Pinhole Viewer[1]

(Nice intro to the "Colored Shadows" activity)

Purpose: To make a simple model of the eye and observe what colored lights look like when viewed through a pinhole viewer.

Materials:
- Empty toilet paper-roll (or a 6 in. length of 2" PVC tubing)
- 12 cm x 12 cm (~ 5 inches) sheet of wax paper
- 12 cm x 12 cm (~ 5 inches) sheet of aluminum foil
- 3 party light bulbs, 25W (red, green, and blue)
- 2 rubber bands
- Tooth pick
- 3 light bulb sockets
- Power strip

Procedure:

- Attach the sheet of wax paper to one end of the toilet paper roll (TPR) with a rubber band.
- Carefully attach the sheet of aluminum foil to the other end with the remaining rubber band.

* ONLY use the red & green light bulbs here:

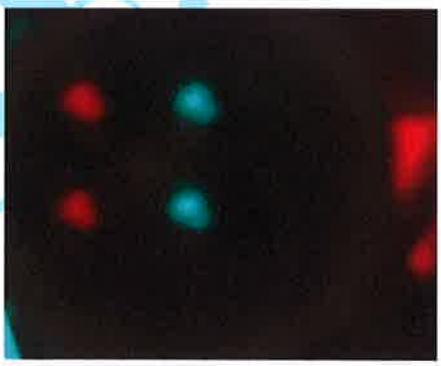
- Screw bulbs into sockets & connect to power strip. (Place the red light bulb on the right side)
- Using just your eyes (not the pinhole viewer!) notice & record where the red light bulb is in relation to the green bulb.

[1] LIGO-SEC/ T. Huynh-Dinh 2011

- Carefully poke a tiny hole (similar to the pupil) in the center of the aluminum foil.
- Predict & record what you think you will see when you look at the red & green bulbs with the pinhole viewer.
- Point the aluminum foil end (with the tiny hole in the center) of the pinhole viewer at the light bulbs and look at the wax paper end. For best results, place the pinhole viewer about a foot from your eyes.
- With the room lights off and the red and green bulbs on, (red on the right first, then red on top) notice & mentally take notes of your observations.

- Try rotating the pinhole viewer clockwise between your thumb & fingers. Did you notice anything?

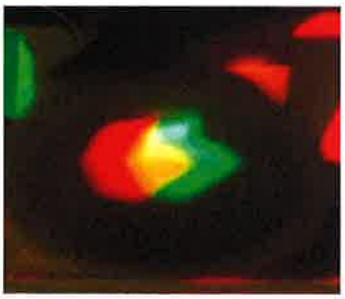
- Add a 2nd hole in the aluminum foil (between the first hole & the edge of the pinhole viewer)
- Predict what you think you will see when you look at the red & green bulbs this time.



- What do you think will happen when you rotate the pinhole viewer clockwise this time?

- Depending on how much time you have, repeat the process each time adding an additional hole to the aluminum foil. (You can suggest locations, or let participants use their creativity)

- For the finale, participants should "poke" a hole with their pinky in the aluminum foil & again predict what they think they will see.



- By now the participants will want you to turn on the blue bulb.
- So what are you waiting for? Turn on the blue bulb!

Results: (Based on the red bulb being on the right of the green one)

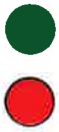
If the red bulb **IS** on the right of the green bulb, then when viewed using the pinhole viewer, the red bulb will now appear to be on the left of the green bulb. (similar to a mirror?)

Eyes only, no pinhole viewer

Viewed **with the pinhole viewer**

When you have the red bulb above of the green bulb, when viewed with the pinhole viewer it would appear to be below the green bulb. (mirrors don't do that!!!)

Eyes only, no pinhole viewer

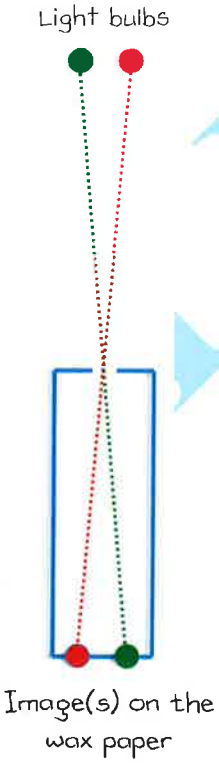


Viewed **with the pinhole viewer**

- With just a hole in the center of the aluminum foil, when the pinhole viewer was rotated clockwise the light bulbs appeared to remain stationary.
- When the pinhole viewer with 2 holes in the aluminum foil was rotated clockwise, the pair of lights from the center hole appeared to remain motionless, while the "outer" pair appeared to circle around the "center" pair in a clockwise motion.
- The more holes you put in the aluminum foil, the more pairs of light bulbs you will see.
- When you poked a hole in the aluminum foil with your pinky you made a fairly large hole and you should have seen three (3) colors! (Red, yellow and green) How do you get three colors with only 2 colored light bulbs?

  Hint: Where was the third color located? (between the red and the green!)

What's going on?



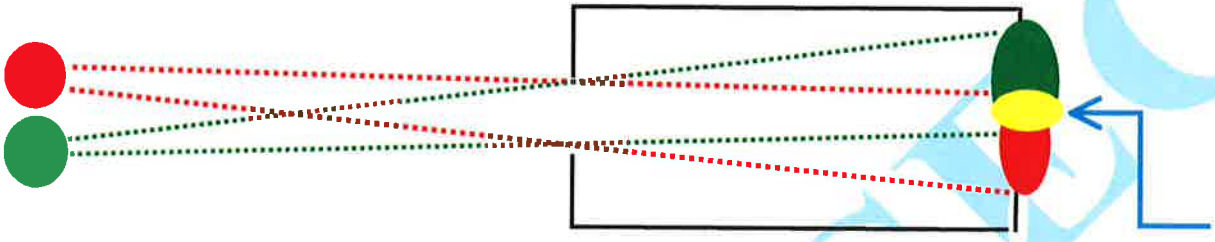
Similar to an eye the pinhole viewer "flips" (reverses) the image(s) onto the wax-paper screen (retina). Older film cameras did the same thing, which is why negatives are the opposite (reverse) of the printed photograph. How does the pupil of the eye (or in this case, a pinhole) reverse everything? Since light travels in straight lines, **only** the light from an object that has the **correct angle** will actually be able to travel through the pinhole and land on the wax-paper. The other light rays will hit the aluminum foil and the bounce off/or scatter in all directions.

← ← Looking at the diagram, can you see what happens to the light rays from the red and green light bulbs?

Notice that the green & red light rays *crossed somewhere close to the pinhole*. The image(s) now appear to have been reversed. If the colored lights are orientated in an up/down position, the light rays will also cross near the pinhole making what was originally on the top appear to be on the bottom.

Multiple images are produced by the addition of extra pinholes. This has no similarity to the human eyeball! But using your imagination, you can almost imagine how an insect might see the world if you made a whole bunch of pinholes, resulting in a possible "compound-eye" image that a bug might see.

Onto the **interesting** observation of the third "new" color (yellow) when you poked your pinky through the aluminum foil. From the diagram below, notice that the "pinhole" is now much larger due to the pinky… resulting in a "new" area of red and green overlap. Our eye/brain system perceives this overlap region as the color yellow! (Fascinating, as Spock would say…)



In this snack, we are dealing with **light** (which is *additive*) and not **pigment** (which is *subtractive*). If you're familiar with the "colored shadows" snack, this should all be a pleasant review for you… If not, let's find out what is going on with R-G-B (Red, Green, and Blue) light and cones in your eyes!

In most humans, equal intensities (strengths) of red, green, and blue light combine to produce white light. Scientists consider red, green, and blue to be the **three primary colors of light**. Primary in the sense that with these three colors, you are able to make all the colors. You happen to have three types of cones in your retina, ones that are specific to the red, green, & blue frequencies.

The **simple algebra of white light**. (aka *simple algebra of color*)

Red + Green + Blue = **White** or W = R + G + B

Red + Green = Yellow (yellow) or W – B = R + G = Yellow (yellow)

Red + Blue = **Magenta** or W – G = R + B = Magenta

Blue + Green = **Cyan** or W – R = B + G = cyan

Please contact LIGO-SEC (tien@ligo-la.caltech.edu) with your comments, suggestions, and/or questions.