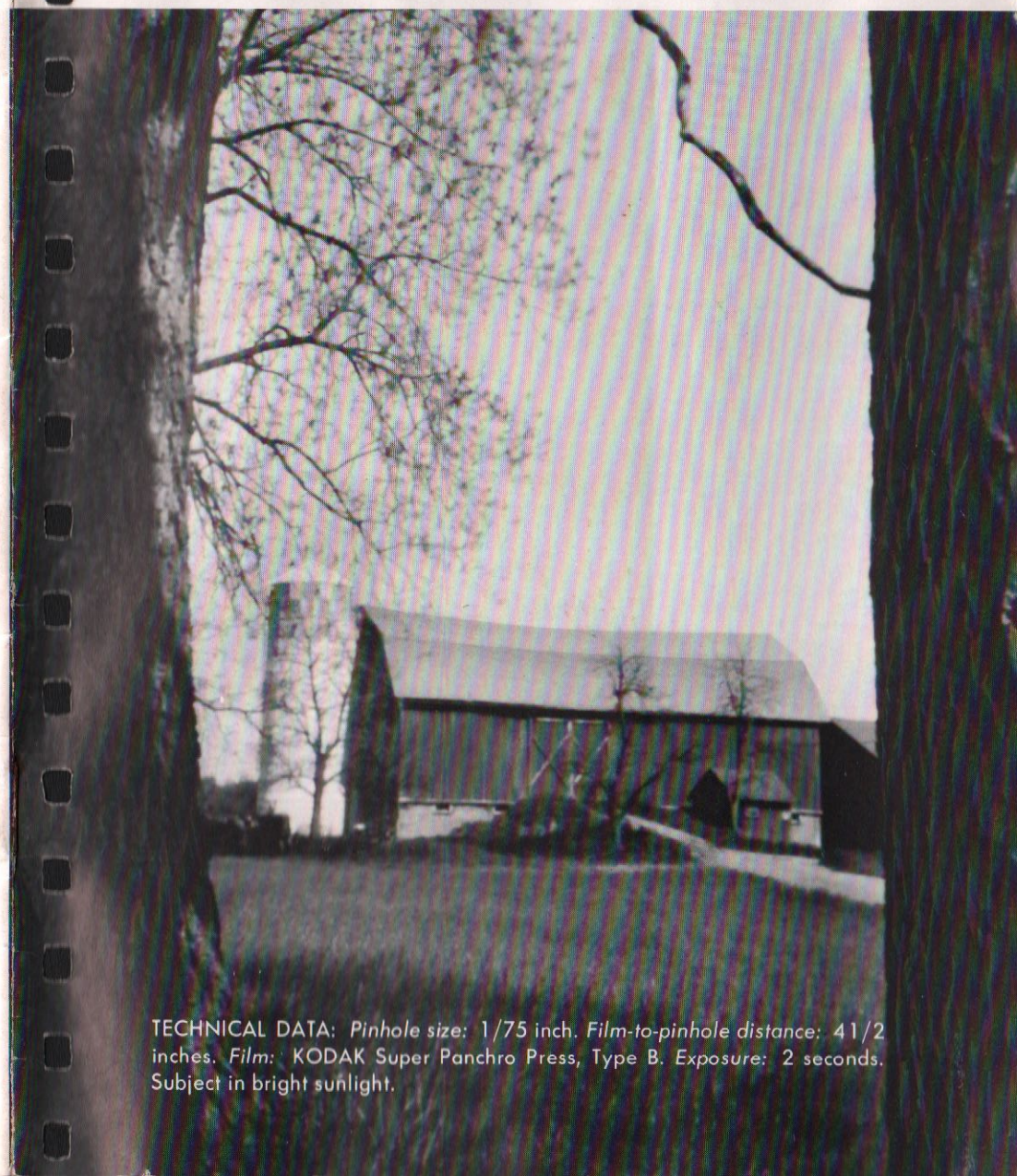
TEACHERS' EDITION

HOW TO MAKE AND USE A PINHOLE CAMERA

AT-38



TECHNICAL DATA: *Pinhole size:* 1/75 inch. *Film-to-pinhole distance:* 41/2 inches. *Film:* KODAK Super Panchro Press, Type B. *Exposure:* 2 seconds. Subject in bright sunlight.

Making and using a pinhole camera is an excellent and inexpensive project for teaching the fundamentals of the picture-taking process. The pinhole camera has some other interesting uses. In nuclear physics, a pinhole camera made of lead is used to survey objects in a room in order to determine those objects emitting gamma rays. The U.S. Soil Conservation Service has used a pinhole camera to record pictures of forest cover.

Making a pinhole camera is a good project for young people because the materials needed are easy to find and exact sizes are not important.

WHAT IS A PINHOLE CAMERA?

A pinhole camera is a small, lighttight can or box with a black interior and a hole about 1/75 inch in diameter in the center of one end. (See Figure 1.) It can be made to accept roll or sheet film, or a film cartridge. The two ends of the camera are parallel. The end opposite the pinhole is flat so that the film is held in a flat plane. The pinhole itself has a cover to prevent light from entering except when a picture is being taken.

MAKING THE CAMERA BODY

With a 126 Film Cartridge

The cartridge pinhole camera is the easiest type to use because all the work can be done in the light. Also, once you have the camera set up, you can shoot 12 black-and-white pictures without changing the cartridge. After exposure, you can send the cartridge to your photo dealer for processing and printing. With other types of pinhole cameras, you load the film into the camera in a darkroom, reload the camera after each picture is taken, and process the film yourself.

To make a cartridge pinhole camera, you'll need a 126 cartridge of black-and-white film, such as KODAK VERICHROME Pan Film, and a piece of black cardboard. Cut and fold the cardboard as illustrated in Figure 2. The cardboard should fit tightly into the groove around the square opening in the cartridge. Cut another piece of cardboard

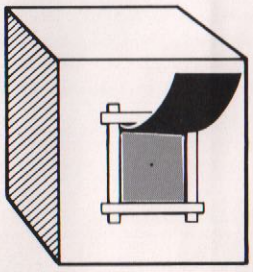


FIGURE 1

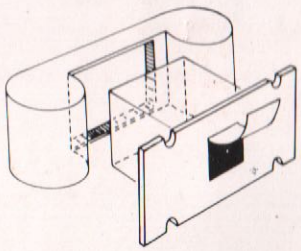


FIGURE 2

for the front of the camera and cut an opening in the center of this piece. Make a tiny pinhole in the center of a 1-inch-square piece of aluminum foil. (Refer to page 4.) Center the pinhole over the hole in the cardboard. Tape the foil to the cardboard on all four sides. Make a shutter for the camera by putting a small piece of black paper over the pinhole and taping it to the cardboard along the top edge. Tape the front piece to the camera body with black masking tape. Tape all the edges so that no light can leak into the camera. Use two rubber bands to hold the camera body tightly in the cartridge opening. (See Figure 3.) Make a film advance lever by trimming a wooden tongue depressor to fit the round opening in the cartridge. Advance the film by turning the "lever" in a clockwise direction.

The film in a 126 cartridge has black borders on the negatives. Also, there is a series of numbers for each picture (5 number 2's, 5 number 3's, etc) printed on the backing paper. In order to get the black borders in the correct position for picture-taking, you have to count the numbers on the backing paper as you wind the film. Advance the film until the third and fourth numbers in the series appear in the cartridge window, and the film should be in the proper position for picture-taking. If the borders happen to be in the edge of the picture area when the film is processed, you can crop the picture to exclude the border if you make your own prints. After the last exposure, be sure to wind the film until all of the yellow paper has passed the cartridge window before you remove the cartridge from the camera body.

With a Coffee Can

When you make a pinhole camera for use with film that isn't in a 126 cartridge, you can use any small, lighttight can or box as the camera body. A 1-pound coffee can with a metal lid makes a good pinhole camera. (See Figure 4.) If your coffee can has a plastic lid, you can paint the lid black. Be sure to paint it inside and out; then before using it, check to make sure no paint has chipped off. Chipped or peeling paint on the lid will allow light to enter the camera and ruin your pictures. You can also use a clean paint can or even a

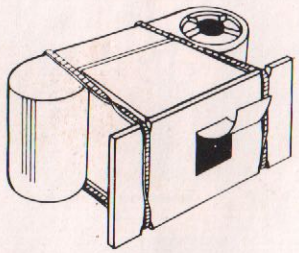


FIGURE 3

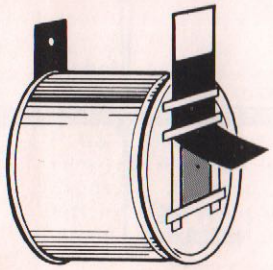


FIGURE 4

round oatmeal box for a pinhole camera.

Paint the inside of the camera body with dull black paint or line it with black paper to prevent light reflections.

THE PINHOLE

The exact size of the pinhole is not critical. With a non-cartridge-type camera, make the pinhole in the permanent end. (It's easiest to attach the film to the removable end.) You can make the pinhole in the box or the can itself, but it's much easier to make it in a separate piece of heavy black paper or thin metal. Then fasten this piece over a larger hole cut in the center of the permanent end of the can or box. Heavy-duty aluminum foil or the backing paper from KODAK roll film is good for this purpose.

For a camera with the pinhole 3 to 6 inches from the film, you'll get the best results if the pinhole is about 1/75 inch in diameter. You can make a hole this size by pushing a No. 10 sewing needle through the paper or metal to a point halfway up the needle's shank. (See Figure 5.) To make a pinhole for a cartridge camera, use only the tip of the needle. You'll get a smoother hole if you rotate the needle as you push it through. If you're using aluminum foil or paper, sandwich it between two lightweight cards while you make the pinhole. This will help you make a smoother, rounder hole.

You can also make a good pinhole in soft aluminum sheet metal. Place the aluminum on a hard surface (such as tempered hardboard). Make a small hole in the aluminum with an awl or an ice pick. Don't press too hard—the tip should just barely break through the surface. (See Figure 6.) The hole will be ragged. Enlarge and smooth it by pushing a No. 10 needle into it from the indented side. You can smooth the rough edges with very fine sandpaper and then open the hole with the tip of the needle. You can use the same procedure to make the pinhole directly in the metal of the can by working the hole through from inside the bottom of the can.

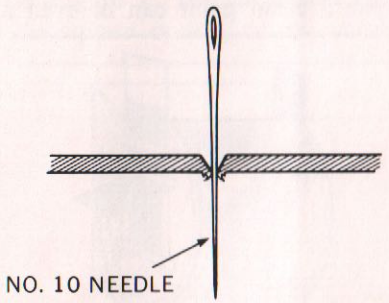


FIGURE 5

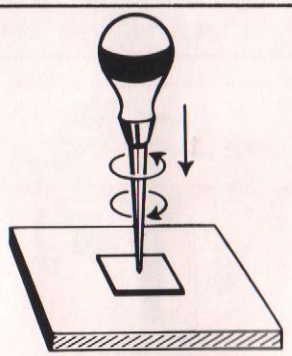


FIGURE 6

If you made the pinhole in a separate piece of card or metal, you should now make a hole 1/4 inch or more in diameter in the center of one end of the camera body. Then tape your pinhole in position over the center of the hole.

You can check your pinhole to make sure it's perfectly round by looking through the back of the camera. To see if the image is clearly visible, aim the camera toward a printed page and see if you can see the letters clearly.

THE SHUTTER AND VIEWFINDER

The shutter for the camera can be a flap of opaque dark paper hinged with a piece of tape. (See Figure 4.) You can use a small piece of black tape to hold the shutter closed while no picture is being made.

A viewfinder for a pinhole camera, while not usually necessary, can be made of cardboard or wire, as shown. (See Figure 4.) The larger frame should be slightly smaller than the film size and located directly above the pinhole at the front of the camera. If the film isn't square, the viewfinder should have its longest dimension parallel to the longest dimension of the film. The small frame is a sighting peephole directly above the film and squarely behind the center of the large frame. In using this viewfinder, tip the camera up slightly to allow for parallax (the distance between the pinhole and the center of the large frame) in aiming the camera at subjects closer than 5 feet.

LOADING A CAN- OR BOX-TYPE PINHOLE CAMERA

The "film" for the camera can be either film or "fast" photographic paper. Paper is easier to handle since it can be loaded in the camera under a safelight. (If you do not have a safelight, you can work by the light of a candle placed 6 or 8 feet away.) Most film, on the other hand, must be handled in total darkness. Whether you want to use film or paper may depend in part on the exposure times. Paper, because it is less sensitive to light than film, will probably require an exposure of about 2 minutes for sunlit subjects. Film may require only 1 or 2 seconds for subjects in sunlight.

Pinhole size: 1/75 inch. Film-to-pinhole distance: 4 ½ inches. Film: KODAK PLUS-X Pan Professional Film (ESTAR Thick Base). Exposure: 2 seconds. Subject in bright sunlight with strong sidelighting.

Pinhole size: 1/75 inch. Film-to-pinhole distance: 4 ½ inches. Film: KODAK ROYAL Pan (ESTAR Thick Base). Exposure: 5 minutes. Subject lighted by one No. 2 photoflood lamp in reflector 10 feet away and aimed slightly above subject. Note: First piano key is 4½ inches from pinhole.

For paper try KODABROMIDE Paper F (glossy) No. 1 or 2, Single Weight. You can obtain this in the 4 x 5-inch size in 25-sheet packages from your Kodak dealer for about 90 cents (corners may have to be trimmed to fit a round camera). For film, you can cut up a roll of KODAK TRI-X Pan Film, 120 or 620, into 2 1/2-inch squares or 2 1/2 x 3 1/2-inch sizes. This must be done in total darkness, of course. (A closet at night will probably be dark enough if lights in adjoining rooms are turned off.) Sheet film, such as KODAK ROYAL Pan Film (ESTAR Thick Base), is easier to use because it's flat.

A camera made from a 1-pound coffee-can will take a 2 1/4 x 3 1/4-inch piece of film or photographic paper. A 3 1/4 x 4 1/4-inch piece can be used if about 1/2 inch is clipped from each corner of the film. A camera made from a 1-gallon paint can will take a 4 x 5-inch piece of film.

When you have the size of paper or film you need, tape it firmly to the inside of the end of your camera opposite the pinhole. The emulsion should face the pinhole. The emulsion side of photographic paper is the shiny side. The emulsion on roll film is on the inside of the curl. Sheet film is identified by notches cut into one of the shorter sides. When the film is held with the notches in the top edge toward the right side, the emulsion is facing you. Another way to determine the emulsion side of either paper or film is to touch both sides with a moistened finger. The emulsion side will feel slightly tacky. (Test near the edge to avoid a fingerprint in the center of the picture.) Taping down the four corners is necessary if you use cut-up roll film or paper. Taping two diagonal corners will work for sheet film. Close the camera, making sure the shutter is closed, too.

MAKING THE EXPOSURE

The camera must be placed on some firm support so that it can be held motionless while the shutter is open. If this is not done, the picture will be blurred. For photographing sunlit subjects with KODAK TRI-X Pan Film or KODAK ROYAL Pan Film (ESTAR Thick Base), open the shutter 1 to 2 seconds; for KODAK VERICHROME Pan Film, 2 to 4 seconds; and for KODABROMIDE Paper, 2 minutes. These times are approximate. Further testing will show you the best exposure for your particular conditions.

Notice the great depth of field in the examples of pinhole photography in this pamphlet. Images of subjects very near the camera, those at a great distance, and those in between, are equally sharp. No focusing is required, of course.

PROCESSING AND PRINTING

Film and paper can be processed in trays, or in plastic or glass dishes. You can use the KODAK Tri-Chem Pack, which includes instructions for developing photographic paper and film.

Print film negatives in the usual way. If you use KODABROMIDE Paper in making the picture, make the exposure long enough to allow the resulting paper negative to be a little darker than an ordinary photographic print. Dry the paper negative and make a contact print from it in the normal way, with the emulsion (picture) side of the negative toward the emulsion (shiny) side of the printing paper.

For further detailed information regarding the processing of photographs, see the 32-page KODAK Publication, *Basic Developing, Printing, Enlarging* (AJ-2), available from your Kodak dealer.

DEMONSTRATIONS

Contact prints can be made in the classroom under low tungsten illumination with a 25-watt tungsten bulb 10 or more feet away (eliminate daylight by using opaque window shades). If there is not time enough to let the negative dry, you can make contact prints from a wet negative that has been washed only a minute or so. Place a sheet of unexposed KODAK AZO Paper E-2, Single Weight, in a tray of water, emulsion (shiny) side up, and immediately slide the negative over it, emulsion (picture) side down. Lift them from the water together and lay them on a flat surface with the negative on top. Expose for about 4 seconds, using a 100-watt bulb 8 inches directly above the negative. To minimize fogging, process the print in dark-

colored trays, if available. Keep the emulsion side of the paper down as much as possible, except for occasional checks. Although this procedure will still permit some fogging of the print, the final result will be satisfactory as a demonstration of photographic principles. Practice will improve your technique in moving swiftly through these steps.

You can build a special pinhole camera that will allow you to process the film in the camera. Thus you can give a demonstration without a darkroom (though the camera must be loaded in a darkroom or under suitable safelight illumination). For this demonstration camera, you'll need to use a metal can with the pinhole in the *lid*. Solder a small metal tube in a hole near the bottom of the can as illustrated in Figure 7. Or, use a small threaded pipe nipple with one nut inside and one outside the camera wall. The inside of the camera and the metal tube should be painted with a material that will not be affected by photographic solutions. Lacquer is readily available and quite satisfactory. Ordinary paint or enamel should not be used as they will soften and deteriorate in the presence of developing solutions.

Pour solutions in and out through a 6- or 8-inch black rubber tube slipped over the metal tube. (Do not use a clear neoprene tube because it lets in light.) A small plastic funnel makes pouring easier. (See Figure 7.) While pouring, keep the tube curved to prevent light from entering. When not pouring, double the tube and hold it with a rubber band.

About 2 or 3 ounces of developer is enough to process the negative. For demonstration, you can develop 1 1/2 or 2 minutes with KODAK VERSATOL Developer, stock solution, at room temperature. Or, you can use the KODAK Tri-Chem Pack, developing film for about 3 minutes, a paper negative for about 1 minute. Agitate the developer by gently moving the can throughout the development time.

At the end of development, pour out the developer through the tube and discard; pour in the fixer; agitate. After fixing for about 2

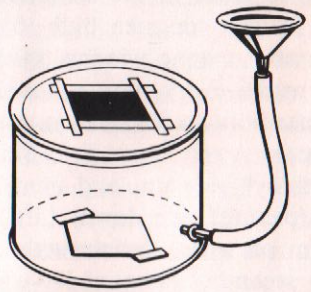


FIGURE 7

minutes (with either fresh fixer from the Tri-Chem Pack or another standard fixer), open the camera and carry out the remaining steps in trays or dishes. If you use KODAK Rapid Fixer, you can open the camera after about 30 seconds. Rinse the camera with clean water, and let it dry thoroughly before covering it and putting it away.

For demonstrations at night or entirely indoors, KODAK ROYAL-X Pan Film (ESTAR Thick Base), in sheets, is a good choice. Satisfactory exposure is about 5 or 10 seconds with a Number 2 reflector-type photoflood lamp about 3 feet from the subject, or 1 minute with normal room lighting. If you use KODAK ROYAL Pan Film (ESTAR Thick Base), in sheets, or KODAK TRI-X Pan Film, in rolls, give about 10 times as much exposure.

You can demonstrate image formation with the can-type camera. However, for this purpose, the pinhole should be located in the bottom of the can, necessitating a second demonstration camera.

Place a piece of ground glass, tissue paper, or waxed paper across the open end of the can opposite the pinhole. When the camera is aimed toward a bright subject (a window or bare lamp), the image appears on the ground glass. You may have to shield the glass from stray light since the image will be very faint.

QUESTIONS AND ANSWERS

Q. *Why is the image upside down?*

A. Light travels in essentially straight lines. Light from a point at the top of the subject goes through the pinhole to form a point of light (actually a small circle) at the bottom of the image. The reverse is true for light from the bottom of the subject. (See Figure 8.)

Q. *Why is the image less sharp with a large pinhole?*

A. Reflected light radiates in all directions from a point on the subject. A small pinhole cuts off most of this light, allowing a small "ray" (actually a small circle of light) to strike the film. The image is formed by many of these rays, or circles, of light. As the pinhole is enlarged, the diameters of the circles also enlarge and overlap, causing an increasingly unsharp image.

Q. *What is the relationship between image size, subject size, the distance between the pinhole and image, and the distance between the pinhole and subject?*

A. Directly proportional:

$$\frac{\text{Subject Size}}{\text{Image Size}} = \frac{\text{Subject-to-Pinhole Distance}}{\text{Image-to-Pinhole Distance}}$$

(See Figure 9.)

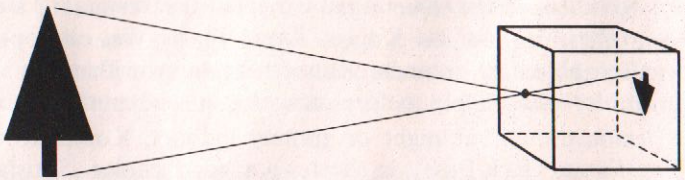


FIGURE 8

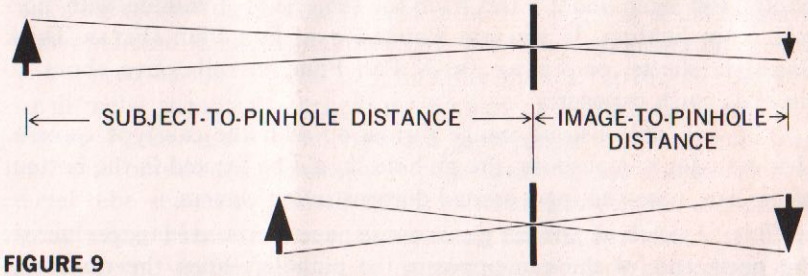


FIGURE 9

Q. *What happens to the shape of the image of a rectangular subject (such as a window) when the camera is tilted? Why?*

A. Parallel lines in the image tend to converge when the camera is tilted. This can be demonstrated by measuring the appropriate subject and image dimensions and distances, and applying the formula in the preceding answer.

Q. *What are the main differences between a pinhole camera and a "regular" camera?*

A. In a "regular" camera, the lens gathers much more image-forming light, permitting shorter exposures. Also, the lens must be placed a definite distance from the film to form a sharp image. Thus the camera must have a shutter that permits the shorter exposure times, and a lens that can be focused or is fixed in a position calculated for best overall focus. Generally, other features (such as a rangefinder, built-in exposure meter, etc) are for convenience.

Q. *If the diameter of a pinhole is doubled, only 1/4 as much exposure is needed. Why?*

A. The volume of light admitted depends on the area of the pinhole. Doubling the diameter quadruples the area. Therefore, the same total amount of light will be admitted in 1/4 the time.

Q. *The relative aperture (f/number) of a lens is approximately the distance between the film and lens divided by the diameter of the lens opening. What is the f/number of a pinhole camera?*

A. If, as an example, the pinhole is 1/50 inch in diameter and 4 inches from the film, the aperture will by $\frac{4}{1/50}$ or $f/200$.

Q. *Using the f/number for your pinhole camera, how can you calculate proper exposure by working from an exposure meter or from an exposure table for a "regular" camera?*

A. You need to extend the exposure information so that it applies to the small pinhole aperture. Exposure for $f/22$ can be found with most meters. If the meter indicates an exposure of 1/30 second at $f/22$, the length of exposure is doubled for each smaller aperture until the aperture near the f/number of the camera is reached. For example: 1/30 at $f/22$ = 1/15 at $f/32$ = 1/8 at $f/45$ = 1/4 at $f/64$ = 1/2 at $f/90$ = 1 at $f/128$ = 2 at $f/180$ = 4 at $f/256$ = 8 at $f/360$ = 16 at $f/512$ = 32 at $f/720$. Thus exposure would be about 4 seconds at $f/250$, or 3 seconds at $f/200$, etc.

EXPERIMENTS

Here are some experiments you may want to try with your pinhole camera.

1. Effect of larger and smaller pinholes on necessary exposure time and image sharpness. (If you succeed in making a pinhole small enough, you'll find the image is less sharp.)

2. Effect of pinhole shape on image. Try round, ragged, square, rectangular, and triangular shapes that are approximately the same size. (Overlapping strips of black paper on thin metal are the easiest means for making some shapes.) You'll find that pinhole shape and smoothness do not affect image shape but do influence image definition.

3. Effect of varying pinhole-to-image distance on sharpness and exposure.

4. Effect of holding a pinhole very close to your eye. What effect does it have on the brightness of the scene you see? On distances at which your eye will focus sharply? (Try holding fine print very close.) Why does it have this effect? This is an illustration of good depth of field, obtainable from a camera with its diaphragm at the smallest opening.

5. Effect of using two or more pinholes in the front of the camera. (You should see an image for each pinhole.)

6. Effect on the image if you use a narrow slit instead of a pinhole. (The image is sharp at right angles to the slit and distorted in the direction of the slit.) What is the effect if the slit is curved? (Same effect as before, except on a curved line.) This phase of experimentation can give a student knowledge of problems with anamorphic lenses.