6 - Pinhole Tube and Telescope

Part I: Pinhole

Purpose: To build a pinhole tube and use it to make a terrestrial measurement.

Materials:

- 2 paper tubes
- aluminum foil
- tracing graph paper
- rubber bands
- 200 Watt unfrosted light bulb with clamp socket
- straight pin
- ruler
- measuring tape
- masking tape
- stand

What do you think?

In the spaces provided, write your best estimate based on your personal experience.

Q1. How many Sun diameters fit between Earth and the Sun? ____________________

Procedure: Building a Pinhole Tube

Refer to Figure 1 for steps 1 through 4.

1. Check that the two paper tubes fit together easily. Slide the inside tube into the outside tube. Check to see whether or not the inside tube slips out on its own. If the inner tube slips out without pulling, you can experiment with adding a layer of tape to the inside tube or wrapping a rubber band around the end of the outside tube to prevent the inside tube from slipping out.
2. Place the aluminum foil over the end of the outside tube. Use a rubber band to hold the foil in place. Be careful to keep the foil smooth over the end of the tube.

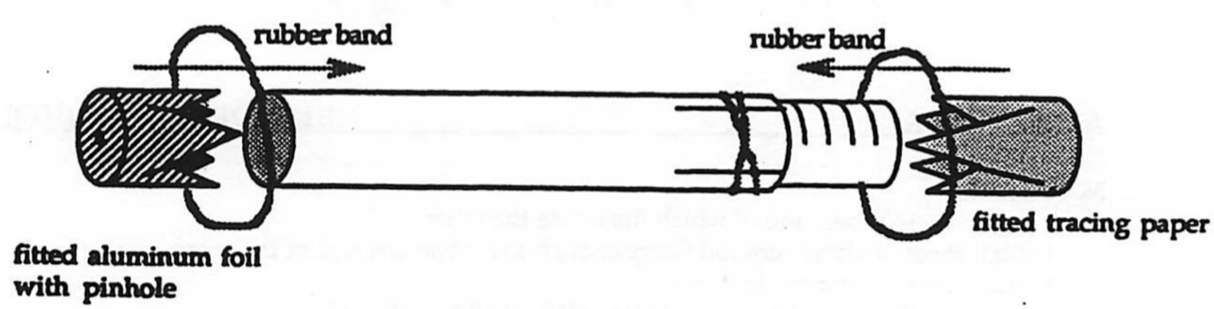

Figure 1: *Pinhole Tube*

3. Using a straight pin, slowly and and carefully punch a small hole in the center of the aluminum foil. Check that the pinhole is round and not a linear rip.

4. Place the graph tracing paper over the end of the smaller tube. Hold the paper in place with a rubber band and be careful to keep the tracing paper smooth over the end of the tube.

Confirm that the instructor or TA has placed a 200-watt light bulb in the room. Keep the bulb off. Refer to Figure 2 for steps 5 - 7.

DO NOT TOUCH THE BULB WHEN IT IS ON OR FOR A FEW MINUTES AFTER IT'S OFF. YOU MAY BE BURNED!

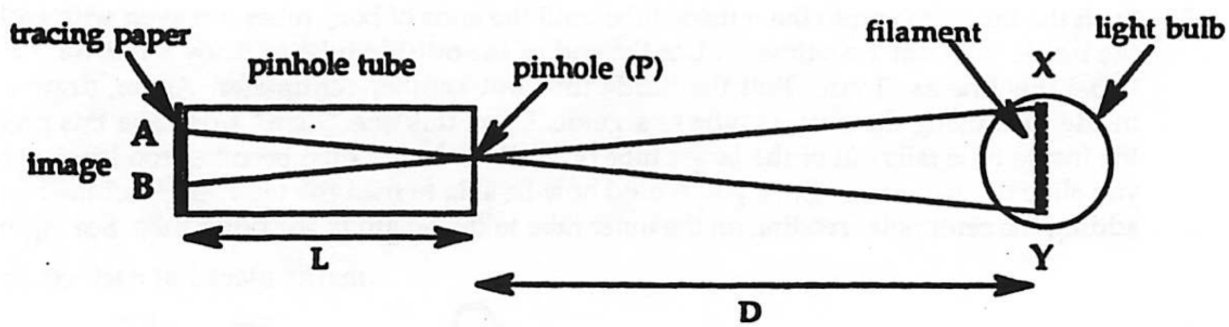

Figure 2: *Diagram of the relationship between the the filament length (XY), pinhole to filament distance (D), length of pinhole tube (L), and length of image of the filament on the tracing paper (AB).*

5. <u>Filament Size</u>: Measure the length of the filament (line XY in Figure 3). (The filament is the tightly coiled piece of wire inside the glass bulb.) To make the measurement, look straight at the bulb from the side and hold a ruler against the glass. Close one eye and estimate the length straight across. The filament is slightly curved therefore measure the straight line distance between the two ends of the filament.

   Q2. The length of the filament (XY) is ______________ cm.

6. <u>Acquire Filament Image:</u> Set up the telescope on the stand a few meters from the bulb. Aim the pinhole at the filament, <u>keeping the pinhole tube horizontal and perpendicular to the filament of the bulb.</u> Slowly move the tube around until you can see an image of the bulb's filament on the tracing paper; it will appear as a small bright line.

7. <u>Investigate</u>: Change the size of the tube by sliding the smaller tube in an out.

   Q3. What happens to the image as you change the length of the tube?

8. Measure: Once you have found a nice image of the filament, mark it on the tracing paper. As accurately as possible, measure the distance between the filament and the pinhole, the length of the tube and the length of the filament's image on the tracing paper.

Q4. The length of the tube is ________________ cm.

Q5. The distance between the bulb filament and the pinhole (D) is ____________ cm.

Q6. The length of the filament's image on the paper screen (AB) is _____________ cm.

Q7. Look at Figure 2. Draw a similar diagram, showing the filament, the tube, and the two triangles, labeling all components as in Figure 2 and adding your measurements from questions Q4 to Q6.

Q8. How is triangle APB related to triangle XPY?

Q9. Calculate the ratio of the bulb-pinhole distance (D) to the filament length (XY):

Q10. Calculate the ratio of the pinhole tube length (L) to the filament image length (AB):

Q11. Discuss the usefulness of the relationship of the ratio in questions Q9 to the ratio in question Q10.

Part II: Simple Telescope or Camera

Purpose: To build a simple telescope or camera and use it to make terrestrial observations.

Materials:

- 1 cardboard tube set
- 1 large lens
- tracing paper
- 1 200 Watt unfrosted light bulb with clamp socket
- meter stick
- stand
- ruler

What do you think?

In the spaces provided, write your best estimate based on your personal experience.

Q12. If you were to replace the aluminum foil in a pinhole tube with a lens, how would the image on the tracing paper change (if it changes)? Compared to those formed by the pinhole tube, would the images be brighter or dimmer? Bigger or smaller? Right side up or upside down? Clearer or fuzzier?

Procedure: Building a Simple Telescope or Camera

Refer to Figure 3 for the following instructions.

Figure 3: *Replace the pinhole with the large lens using the red cap.*

9. Build the telescope: Remove the pinhole from the tube (if it's still on). Fit the large lens snugly against the front of the outer tube, making sure it's positioned perpendicular to the tube and well centered in the tube. Leave the tracing paper on or add a new piece of tracing paper to the end of the inner tube and secure it with a rubber band.

10. Investigate: Change the size of the tube by sliding the smaller tube in an out.

Q13. What happens to the image as you change the length of the tube?

11. Measure: Stand about 3 meters from the 200-watt bulb. With the room lights off, aim the lens end of the tube at the bulb. Acquire a clearly focused image of the filament on the tracing paper.

Q14. The distance between the lens and light bulb is ______________ m.

Q15. Length of the tube is ______________ cm.

Q16. Describe the image you see on the tracing paper.

12. Move Away and Measure: Take your telescope to the side of the room farthest from the bulb. Acquire a clearly focused image of the filament on the tracing paper.

Q17. Distance to light bulb is ________________ m and length of the tube is ______________ cm.

Q18. Is this length of the telescope tube longer or shorter than it was when you were closer to the bulb?

Q19. If you wanted to project a clear image of a very distant object, would the telescope length have to be longer or shorter?

13. Observe a Distant Object: Step out of the laboratory and aim the telescope at a very distant object. Adjust the sliding tube until the image is focused clearly on the paper.

Q20. Describe the distant object:

Q21. Length of the tube is ______________ cm.

Q22. Relative to the telescope tube length measured in question Q17, did you have to lengthen or shorten the telescope to bring the image into focus?

*For a very distant object, the length of the tube or the distance between the tracing paper and the lens is called the **focal length of the lens**. Focal length is defined as the distance at which a lens (or mirror) will focus to a point light from a source very far away.*

Q23. Thinking about the images you created when standing close and far from the bulb and then the distant object, in what ways are the images similar and different?

You have now built a camera that is fundamentally the same as one that an astronomer might use. Astronomers seldom use telescopes to simply view the sky visually. Far more often, they use optical telescopes for taking pictures or gathering light that is analyzed with special equipment such as spectrographs. The lens collects the light coming from a distant object. When taking astronomical pictures the image can be focused on a CCD detector, like a digital camera. The tracing paper on your tube takes the place of a CCD.

CCDs were not invented until the late 1960's. Photographic film was not invented until the 1800's. Before then, astronomers looked through their telescopes and made drawings of what they saw. You will now convert your telescope so you can look through it.

Part III: Basic Use of Telescope

Purpose: To build a telescope and use it to make terrestrial observations.

Materials:

1 cardboard tube set
1 large lens
1 small lens in foam lens holder
stand
tracing paper

Procedure: Building a Simple Telescope

Refer to Figure 4 for steps 5 and 6.

14. Convert the Camera to a Telescope: Remove the tracing paper from your pinhole tube. Gently squeeze the foam holder and press the lens/holder assembly into the end of the smaller tube. Use the white cardboard ring to help push the foam holder into the tube. Be sure the lens is positioned perpendicular to the end of the tube. (You may have to twist the holder to position the lens properly.)

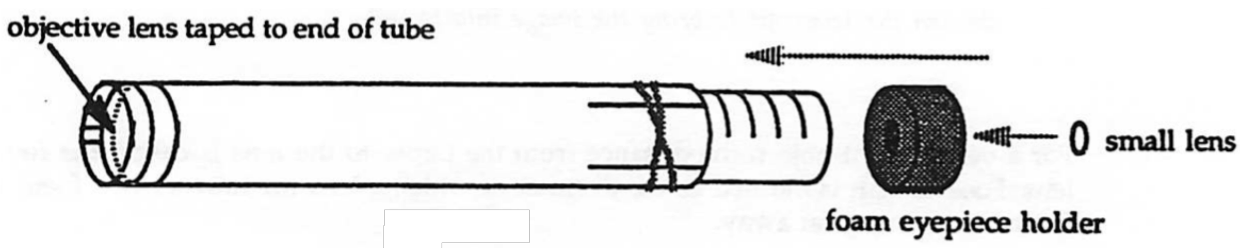

Figure 4: *Replace the tracing paper end of the tube with the small lens inserted in the foam lens holder. Make sure the lens is positioned perpendicular to the tube.*

NEVER LOOK AT THE SUN THROUGH THE TELESCOPE!

The large lens is called the objective lens. The small lens is called the eyepiece.

The telescope with the eyepiece is doing two things: 1) the objective lens is forming a very small image of a distinct object near its focal point, and 2) the eyepiece is acting like a simple magnifying glass, enlarging the small image.

15. Measure: Take the telescope with the stand and go outside to observe an object at a great distance. Looking through the eyepiece, aim the objective end of the telescope at the object. Adjust the telescope length until you see a focused image of the distant object. Measure and record the distance between the two lenses.

Q24. Length of the tube is ______________ cm.

16. Record your observation on the observing log sheet (next page).

Observing Log Sheet

Fill in the information. In the circle below, make sketches of what you can see and provide any written description of the object in the space provided.

Object Name: ____

Date: ____________________________________

Time: ____________________________________

Location: _________________________________

Azimuth: _________________________________

Altitude: __________________________________

Weather Conditions: ____

Description:

Part IV: Calibrating your Telescope

Purpose: To calibrate your telescope

Materials:

- 1 simple telescope
- stand
- meter stick
- ruler

17. Measure: Tape a meter stick vertically against a wall so that it is five to ten meters from the table. Position your telescope on the table and focus it on the meter stick. As you move forward, be careful to use the correct units. Recall: 1 m = 100 cm = 1000 mm.

    Q25. How many millimeters of the meter sick are visible in the whole field of view of the telescope?

    Q26. How far, in meters, is the meter stick from the objective lens of your telescope?

18. Find the telescope scale: Divide your answer to question Q25 by your answer to question Q26. Double check the units!

    Q27. Q25/Q26 = (size)/(distance) = ______________________ (units: mm/m)

    The number in question Q27 is the telescope's calibration scale. This scale is a size to distance ratio. The scale tells you the size of the object in millimeters that fills the field when viewed at a distance of one meter. This scale can be used to determine an object's size when the distance is known or to determine the distance to the object when the size is known.

19. Application: Set up your telescope to focus on a large object on the opposite side of the room. Carefully observe the portion of the object that fills the entire field-of-view of the telescope.

    Q28. Description of your chosen object:

    Q29. The distance from the objective lens to the object your are viewing is _______ m.

    Q30. Using the telescopes calibration scale, calculate the width of the portion of the object you observed to fill the field of view: _____________ mm.

Q31. Check your work by measuring the width of the portion of the object you observed. What is the difference between the calculated size and the measured size? Given the equipment we are using, if the difference (error) is less than 1/10th of the measured distance (10% error), your calculated distance is accurate.

Q32. Now that you have calibrated your telescope, go back to your observation log, and make an educated guess of either the size of the object you observed or its distance. Describe you thought process.

Q33. If you know the focal length of your telescope and the width of the image it creates, what else would you need to know to calculate the distance between the telescope and the object on which the telescope is focused?