LU 8.2 Pinhole camera

Introduction

The pinhole camera is a simple device which allows light to pass only through a very small hole of the size of a pin tip. By putting a screen (flat surface) at a distance from this hole, you can see the image of an object (present in front of the pinhole on other side) on the screen. If the screen is a thin translucent sheet, then the image can be observed on both sides of screen. See figure 1 below.

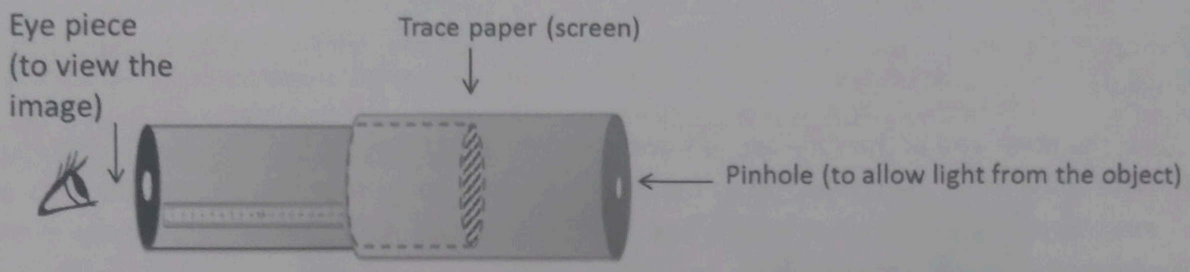

Figure 1 *Schematic of pinhole camera that also acts as a measuring device*

In this unit, you will make a pinhole camera and use it as a measurement device. You will also understand how image is formed by a pinhole.

Materials

Black chart paper, tracing paper/translucent polythene sheet, printed ruler on paper or graph paper, measuring tape, scissors, adhesive, cutter, sticky tape, aluminium foil used in kitchen.

Task 1: Making a pinhole camera

This stage is one of making and the task is to come up with a working pinhole camera. Instructions for making are given below.

i. Cut a rectangular piece from the black chart paper and roll into a hollow tube. Secure with sticky tape or with rubber bands so that the tube is firm. The diameter should be approximately 3 cm and height 25 cm.

Figure 2(a): *Rolling chart paper*

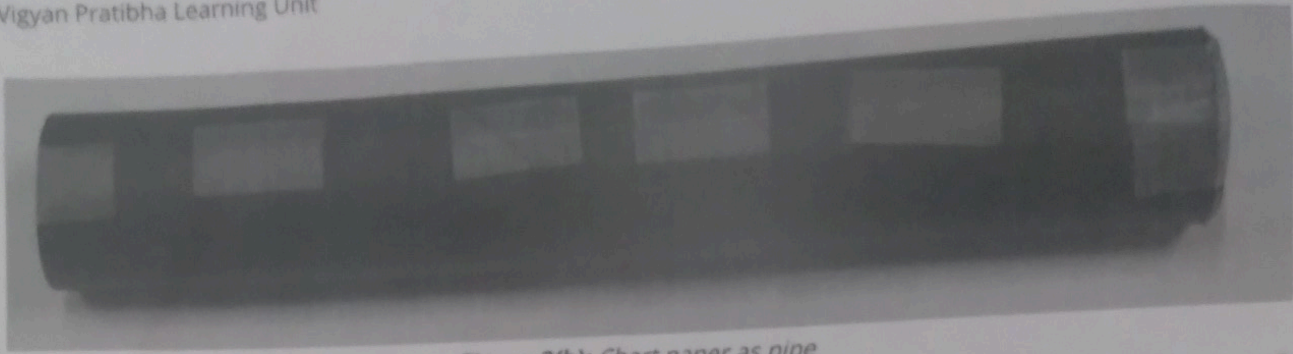

Figure 2(b): *Chart paper as pipe*

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 aluminium foil or kitchen paper tissue are rolled.)

ii. Cover the other end of the tube with a translucent sheet of tracing paper or a similar material. This sheet will work as the screen. Let us call this tube as the image tube (IT). Put the markings on the screen as shown in figure 3 at every 5 mm. The markings will help in measuring the size of the image formed on the screen in task 3.

Figure 3: *Markings on screen for measuring image size*

iii. Fold another rectangular chart paper into a cylindrical tube such that it is smaller in length and slightly larger in diameter than the IT, so that the IT can slide inside smoothly. Cover one end of this tube with a circular black chart paper or aluminium foil and make a hole in the centre using a pin (aluminium foil is slightly easier to work with). We will call this tube the pinhole tube (PT).

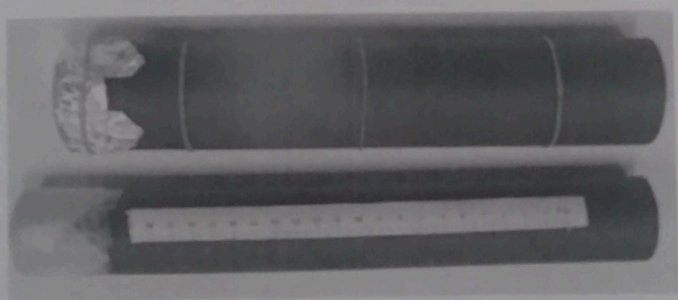

Figure 4: *IT and PT*

iv. Insert IT inside PT (as shown in figure 5) till the screen just touches the pinhole (refer figure 1). Mark a point 'O' on the IT where PT ends. Now take the IT out and stick a strip of white paper on it along its length (which is already done in figures 4 and 5). Taking point 'O' as zero, mark 5 mm intervals on the paper so that it can be used as a scale [You may also use a printed scale, if available]. This scale will be used to measure *l*, i.e., the distance between the screen and pinhole.

Now the pinhole camera is ready to use!

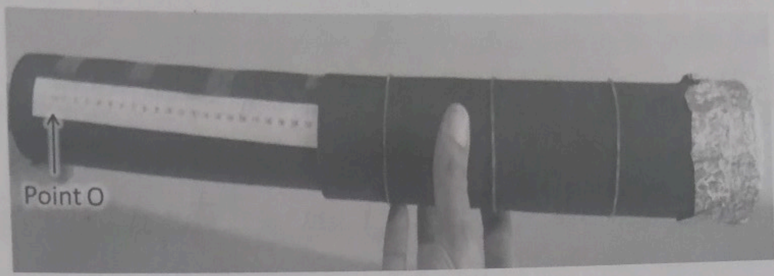

Figure 5: *Assembling the camera*

v. To view an image, point the pinhole towards the object (the object should be brightly lit) and adjust the distance between the screen and the pinhole to view a clear image of the object on the screen. A picture of Homi Bhabha Centre for Science Education building, Figure 6(a), when viewed through the pinhole is shown in Figure 6(b).

Figure 6(a): *Object*

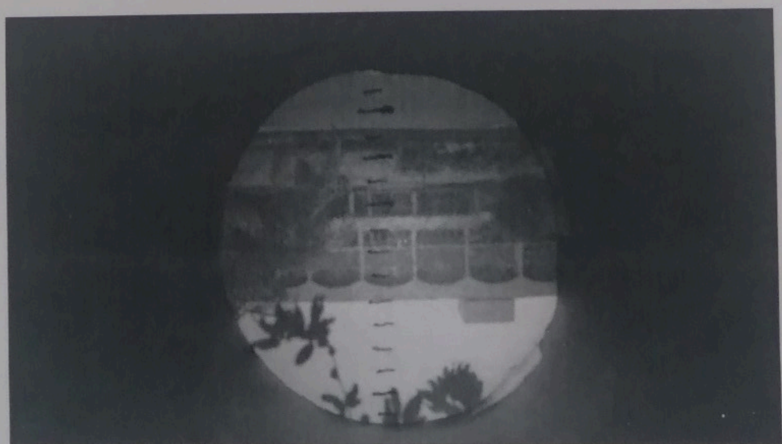

Figure 6(b): *Image in pinhole camera*

Q1. What has changed from the object to the image? Can you describe the changes and think of reasons?

The Reflection of Light through hole has changed the object to image. And it turns the image upside down.

Q2. What happens to the image:

(I) if without changing the pinhole camera setting, if you move the pinhole further away from the object? Compare your image in terms of what view is covered now and before, size of image etc.

If we move futher away from the object the area of view gets bigger and the Image gets blured.

(ii) if you increase the distance between the pinhole and the screen?

Image is not clear as we gets backward between the pinhole and the screen.

(iii) if the illumination (brightness) of the object changes, or you look towards another object with lesser illumination?

In lesser illumination the image gets blured and appers dark.

Q3. Now explore what happens if pinhole size is smaller and larger respectively. First, make some guess of how variation in the pinhole size will affect the image. [You may compare the same object with pinhole cameras of different groups, which may vary in pinhole size.]

The area of the view gets bigger and the image gets more clear if the pinhole size is larger. The area of the view gets smaller and the image is clear.

Task 2: Constructing a model to explain the image formation in task 1

Here our aim is to construct a geometrical model that would explain the image formation observed in task 1.

One of the understandings that evolved over the years is that when light travels in a medium of constant refractive index, it travels in a straight line. Therefore, the path of light is represented using a ray. You must have seen ray diagrams in your science book.

Q1. Let us try to draw a ray diagram to represent the image formation obtained in task 1. One ray TP starting from an object which goes in a straight line towards the pinhole P will meet the screen at point T', as already drawn in figure 7 below. Can you draw three rays similar to TPT' originating from different points from the object in the figure?

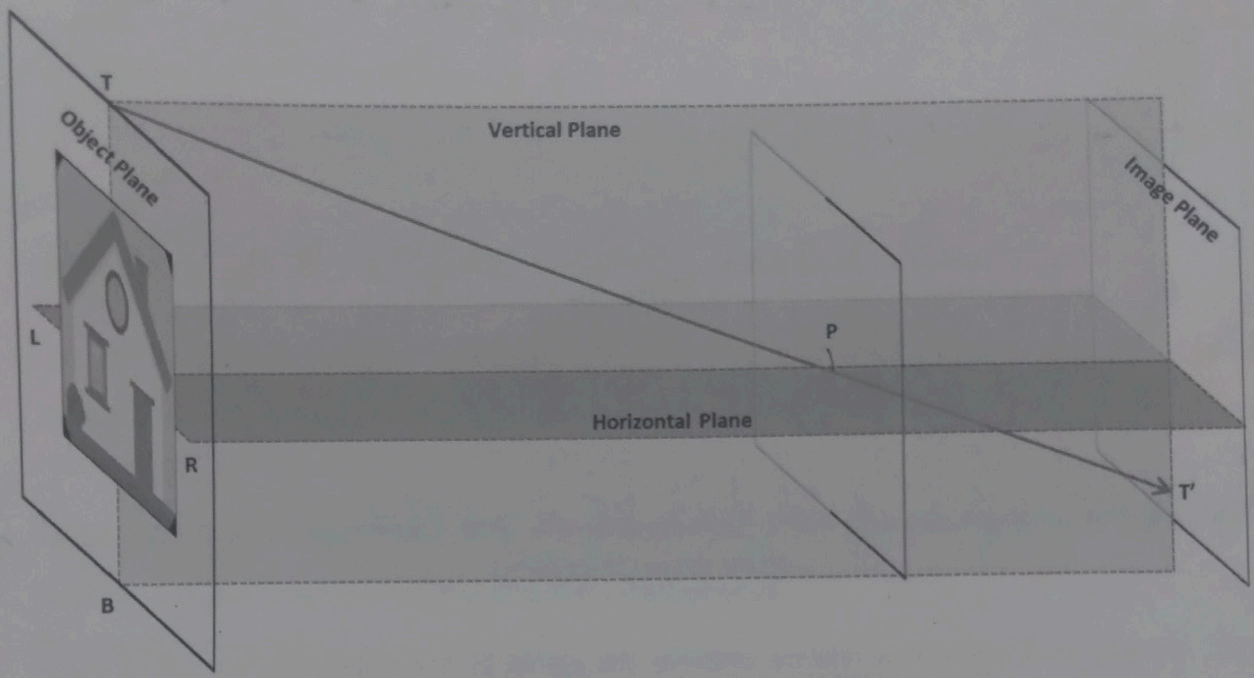

Figure 7: *Draw rays originating from the object and falling on screen*

Q2a. Refer to figure 8. Consider the ray ZPZ'. The ray starts from a green coloured point Z in the object. There is a brown coloured point at Q. What do you think will be seen at Z' in the image plane? A green dot or a brown dot? Similarly, suppose there is another ray QPQ'. What will you see at Q' in the image plane?

The image will be upside down so Z will be Q (brown) and Q will be Z (green).

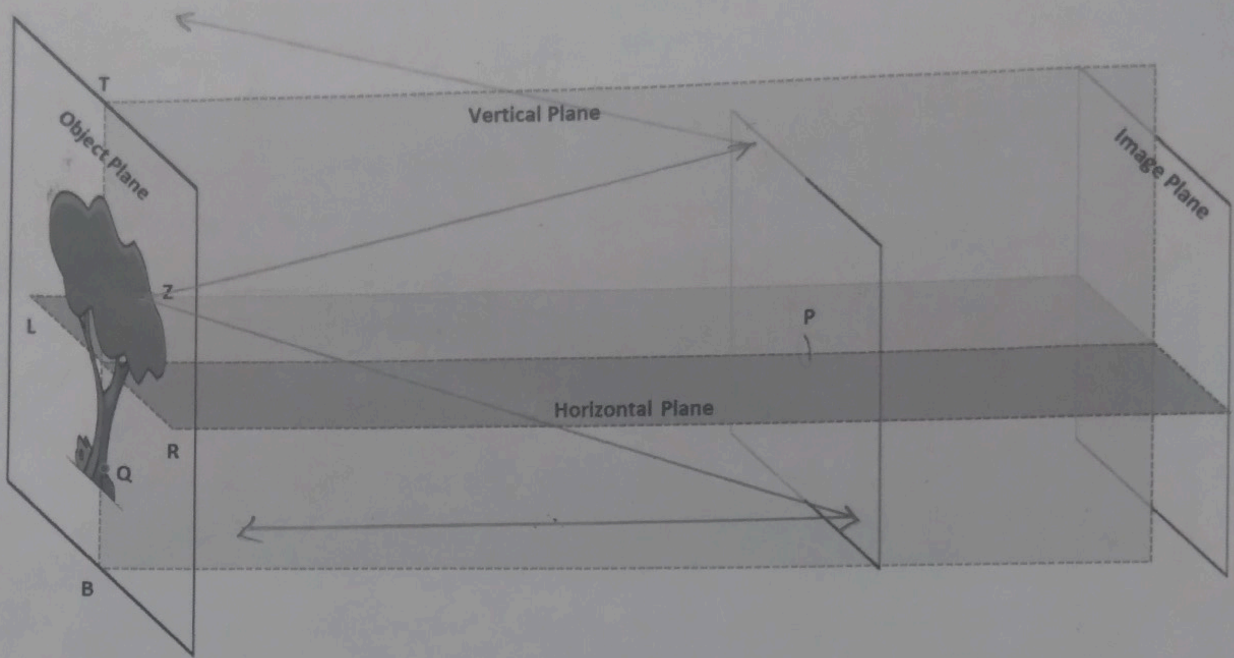

Figure 8: By drawing rays originating from the object, predict where green and brown points would be observed on the screen (image plane).

Q2b. Do you think there is a relation between the points on the object and the image plane? Discuss.

There is a relation between the points on the object and the image plane as the object in the left side appers in the opposite direction of the image in the right side.

Q2c. Referring to figure 8, can you explain the orientation of the image observed?

The vertical plane gets upside down.

Q2d. What should be the light path if the image was to be of same orientation as the object? Check if this is observed in any of the pinhole cameras made by you or your friends.

Not possible.

Q3. Now, with the knowledge of light path discussed in the previous question, draw two rays in figure 8 which originate from the same point on the object, fall on the surface surrounding the pinhole (which acts as a blocking surface), and don't enter the hole. Where will these rays go?

These rays will be reflected back.

Q4. If this blocking surface is removed, then where would these rays go? What would be the effects of these light rays on the image on the screen?

If there is no blocking surface the rays will pass through the translucent sheet and the image can not be seen.

Q5. What do you think will happen to the image if the size of the pinhole is too big? Is your answer consistent with your observations in task 1?

Yes, The image gets big and blurred if the size of the pinhole is too big.

Further questions to discuss: Based on the above model/representation of image formation, answer the following questions:

Q6. To get a clear image, why do you think object should be well-illuminated?

To get a clear image, the object should be well-illuminated because so that we can see the image of the object clearly.

Q7. What do you think will happen to the image, if the size of the pinhole is too small? Is your answer consistent with your observations in task 1?

Yes, if the size of the pinhole is too small the image of the object gets smaller but is still clear.

Task 3: Measuring the height of a very tall object

Pilot (Ideal scenario)

Figure 9 below shows the diagram for image formation in a pinhole camera.

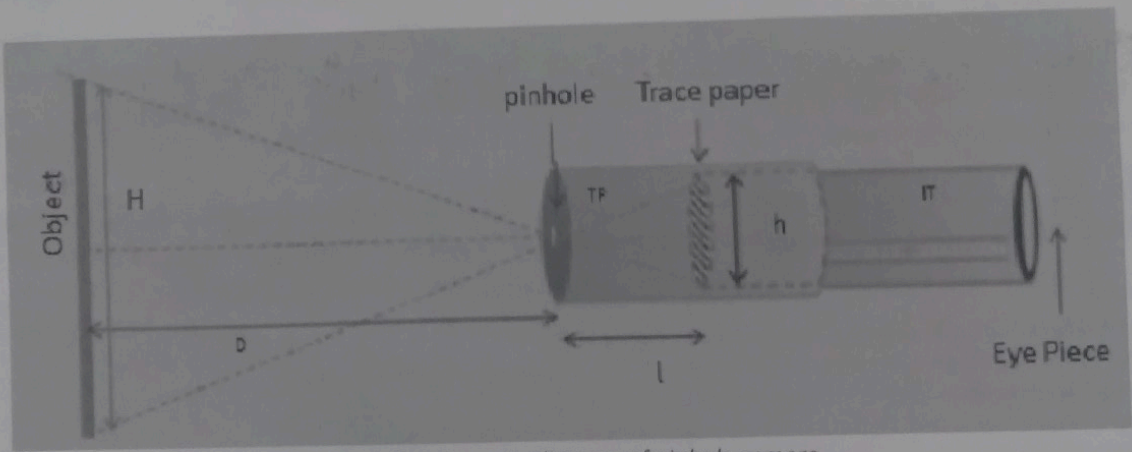

Figure 9: *Schematic diagram of pinhole camera*

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.

Once you know D, l, and h you can find the height of the object H based on the following considerations.

Consider the two triangles in figure 9 with shared vertex at the pinhole. Since they are similar triangles, $h/l = H/D$. *Rearranging we get* $H = hD/l$

You may use the formula directly at this point without deriving it but you might want to check the properties of similar triangles to learn how the formula is derived.

Working (real) example

Now, we will make use of this equation in a real-life example. Take your pinhole camera, and capture an image of a distant (well-illuminated) object such as a building or a tree. Measure D using a tape, measure L using the scale on the inner tube, and h using the scale marked on the screen.

Obtain clear inverted image for multiple values of D. Tabulate your reading of D, l and h below:

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

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

Q1. Can you estimate the height of the object by any other methods? Compare it with the answer you obtained using pinhole camera?

____

Discuss

Q2. If you want to see a bigger image on the screen (without changing the pinhole screen distance), should you move the pinhole closer to the object or farther away?

To see a bigger image on the screen (without changing the pinhole screen distance we should move the pinhole screen closer to the object to see bigger.

Q3. What will happen to the image if you make the screen using a transparent plastic sheet instead of translucent sheet?

If we use a transparent plastic sheet instead of translucent sheet we will see a white dote in the middle of screen and nothing will be visble.

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