PhyzLab:
Pinhole Puzzles

an investigation of pinhole optics

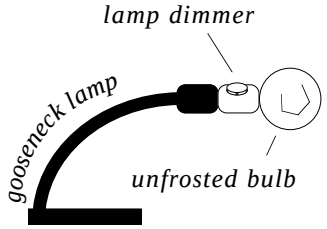
Adapted from "Pin Holes and Shadows" by Dewey Dykstra and research by Lillian McDermott and Fred Goldberg.

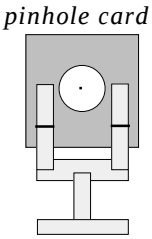
• Purpose •

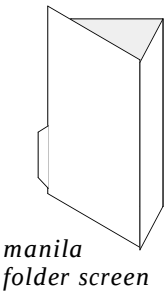
In this activity, you will explore the characteristics of pinhole images and the method by which a pinhole image is formed. It's a bit tricky, and some findings will surprise you. You'll get nothing out of this investigation unless you give thoughtful consideration to your predictions, make careful observations, and construct thorough conclusions based on your observations.

• Apparatus •

___ gooseneck lamp with lamp dimmer
___ 40W unfrosted bulb with 4-sided filament
___ one-hole pinhole card (aluminum foil with a single pinhole on a card with a large opening)
___ three-hole pinhole card
___ card holder ("goalposts" or equivalent)
___ hole poker (thumbtack or equivalent)
___ screen (manila folder or equivalent)
___ meterstick







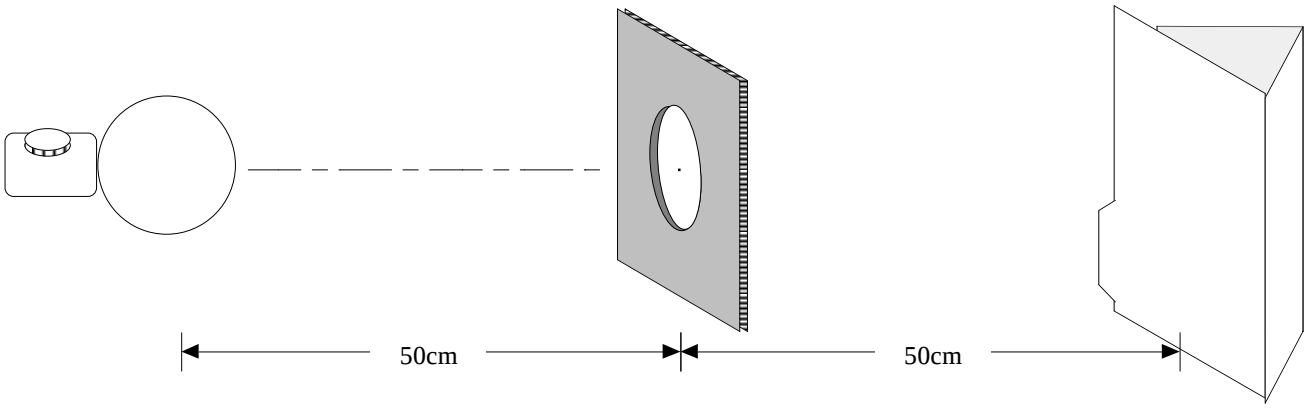
• Procedure •

CAUTION: THE LIGHT BULB GETS VERY HOT! DO NOT TOUCH IT WHEN IT IS ON!

1. INITIAL OBSERVATIONS

a. Prepare a pinhole card. Cover the opening of the pinhole card with a piece of aluminum foil. Use the hole poker to make a hole in the foil at the center of the opening.

b. Arrange the apparatus as shown below. The pinhole card is held in the goalposts. Now put the screen down (on its face) and turn on the light. Note that the gooseneck of the gooseneck lamp has been adjusted so that the center of the filament is centered on line with the pinhole.



c. Prediction. What will appear on the screen when the light is turned on? Describe in words in the space below and sketch your prediction on the diagram above. Don't forget to draw the filament in the bulb (as shown in the "Apparatus" diagram above). Discuss your answer with your group. Do all members agree? If there are alternate opinions, record them.

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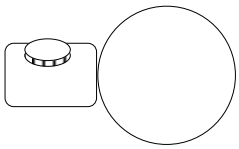
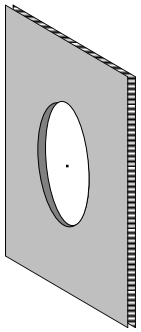
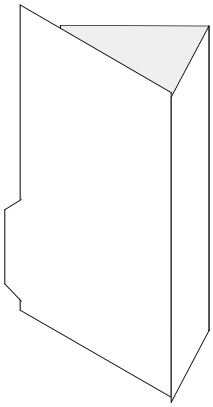
d. Observation. When the group is pretty sure of its ideas, turn on the light. Sketch your observation of the filament in the bulb and the image on the screen.





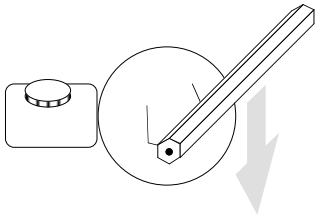


e. Conclusion. How do your observations compare to your prediction? (Is this what you expected to see?) Discuss the results with your group. Can the group explain any discrepancies between predictions and observations? If so, write the explanation; if not, write about the aspects that remain unclear.

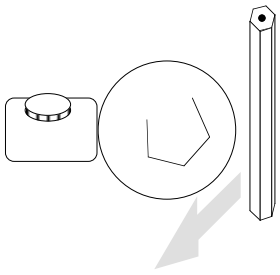
2. SO IS IT, LIKE, TOTALLY FLIPPED OUT?

a. Prediction/Interpretation of previous observations. Is the image flipped upside down? Is it flipped left and right? Explain the reasoning behind your answer. Discuss your answer with your group. Do all members agree? If there are alternate opinions, record them.

b. Observation. Hold a pencil horizontally over the front of the bulb. Lower it until it blocks part of the image of the filament. Move it downward past the filament, watching the image as you do so. (See diagram.) Record your results.



c. Observation. Hold a pencil vertically to the left of the front of the bulb. Move it to the right until it blocks part of the image of the filament. Move it to the right past the filament, watching the image as you do so. (See diagram.) Record your results.



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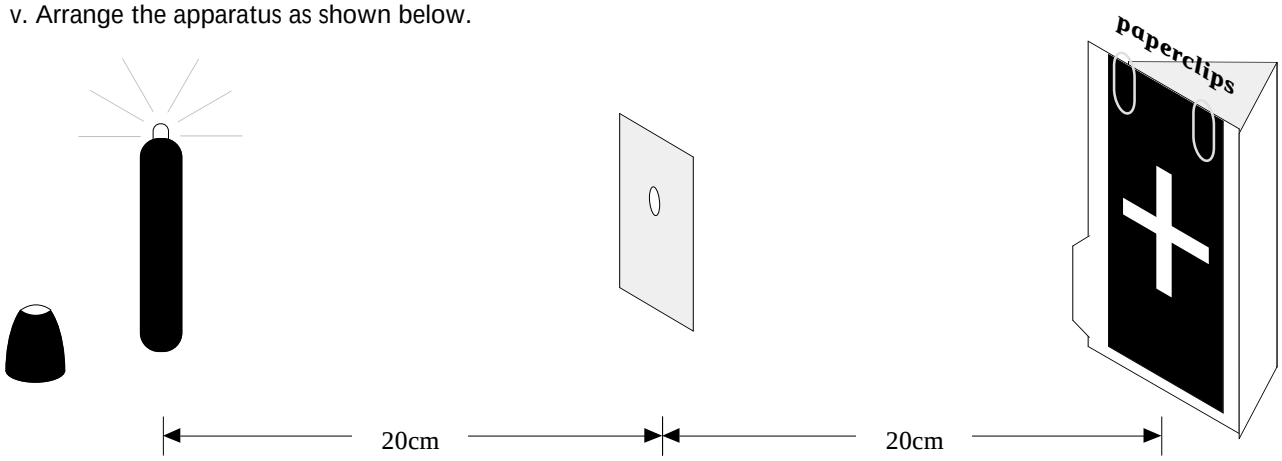
d. Conclusion. How do your observations compare to your prediction? Discuss the results with your group. Can the group explain any discrepancies between predictions and observations? If so, write the explanation; if not, write about the aspects that remain unclear.

3. RAY TRACING

a. Obtain a mini maglite™, an index card, two paperclips, and the Ray Tracing Patterns (1-3).

b. Setting up.

i. Set aside the gooseneck lamp (the mini maglite will be the light source in this activity).
ii. Put a hole-punch hole in the index card (if this hasn't been done yet).
iii. Replace the pinhole card with the index card.
iv. Attach Ray Tracing Pattern 1 to the screen using the paperclips.
v. Arrange the apparatus as shown below.



c. Activity.

i. Completely unscrew the mini maglite's top section (lens and reflector) so that you can see the tiny—but bright—exposed bulb.
ii. Move the mini maglite until the light that passes through the index card hole strikes the center of the cross.
iii. Now, simply move the light around to completely trace out the cross.
iv. Allow each member of the group to trace the pattern while you move on to the next step.

d. Observations. Was there anything unusual or unexpected about this activity? What was your method for successfully tracing the pattern?

e. After everyone in the group has successfully traced Ray Tracing Pattern 1, replace it with Ray Tracing Diagram 2.

f. After everyone in the group has successfully traced Ray Tracing Pattern 2, replace it with Ray Tracing Diagram 3.

g. Any additional comments/observations?

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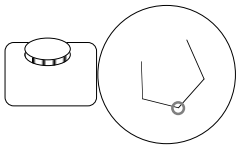
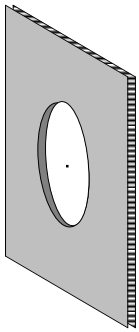
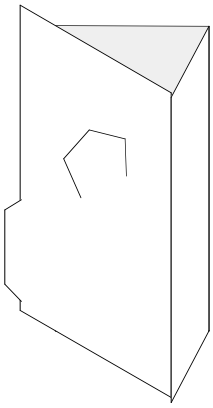
3. HOW DOES IT DO THAT?

Explanation. How is the pinhole image of a filament on the screen formed? What happens between the filament and the screen to produce an image with the characteristics you've observed? Can you illustrate your answer using a ray diagram? Consider light coming from the circled part of the filament. How does that light end up on the screen? What part of the light got through the filament, and what did that light do while traveling from the pinhole to the screen? (Draw two more rays of light coming from other parts of the filament. How do they get from the filament to the screen?)







5. MOVING PICTURES

a. Moving the screen. Recap and turn off the mini maglite. Arrange the apparatus as shown in 1.b.

i. Prediction. What do you think will happen to the image if the screen is moved closer or farther from the pinhole? Will it move, change size, blur, disappear or what? **Make three sketches: one of the "standard" pinhole image (as in the sketch from part 1.d), one of what it will look like if you move the screen closer, and one of what it will look like if you move the screen farther.** Discuss your answer with your group. Do all members agree? If there are alternate opinions, record them.

standard	**screen closer**	**screen farther**

ii. Observation. When the group is pretty sure of its ideas, move the screen closer and then farther from the pinhole and record the results. Consider the following characteristics of the image: position, size, sharpness, and brightness. Do any of these change?

standard	**screen closer**	**screen farther**

iii. Conclusion. How do your observations compare to your prediction? Discuss the results with your group. Can the group explain any discrepancies between predictions and observations? If so, write the explanation; if not, write about the aspects that remain unclear.

b. Moving the filament.

i. Prediction. Based on your explanation above (don't worry if its right or wrong yet), what do you think will happen to the image if the filament is moved closer or farther from the pinhole? Will it move, change size, blur, disappear or what? **Make three sketches: one of the "standard" pinhole image (as in the sketch from part 1.d.), one of what it will look like if you move the filament closer, and one of what it will look like if you move the filament farther.** Discuss your answer with your group. Do all members agree? If there are alternate opinions, record them. (Record prediction on next page.)

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standard	bulb closer	bulb farther

ii. Observation. When the group is pretty sure of its ideas, move the filament closer and then farther from the pinhole and record the results. Consider the following characteristics of the image: position, size, sharpness, and brightness. Do any of these change?

standard	bulb closer	bulb farther

iii. Conclusion. How do your observations compare to your prediction? Discuss the results with your group. Can the group explain any discrepancies between predictions and observations? If so, write the explanation; if not, write about the aspects that remain unclear.

6. JUMBO PINHOLE (AN OXYMORON?)

a. Arrange the apparatus as in part 1 of the lab and again observe the "standard" pinhole image of the filament.

b. Prediction. What about the image—if anything—would change if the pinhole were replaced by a larger hole (the size of a hole-punch hole)? Explain the reasoning behind your answer. **Include a sketch that expresses your answer and explanation visually.** Discuss your answer with your group. Do all members agree? If there are alternate opinions, record them.

c. Observation. When the group is pretty sure of its ideas, put the index card in the card holder and place the hole-punch hole where the pinhole used to be. Observe the resulting image. Record your observations in words and a sketch.

d. Conclusion. How do your observations compare to your prediction? Discuss the results with your group. Can the group explain any discrepancies between predictions and observations? If so, write the explanation; if not, write about the aspects that remain unclear.

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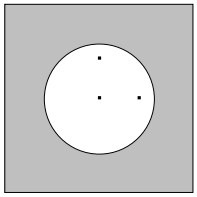
7. HOLEY ALUMINUM!

a. Prediction. What difference in the "standard" (small pinhole) pinhole pattern—if any—would occur if more pinholes were poked through the aluminum? Explain the reasoning behind your answer. **Include a sketch that expresses your answer and explanation visually.** Discuss your answer with your group. Do all members agree? If there are alternate opinions, record them.

c. Observation. When the group is pretty sure of its ideas, replace the one-hole pinhole card with the three-hole pinhole card. Observe the resulting image. Record your observations in words and a sketch.



d. Conclusion. How do your observations compare to your prediction? Discuss the results with your group. Can the group explain any discrepancies between predictions and observations? If so, write the explanation; if not, write about the aspects that remain unclear.

8. MOVING PICTURES (AGAIN!)

a. Prediction. How will the image formed by the three pinholes change if the screen is moved closer or farther from the pinhole card? Explain the reasoning behind your answer. **Include a sketch that expresses your answer and explanation visually.** Discuss your answer with your group. Do all members agree? If there are alternate opinions, record them.

standard	**screen closer**	**screen farther**

b. Observation. When the group is pretty sure of its ideas, move the screen closer and then farther from the pinhole and record the results. Does the pinhole image change in any way?

standard	**screen closer**	**screen farther**

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c. Conclusion. How do your observations compare to your prediction? Discuss the results with your group. Can the group explain any discrepancies between predictions and observations? If so, write the explanation; if not, write about the aspects that remain unclear.

9. CAST A LONG SHADOW

a. Obtain a small square transparent plate (glass or equivalent) and an overhead projector marking pen.

b. Prediction. If the pinhole card were replaced by a small dot on the glass plate, what would appear on the screen? Also, how would the image on the screen change if the glass plate were moved closer to or farther from the screen. Explain the reasoning behind your answer. **Include a sketch that expresses your answer and explanation visually.** Discuss your answer with your group. Do all members agree? If there are alternate opinions, record them.

b. Observation. When the group is pretty sure of its ideas, use the overhead pen to draw a small dot at the center of the glass plate and replace the pinhole card with the glass plate. What appears on the screen? Include a sketch.

c. Conclusion. How do your observations compare to your prediction? Discuss the results with your group. Can the group explain any discrepancies between predictions and observations? If so, write the explanation; if not, write about the aspects that remain unclear.

d. Prediction. What would appear on the screen if two dots were added to the dot on the glass plate (one above and one to the side)?

e. Observation. What appears on the screen when two dots are added to the dot on the glass plate (one above and one to the side)?

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