



# LASER CLASSROOM

Bringing STEM to light®

## BIG IDEAS

- Demonstrate the law of reflection by creating a Pepper's Ghost with the PepperGram.

## WHAT YOU'LL NEED

- What You'll Need
- A smartphone
- A PepperGram Projector
- A mounting square

## RELATED PRODUCTS

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Peppergram Projector for Phone



Peppergram Projector for Tablet

## PEPPERGRAM VS. HOLOGRAM

Holograms have been hugely popular in movies and video games for the last 40 years. What do you think a hologram is? How is it different to a normal projection, like in a movie theater?

### PEPPER'S GHOST

Pepper's Ghost is an illusion that uses the law of reflection to create a scarily realistic ghostly image. It is often mistaken for a hologram, but it is, in fact, not a hologram at all!

### THE LAW OF REFLECTION

Simply put, the law of reflection states *angle of incidence = angle of reflection*. To find these angles, take a look at *Figure 1*. You measure these angles from an imaginary line called the normal, which is basically

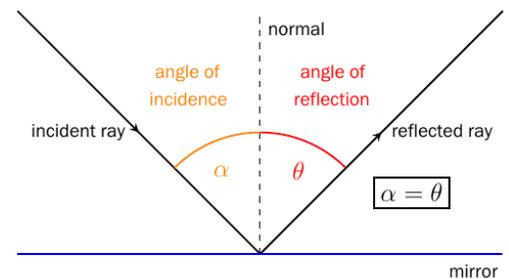


Figure 1: The Law of Reflection

any line at 90° to your reflective surface. The angle of incidence is the angle between the ray moving from the source of light to the mirror (the incident ray) and the normal. The angle of reflection, then, is the angle between the reflected ray and the normal.

### HOW THE PEPPERGRAM WORKS

We're going to create a Pepper's Ghost using a PepperGram; a device which makes a video played on your smartphone appear to float in mid-air. The PepperGram is made of stiff, reflective plastic. When bent into shape and placed on a smartphone, each of the four sides are at a 45° angle to the screen, as shown in the photograph in *Figure 2*.

The diagram in *Figure 3* shows one of the four sides - they all work the same way, independently. While it may look like all four sides

are working together to create a floating 3D image, the PepperGram would work just as well with only one side.

The video played on the smartphone is reflected against the side of the PepperGram and directly outwards.

To the viewer, the image in the video appears to float inside the PepperGram. This is the Pepper's Ghost, and it is a virtual image. Your eye expects light to always travel in straight lines, so it is tricked into thinking that the video is actually straight ahead, inside the PepperGram. This is why the virtual image appears the same distance from the reflective surface as the real object actually is.

### **BUT IT ISN'T A HOLOGRAM!**

The images created by the PepperGram may look just like holograms, but they aren't! Holograms are actually three-dimensional "photographs" of objects. By shining lasers at the object from different angles, the size and shape of the object is recorded on holographic film, producing a holographic print.

When you look at a reflective holographic print, you see the 3-D object from a head-on perspective. The object appears to float behind the print, as if you were looking at it through a window. You can turn the print (or move your head), and the perspective of the picture will change - you'll see the object from a different angle! One can also shine a laser through the holographic print (a transmission hologram) and project the image onto a screen (a real image), which can then be viewed from different angles as well.

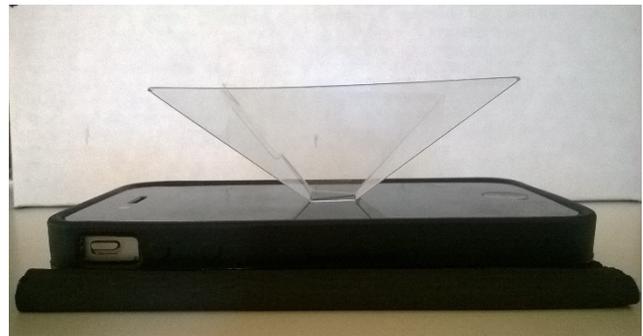


Figure 2: The PepperGram Setup

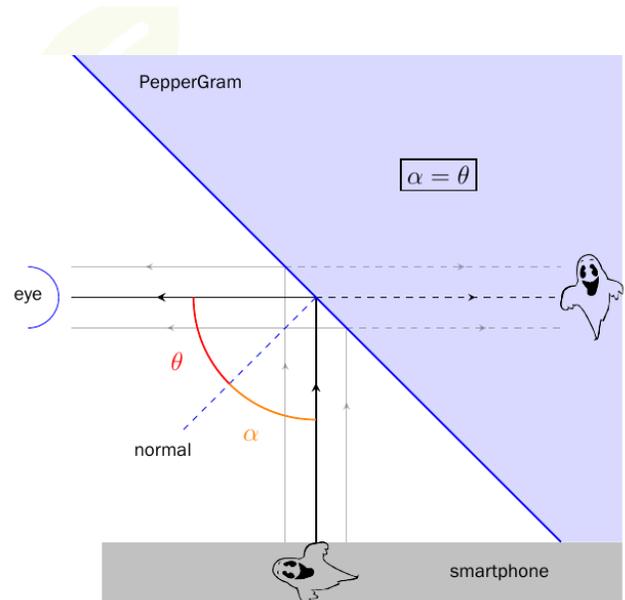


Figure 3: One side of the PepperGram

## **HOLOGRAMS IN REAL LIFE: SECURITY**

The next time you hold a bank note up to the sun, see if you can spot its security hologram. This is usually a strip of words or pictures, depending on the currency, that changes color and shape as you move the bank note around.

Security holograms are also used in passports and on credit cards. Their purpose is to make forgery more difficult - the holograms are copies of a master hologram that's very expensive and difficult to make yourself. This way, they discourage people from making fake money!

# ACTIVITY SHEET: PEPPERGRAM VS. HOLOGRAM

Let's create a Pepper's Ghost with the PepperGram. Try to make the room as dark as possible. This will make for clearer images.

1. Remove the protective film from each side of the PepperGram.
2. Fold along the three lines on the PepperGram - you might have to press quite hard to get the plastic to snap into place. Your PepperGram should now look like an upside-down pyramid.
3. Wipe down the PepperGram with a clean cloth. You'll want it free of fingerprints and dust for the best result.
4. Search YouTube for any "4 Faces Hologram Videos". For a jellyfish, try this one: <https://www.youtube.com/watch?v=WFvInYxEJGU>. Make sure your smartphone screen is set at its brightest.
5. Place the PepperGram in the middle of the screen. You can use one of the mounting squares to stick it down so that it doesn't move. View the PepperGram at eye-level and play the video!

Move the PepperGram slightly lower than eye-level. What do you see now? Referencing of the law of reflection, why do you think it's important that you look directly into the side of the PepperGram?

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The reflected light rays are moving in only one direction - horizontally from the side of the PepperGram. They can't move upwards to meet your eye above the PepperGram, because then the angle of reflection would be bigger than the angle of incidence, and the law of reflection would be broken!

Now pause the video. Take a good look at the jellyfish, then move around the PepperGram and compare. What do you notice? Does the jellyfish "turn around"?

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If the jellyfish were a hologram, you should see the sides and back of the jellyfish when you go to the other side of the PepperGram. Now switch off the screen of the smartphone. Is the jellyfish still swimming? What does this tell us about the image?

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Remember that a hologram is a photograph taken of an image. This means that you can't "switch off" a reflection hologram, like you switched off your jellyfish. This proves that what we created was a Pepper's Ghost, and not a hologram!