Pinhole Camera

Motivation for the Learning Unit

Can one see full and complete image of a huge object using just a hole which is just the size of a pin? Moreover can you measure the height of that huge object without using any sophisticated instrument or technique?

In this learning unit students will make pinhole camera using just _ that can capture very detailed image as well as measure distances.

Minimum Time Required: 4 sessions of 40 minutes.

Type of Learning Unit : Classroom and Field activity.

Group of 4 students. Unit is in two parts. Task 1 is the design part and Task 2 is the measurement of height of an object using a pinhole camera.

Learning Objectives

(i) To design, understand the working and use of a pinhole camera.
(ii) To learn a technique of measuring size of a distant object.

Links to Curriculum

Ray nature of light and image formation from pinhole (NCERT Class 6 Science textbook, Chapter 11: Light, Shadows and Reflections).

Introduction

Pinhole camera is an elementary device which captures the image of an object on to a small screen. It allows light from the object to pass through a very small hole which is just the size of a pin. Collecting this light on a screen forms an up-side down and left-right reversed image of the object. This device demonstrates the ray nature of light. The pinhole camera described here can be made using household items.

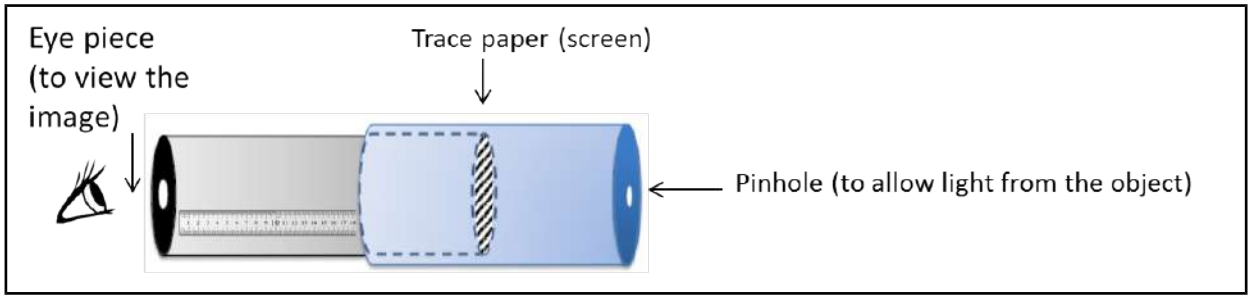


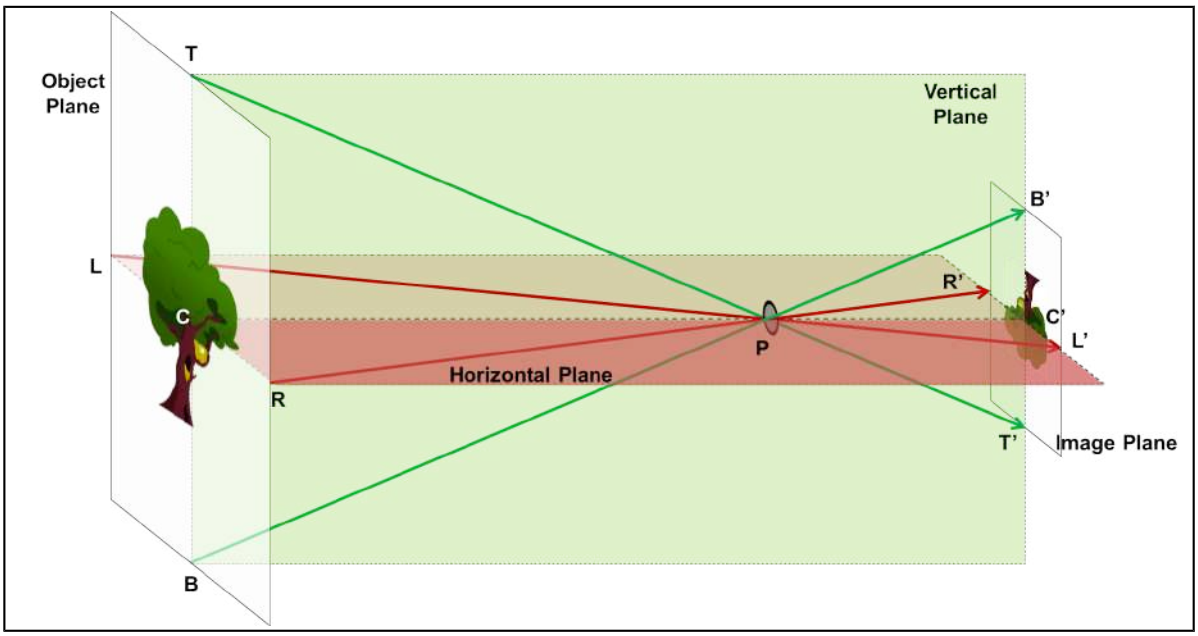
Figure 1: One design of a Pinhole Camera

Materials Required

- Black chart paper, tracing paper/translucent polythene sheet, print out of a ruler on paper, measure tape, scissors, adhesive, cutter, cello tape, aluminum foil used in kitchen.

Formation of Image in a Pinhole Camera

To understand how the image is formed on the screen, which is the tracing paper, we follow the rays of light emitted by the object. Let us label the pinhole as P. For the sake of understanding let us take the object, a tree, in a rectangular plane, namely object plane.



Consider rays of light coming from points labeled L, R, T, B and C corresponding respectively to left, right top, bottom and center positions on the square. The object is placed such that C is aligned to the pinhole P. A ray of light from any point on the object can enter the pinhole, only if it travels along the straight line connecting that point and P. This means a ray from C traveling along the segment CP enters the pinhole and continues to travel in the same direction, which is along the segment CPC', reaches the screen to form the image C' of C at the centre. Now consider a ray from T, this will enter the pinhole traveling along the segment TP and will travel further in the same direction forming the image T' corresponding to T on the screen. Since T is at a higher elevation to C and so also to P, the image of T will be formed at the bottom of the screen. For the same reason, the image of the B will be formed at the top of the screen, R at the left of the screen and L at the right of the screen. Thus this real image (L'R'T'B'C') on the screen will not only be inverted but also left-right reversed.

The following two conditions are required for the formation of a good visible image on the screen,

i. The object should be well illuminated. (For example: Any object outdoors well illuminated by the bright sunlight)

ii. If the size of the pinhole is too small, very little light will enter, forming a very faint image which will be difficult to see. If the size of the pinhole is too big, other effects will distort the image. The size of the pinhole should be optimum to allow sufficient light to enter for a good image formation with clarity.

Task 1: Making Pinhole Camera

1. Cut a rectangular piece from the black chart paper and fold into a hollow tube such that the longer side of the paper is the height of the tube, and tape it or use rubber bands so that the tube is firm. You can keep the diameter up to 3cm and height 25 cm.

Fig. 2(a): Rolling cardpaper

Fig. 2(b): Cardpaper as pipe

Fig. 2(c): Cello Tape on pipe

You can also vary the diameter and length of the tube. Smaller diameter will increase the clarity of the image. (One can also use the cardboard tubes on which the aluminium foils or kitchen paper tissues are rolled.)

2. Cover the other end of the tube with a plastic semi-transparent sheet. This sheet will work as screen. Let us call this tube as the image tube (IT). Put the markings on screen on every 5 mm. This will help in measuring size of the image formed on the screen in task 2.

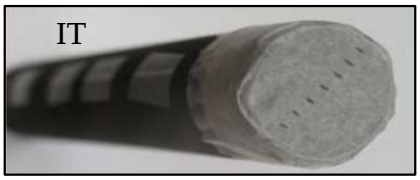


Fig. 3: Wrapping trace paper for screen

3. Fold another rectangular chart paper into a cylindrical tube such that it is smaller in length and slightly larger in diamer than of the IT and the IT can slide inside smoothly. Cover one end of the tube with a circular chart paper and make a hole using a pin in the centre. One can also use a sheet of aluminum foil for this purpose. We will call it Pinhole tube (PT).

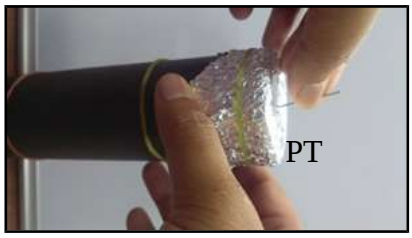


Fig 4: Making a camera

> A good pinhole can be made in both a black chart paper and the foil, but aluminum foil is preferable as it will be slightly easier to work .

4. Insert IT inside PT such that the screen just touches the pinhole (refer Fig. 1). Mark a point ‘O’ on the IT where PT ends. Now bring the PT out and stick a strip of white paper on IT along its lenght. Considering point ‘O’ as a zero point, put markings at 5 mm intervals on the paper so that it can be use as a scale. This scale will be used to measure l i.e. the distance between the screen and pinhole. Now the pinehole camera is ready to use.

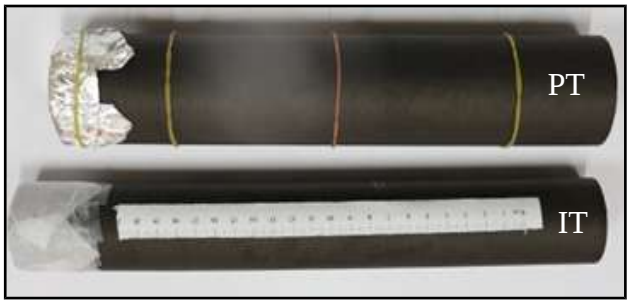


Fig. 5 (a): Pasting scale on image tube (left)

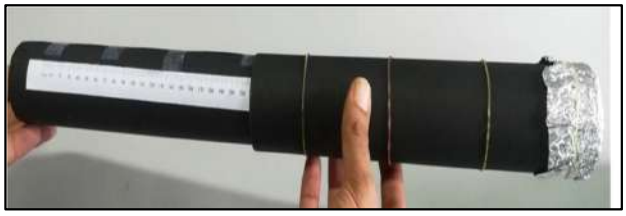


Fig. 5 (b): Pinhole camera is ready to use

5. To view an image, point the pinhole towards the object and adjust the distance between the screen and the pinhole to view a clear image of the object on the screen. Shown below is a picture of a building when viewed through the pinhole. One can notice the image of the object is up-side down and left-right reversed.


Fig. 6 (a): Object

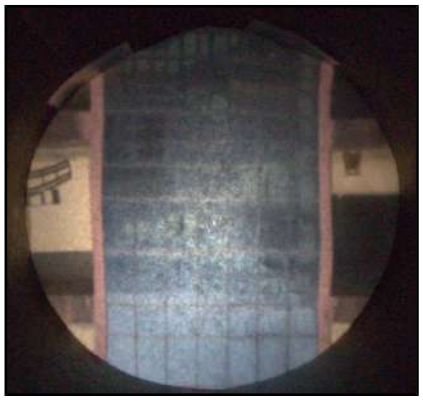


Fig. 6(b): Image in Pinhole camera.

Fig. 6 (c): Object

Fig. 6(d): Image in pinhole camera.

Teachers shall explain here how the image is left-right, up-down reversed. Notice the ladder and its shadow in first object and overhead tank in second object.

Discussion

1. What will happen to the image if,

I. hole becomes bigger?

When pinhole size is small, very few rays from the object enters the pinhole. If pinhole size is big, many rays at different angles enter the hole, forming images at different places on the screen reducing the clarity of image.

II. you increase the distance between pinhole and screen?

See diagram above. Image planes makes a triangle PB'T' with the pinhole. If you move screen closer to pinhole, a smaller triangle will be formed reducing the size of the image.

III. you move pinhole away from the object?

It will form a bigger triangle increasing the size of the image. Also a larger horizon will be covered and you will see more objects.

Task 2: Measuring the Height of a Huge Object

Rays from object fall on trace paper (screen) after passing through pinhole, and forms an image on the screen (Fig. 7). You have to measure three quantities, distance (D) between pinhole and the object, screen-pinhole distance (l) and size (h) of the image on the screen.

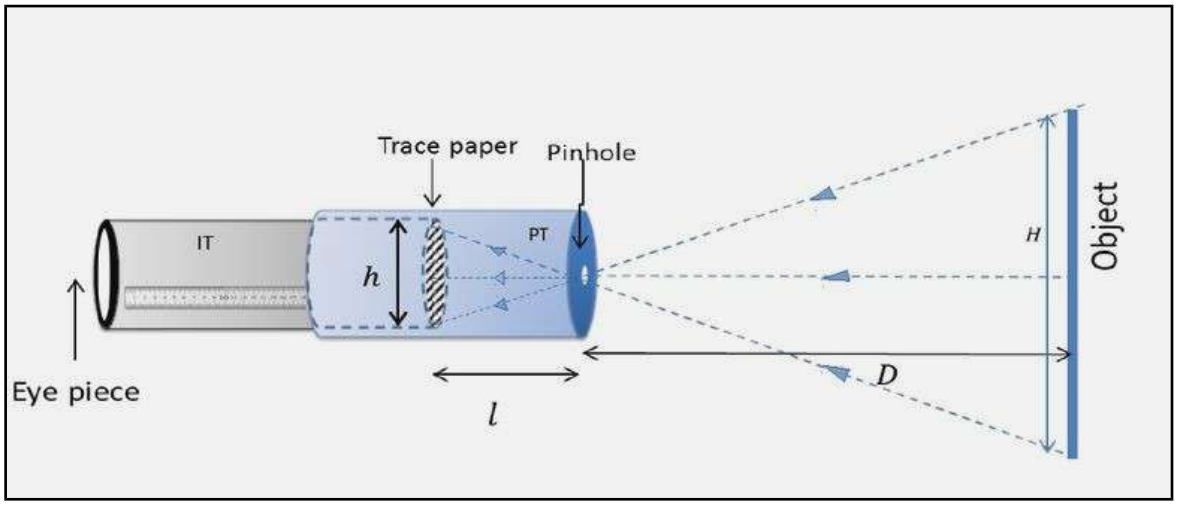


Fig. 7: Ray Diagram

1. Let height of the object be H.
2. Measure the distance D between the pinhole and the tree.
3. Move the IT such that you can see a clear inverted image of the object, such that the top of the image and bottom of the image simultaneously coincides with a marking on

the screen. Count the number of markings n between the top and the bottom of the image on the screen. Then the height h of image in mm is $5(n\text{-}1)$.

4. Using the scale on the IT, note down (l).
5. The height of the object is given by the formula $H = hD/l$. As you vary l, h will also change. Tabulate your reading below:

D (cm)	d (cm)	$H = hD/l$ (cm)

Average height of the object, (Mean) H = _____

Teachers should also try to get estimate of the height of the object from other method (such as by knowing the height of each floor and multiplying by the number of floors) or from official records, to match the answer obtained from pinhole camera.

Questions to Think

- If you place a second pinhole behind the screen of first pinhole, will the image now be still inverted, or upright, left right reversed or not left right reversed than compared to the original object?
- As we calculate H knowing D can we calculate D knowing H using methodology discussed in Task 2?

Suggeted Readings

1. A brief history and principle of pinhole camera: http://www.alternativephotography.com/pinhole-history/
2. A website dedicated to pinhole camera's (History, principles, technical detail, etc): http://www.pinhole.cz/
3. A detailed history of pinhole cameras and its construction is available at: https://jongrepstad.com/pinhole-photography/pinhole-photography-history-images-cameras-formulas/