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

This guide recommends using the 3-Hole PUNCH Pinhole Projector (3HPPPP) for events in three settings. For outdoor events on a sunny day, we recommend using our 3HPPPP in tandem with Solar Protection ("Eclipse") Glasses. For both outdoor and indoor events, we suggest adding a tabletop demo using an LED desk lamp with cut-out masks that change the shape of the light source. If you have access to sunlight filtering through blinds or the leaves of plants, we strongly encourage you to make the connection with pinhole images of the Sun on a wall, sidewalk, or clipboard with white paper. Pinhole projection can provide experiences that excite wonder, curiosity, and a lifetime of attentiveness to the natural world, with or without an eclipse.

To support effective facilitation, we encourage you to view our 6-min “how-to” video and/or to consult the 5-Section Interactive PowerPoint (PPT) (“REALLY Understanding Pinhole Projection of the Sun”). The PPT slides explain how a small, lensless hole of any shape can create an inverted image of the Sun or other bright source of light. See the Table below for a description of the 5 Sections. We also recommend showing or printing out this subset of slides to accompany the field-tested enrichment activities on pp 2-4.

The URL for Video & PPTs = https://punch.space.swri.edu/punch_outreach_pinholeprojector.php

<table>
<thead>
<tr>
<th>Section</th>
<th>Title of this Section</th>
<th>Description of this Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How to Use the 3-Hole PUNCH Pinhole Projector (3HPPPP)</td>
<td>introduces the 3HPPPP, demonstrates outdoor &amp; indoor use, and describes differences from a pinhole camera/viewer.</td>
</tr>
<tr>
<td>2</td>
<td>Observing Pinhole Images of the Sun in Our Everyday Environments</td>
<td>teaches you how to observe the phenomenon of pinhole images of the Sun in our everyday world, both indoors and outdoors.</td>
</tr>
<tr>
<td>3</td>
<td>Exploring Pinhole Projection Using Your Own Hands</td>
<td>invites you to explore the behavior of pinhole projection by experimenting with your own hands (try both palms up!)</td>
</tr>
<tr>
<td>4</td>
<td>Explaining and Understanding How Pinhole Imaging Happens</td>
<td>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.</td>
</tr>
<tr>
<td>5</td>
<td>APPENDICES: More Insights &amp; Resources</td>
<td>offers more insights &amp; resources (e.g., explaining the relationship between pinhole images and the view through “eclipse” glasses)</td>
</tr>
</tbody>
</table>

The guidance below assumes that you can carry out the instructions on the back of the 3HPPPP. Here are some additional tips to evoke the most joy and curiosity in your learners: 1) For safety reasons provide a demo before passing out the projector. 2) Notice the position of the Sun in the sky in advance and choose a vertical, horizontal, or angled projection surface so that the sunlight passing through the holes creates the least distorted shapes of light on the surface. 3) At large events it is handy to carry a clipboard with a white sheet of paper as a portable projection surface. 4) To prevent spoiling the first surprise, keep your hand behind the holes until after the learners predict what they think they will see when you allow the sunlight to pass through to the projection surface. The first “aha” is how the three shapes of light (triangular, round, and square) all change to round as the 3HPPPP is pulled away from the projection surface. The second “aha” occurs as you continue to pull the projector back to make the pinhole images of the Sun larger than the holes themselves! This is a fun demo to do, eclipse or not!
**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 to supporting sections of the 5-section PowerPoint. **Turquoise highlights indicate any materials needed in addition to the 3HPPP** for each activity below (1-5).

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.]

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 for a guided “Waffle Fingers” exploration and Section 5 Appendix A to understand how the direct view through eclipse glasses relates to the pinhole images.] During a solar eclipse, it is easy to tell that a pinhole image is inverted compared to direct viewing. Pinhole images are inverted both top-to-bottom & right-to-left. Try to notice this during an eclipse!
4. Use the 3HPPP as part of an indoor demo (not just on rainy days!) with “paper-plate” cut-outs (made with scissors or an exacto knife) scotch taped to a LED desk lamp to change the shape of the light source (see below). The opening of the cutouts (e.g., star-shape or “F”-shaped) must be smaller than the lamp’s flat surface of light. Be sure to show that when the Projector is held 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:  


TIP: In the images below, 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. See Section 1 for more on the star-shaped demo shown below.

See Section 5 Appendix A 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. Even younger learners can observe that the “flags” of the “F” on the projection surface are pointed toward them, and the “flags” of the “F” on the mask affixed to the lamp are pointed away from them.

See this this subset of slides to find out more about the images below.
5. **Estimate the Diameter of the Sun Using the 3-Hole PUNCH Pinhole Projector (3HPPP)**

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

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 *exactly the same shape and size as the circle*.

b. Carefully maintain the position of the Projector as you measure the distance between the 3HPPP and the paper where the Sun’s image is projected onto the circle (measuring in mm is recommended).

c. Measure the diameter of the circle (this should be the same as the diameter of the Sun’s image). Be sure to use the same units as the distance measured in Step b above (mm recommended)

d. Use these data to make your estimate of the Sun’s diameter (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.

\[
\frac{\text{Diameter of Sun}}{\text{Distance to Sun}} = \frac{\text{Diameter of the Sun's image (your measurement)}}{\text{Distance from the Projector to the Sun's image (your measurement)}}
\]

**MATHEMATICAL STEPS**

i. Make sure that both the ‘Diameter of the Sun’s image’ and the ‘Distance from the Projector to the Sun’s image’ that you measured are in the same unit. Millimeters (mm) is recommended.

ii. Divide the ‘Diameter of the Sun’s image’ by the ‘Distance from the Projector to the Sun’s image’.

iii. Solve the equation by multiplying the number you determined in Step ii (above) by the known 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 you chose (miles or kilometers)!

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