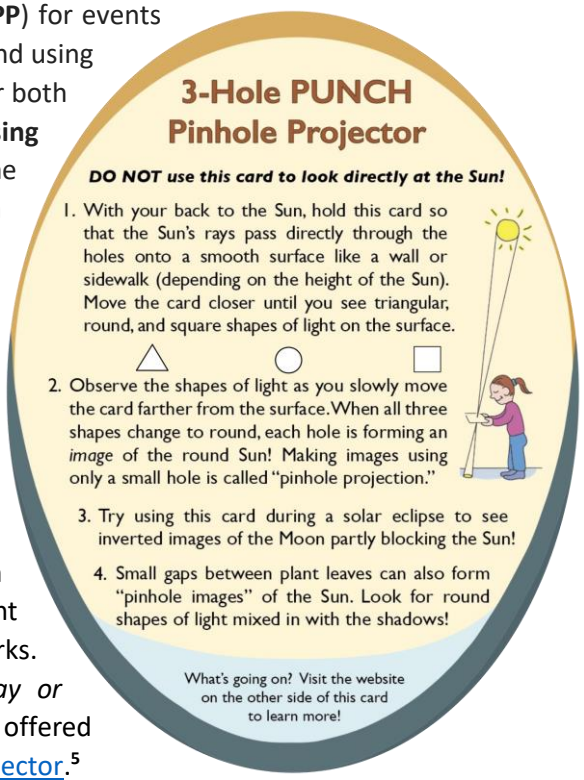
# Facilitator Guide for the 3-Hole-PUNCH Pinhole Projector (with 5 enrichments)

We recommend using the **3-Hole-PUNCH Pinhole Projector** (**3HPPP**) for events in three settings. For outdoor events on a sunny day, we recommend using our 3HPPP in tandem with **Solar Protection ("Eclipse") Glasses.** For both outdoor and indoor events, we suggest adding a **tabletop demo using an LED desk lamp**[1] with cut-out masks that change the shape of the light source. For events with access to sunlight filtering through blinds or the leaves of plants, we strongly recommend guiding participants to notice natural pinhole images of the Sun and recognize this as the same phenomenon caused by the holes of the Projector. Pinhole projection *can* provide powerful experiences that excite wonder, curiosity, and a lifetime of attention to the natural world, with or without an eclipse.




We strongly urge you to view our short "how-to" home videos[2] which encapsulate the results of extensive field-testing and show how to lead inquiry that maximizes wonder and curiosity both indoors and outdoors. Our downloadable PDF and PowerPoint presentations (Table below) clarify how pinhole imaging *really* works. We also recommend showing or printing the *Slides for Display or Presentation* (pdf[3], ppt[4]) to accompany the field-tested activities offered here. All resources are linked from the overall webpage for the Projector.[5]

| Section | Title of this Section | Description of this Section |
|---|---|---|
| **1** (pdf[6], ppt[7]) | **How to Use the 3-Hole-PUNCH Pinhole Projector** | introduces the 3HPPP, demonstrates outdoor & indoor use, and describes differences from a pinhole camera/viewer |
| **2** (pdf[8], ppt[9]) | **Observing Pinhole Images of the Sun in Our Everyday Environments** | teaches you how to observe the phenomenon of pinhole images of the Sun in our everyday world, both indoors and outdoors |
| **3** (pdf[10], ppt[11]) | **Exploring Pinhole Projection Using Your Own Hands** | invites you to explore the behavior of pinhole projection by experimenting with your own hands (try both palms up!) |
| **4** (pdf[12], ppt[13]) | **Explaining and Understanding How Pinhole Imaging Happens – Part 1** | guides your quest for explanations and deeper understanding of how pinhole imaging happens. After this, you will *really* understand why small, lens-less holes can create images |
| **5** (pdf[14], ppt[15]) | **Explaining and Understanding How Pinhole Imaging Happens – Part 2** | offers more insights & resources (e.g., explaining the relationship between pinhole images and the view through "eclipse" glasses) |

**NOTE**: Superscript numbers refer to explicit tiny URLs in **Appendix B**.

The guidance below assumes that you can carry out the instructions on the back of the 3HPPP. Notice the position of the Sun in the sky and choose a vertical, horizontal, or angled projection surface that allows the sunlight to pass through the holes to create the least distorted shapes of light on the projection surface. The 3HPPP can surprise and delight learners whether or not an eclipse is in progress. This is due to the Projector's design with three holes of different shapes, all of which project images of the round Sun on a smooth, pale-colored projection surface as you pull the 3HPPP away from it. See how far you can pull back to make images larger than the holes! Field testing with diverse learners revealed the curiosity and wonder evoked as they witnessed the triangular, round, and square shapes of light (that they had predicted would appear on the projection surface) change before their eyes *into* 3 round shapes of light = pinhole images of the Sun! Take care not to ruin this surprise by keeping your hand behind the holes until after the learners predict what they think will happen.

**Five Enrichments:** The claim that the 3HPPP is showing us an actual image of the round Sun through each of the holes can become more persuasive to learners in diverse ways, depending on their age, interests, and background. Below are FIVE field-tested options with references and links. *Underlined italics indicate materials needed* in addition to the 3HPPP for each activity.

1. **Combine use of the 3HPPP with *solar protection glasses*** to reveal the striking round shape of a non-eclipsed Sun. This establishes the fundamental visual connection between the round shape of the pinhole images and the roundness of the Sun. Plus, it combines two safe ways of observing the Sun with or without an eclipse in progress.


2. **Connect 3HPPP results to the round or eclipsed shapes of light among shadows** cast in our everyday environment (e.g., sunlight streaming through small, odd-shaped gaps between the leaves of a plant or through gaps at the edges of window blinds). [See Section 2.[8,9]]

Morning sunlight passes through odd-shaped gaps between leaves.

Round shapes of light (pinhole images of the Sun) appear on the side of a building.

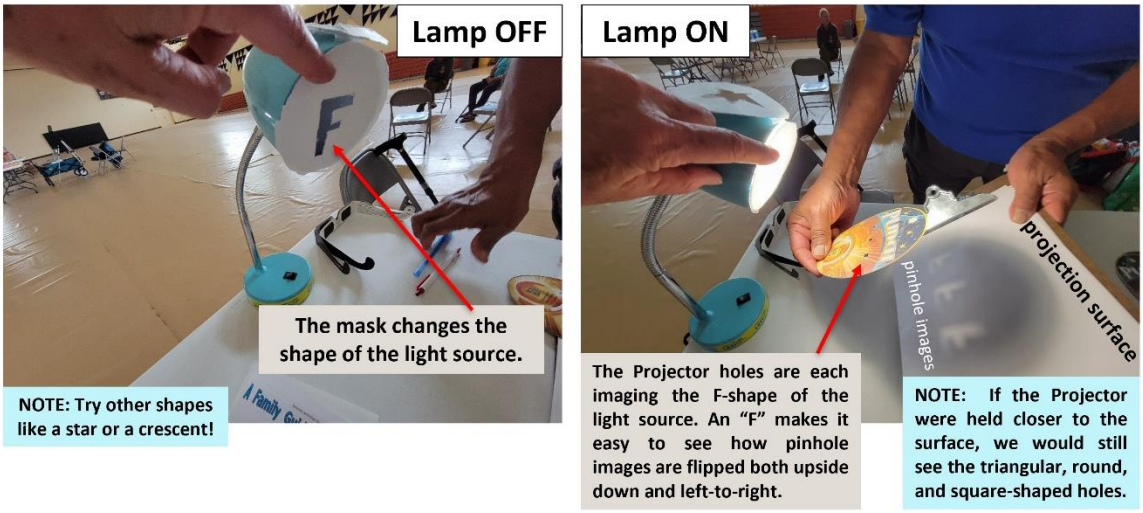
3. **Compare 3HPPP results with the rectangular gaps between crossed fingers** ("Waffle Fingers") to create round or eclipsed images of the Sun on a sidewalk or fence. [See Section 3[10,11] for a **guided "Waffle Fingers" exploration** and Section 5[14,15] to understand the relationship between the direct view through eclipse glasses and the inverted appearance of pinhole images.] During a solar eclipse, it is easier to tell that a pinhole image is inverted compared to direct viewing. Pinhole images are inverted both top-to-bottom & right-to-left.

View through solar protection glasses

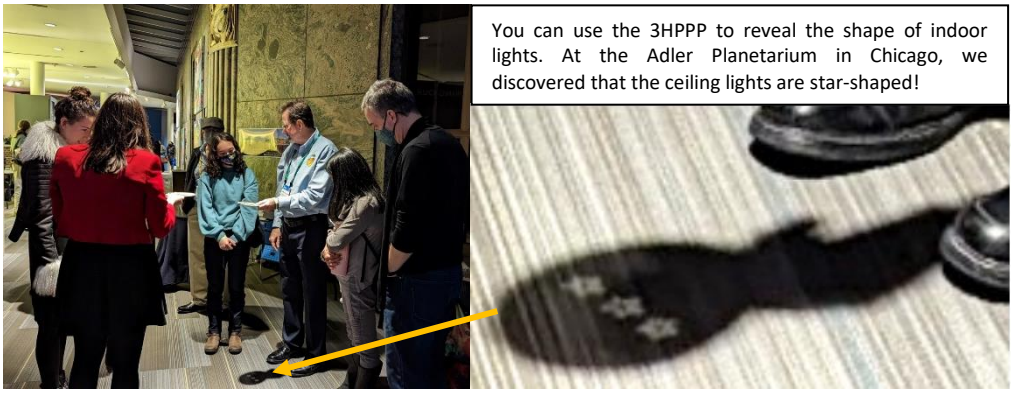
Corresponding Pinhole image

4. **Use the 3HPPP as part of an indoor demo (not just on rainy days!).** Use an ***LED desk lamp***[1] along with cut-out masks to change the shape of the light source (See **Appendix A** for cut-out mask instructions). Be sure to show that when you hold the Projector *very* close to the projection surface (*clipboard with white paper*) you still see the triangle, round, and square shapes of light corresponding to the projector holes. But as you draw the Projector away from the surface toward the "masked" LED light, you see the inverted shape of the cut-out projected onto the surface through all three holes. Below are two delightful examples: **a.** Using a **star-shaped mask/cut-out**, and/or **b.** Using an **"F"-shaped mask/cut-out**.

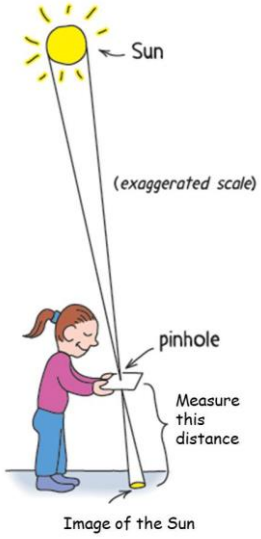
See **Section 5**[14,15] for more on the F-Shape Demo shown below. An F-shaped cut-out easily reveals the inversion of the pinhole images top-to-bottom and left-to-right.




See the *Slides for Display or Presentation* (pdf[3], ppt[4]) to find out more about the images below.



## 5. Estimate the Diameter of the Sun Using the 3HPPP




This activity works best with groups of 2 to 4 people. You need a *small coin* (dime or penny), *white paper* for projection surface, *marker pen*, the 3HPPP (or other pinhole projector), and a *measuring device* (ideally that uses millimeters).

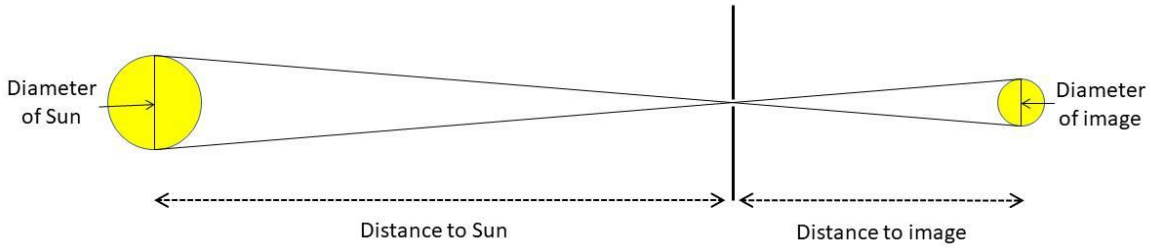
a. Trace a circle around a small coin (dime or penny) on white paper. Project the Sun's image onto the white paper and adjust the angle and distance between the 3HPPP and the paper so that the image of the Sun has *the same shape and size as the circle*.

b. Measure the distance between the 3HPPP and the paper (We recommend measuring in millimeters).

c. Measure the diameter of the circle using the same units as the distance measured in Step b above.

d. Use these data to make your estimate of the Sun's size (see below):

**Estimating the Sun's diameter is based on the properties of similar triangles.**




Because the two triangles are similar, the ratios of the diameters to distances are equal.

$$\frac{\text{Diameter of Sun}}{\text{Distance to Sun}} = \frac{\text{Diameter of image}}{\text{Distance to image}}$$

**MATHEMATICAL STEPS**

i. Make sure the distance and diameter you measured are in the same unit. We recommend millimeters (mm).

ii. Divide the measured diameter of the circle by the measured distance between the Projector and the white paper.

iii. Multiply that number by the distance to the Sun (93,000,000 miles or 150,000,000 kilometers).

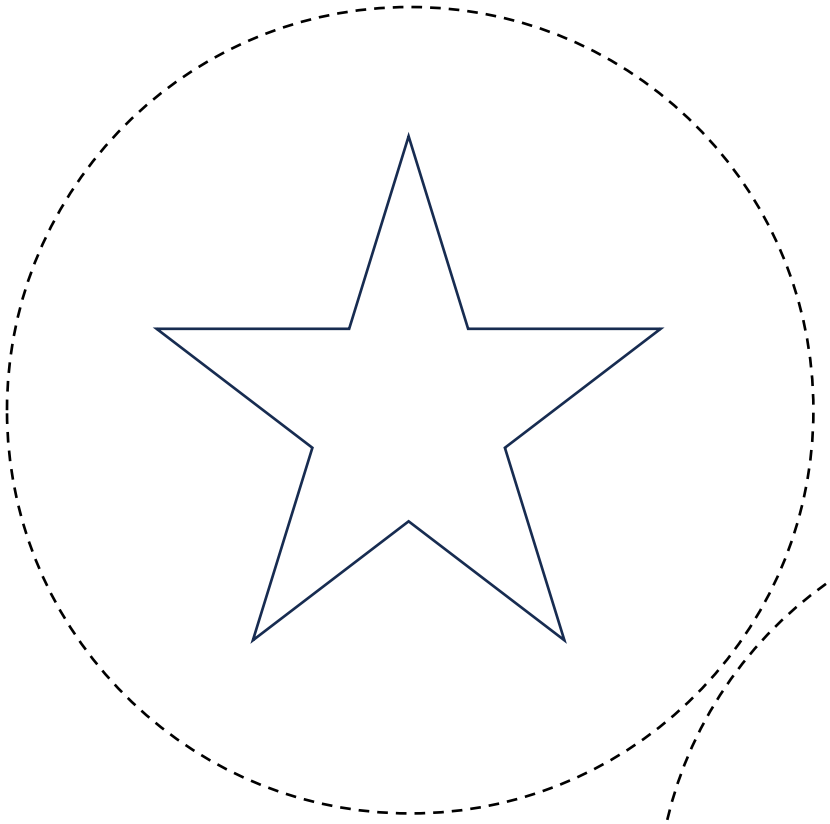
iv. This is your estimate of the Sun's diameter in whichever unit (miles or kilometers) you chose!

v. Compare your estimated diameter of the Sun to the diameter you find on the web. How close did you get? What are possible sources of error? How could you improve your estimate?

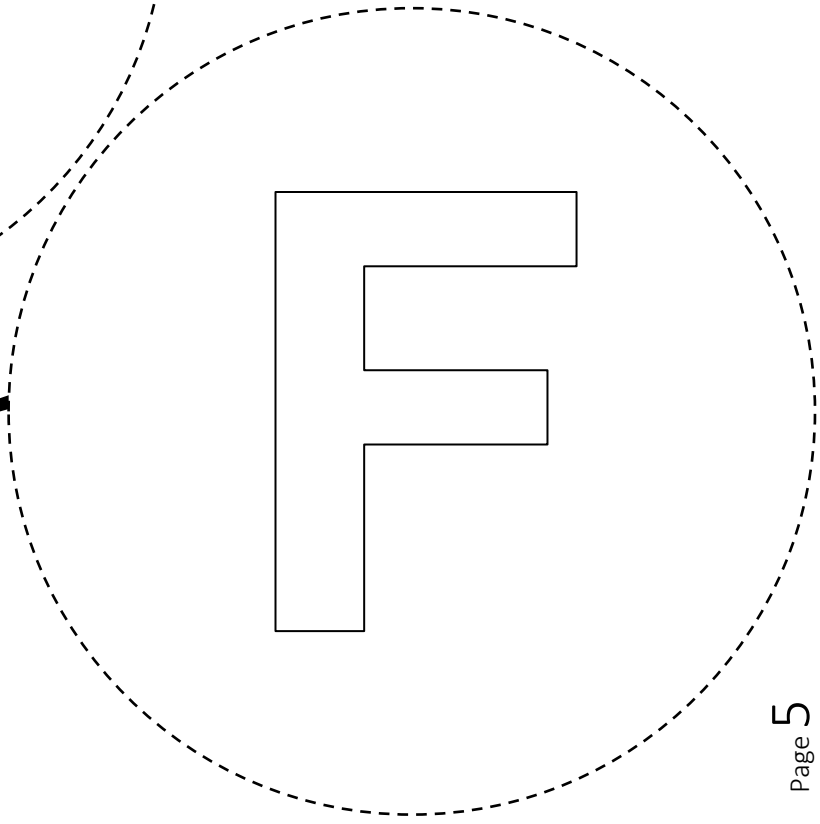
# Appendix A: Instructions for Cut-out Masks to Support Indoor Demo

**Materials**: LED Desk Lamp[1], scissors or x-acto knife, scotch tape, card stock (optional)

1. Use LED light sources. Incandescent bulbs will burn paper masks. Adjust ambient light as needed.
2. Cut out the templates below. They will fit the size of the lamp we recommend. For a different lamp:
    - Make the circle at least as big as the diameter of your lamp to avoid extraneous light.
    - Make the cutout shape (e.g., star, F) smaller than the diameter of the light source.
3. Tape the cut-out masks to the lamp. **TIP:** In the top-left photo on page 3, note how the star "mask" is scotch taped to the top of the lamp head, and the "F" mask is taped to the bottom so that it is easy to flip between one or the other for your demonstration.
4. Try making your own shapes. See if the left-to-right & top-to-bottom inversions are detectable. A crescent is another shape that has worked well in field testing.



Circle diameters = ~4 inches



# Appendix B: Reference Links

[1] LED desk lamp [tinyurl.com/PUNCHOutreachDeskLamp]

[2] short "how-to" home videos [tinyurl.com/PUNCHOutreachPinholeVideos]

[3] Slides for Display or Presentation (pdf) [tinyurl.com/PUNCHOutreachPinholeSlidesPDF]

[4] Slides for Display or Presentation (ppt) [tinyurl.com/PUNCHOutreachPinholeSlidesPPT]

[5] overall webpage for the Projector [tinyurl.com/PUNCHOutreachPinhole]

[6] How to Use the 3-Hole-PUNCH Pinhole Projector
[tinyurl.com/PinholeUnderstandSection1PDF]

[7] How to Use the 3-Hole-PUNCH Pinhole Projector
[tinyurl.com/PinholeUnderstandSection1PPT]

[8] Observing Pinhole Images of the Sun in Our Everyday Environments
[tinyurl.com/PinholeUnderstandSection2PDF]

[9] Observing Pinhole Images of the Sun in Our Everyday Environments
[tinyurl.com/PinholeUnderstandSection2PPT]

[10] Exploring Pinhole Projection Using Your Own Hands
[tinyurl.com/PinholeUnderstandSection3PDF]

[11] Exploring Pinhole Projection Using Your Own Hands
[tinyurl.com/PinholeUnderstandSection3PPT]

[12] Explaining and Understanding How Pinhole Imaging Happens – Part 1
[tinyurl.com/PinholeUnderstandSection4PDF]

[13] Explaining and Understanding How Pinhole Imaging Happens – Part 1
[tinyurl.com/PinholeUnderstandSection4PPT]

[14] Explaining and Understanding How Pinhole Imaging Happens – Part 2
[tinyurl.com/PinholeUnderstandSection5PDF]

[15] Explaining and Understanding How Pinhole Imaging Happens – Part 2
[tinyurl.com/PinholeUnderstandSection5PPT]