LASER CLASSROOM
Bringing STEM to light®

BIG IDEAS

- Demonstrate the formation and properties of virtual images by creating a Pepper's Ghost with the Reflect View.

WHAT YOU'LL NEED

- 1 Reflect View
- 1 White LED
- A printed picture with a black background
- A smartphone

RELATED PRODUCTS

Reflect View Classroom Pack
Click here to purchase!

PEPPER'S GHOST

Think about the last time you stood in front of a window at night, while the lights in your room were on. What did you see?

WHAT IS PEPPER'S GHOST?

By reflecting a real person against a pane of glass, one can create the image of a ghost floating in "mid-air". This is called Pepper's Ghost, and it's been around for ages!

HISTORY OF PEPPER'S GHOST

Pepper's Ghost was first mentioned over 400 years ago, but not demonstrated until an inventor named Henry Dircks created the Dircksian Phantasmagoria in 1862. This was a device that theaters could use to make ghosts appear and disappear on stage at a moment's notice. But it was a complicated trick that required theaters to be completely rebuilt.

When a professor named John Pepper realized that the illusion could be more simply created, the Pepper's Ghost that we know today was developed. Pepper first showed off the new trick during a performance of Charles Dickens' A Haunted Man. The illusion was such a huge success that it was nicknamed Pepper's Ghost, instead of after its original inventor Dircks.

Pepper's Ghost has since been used in theatrical productions, magic shows and haunted houses - and is still in use today!

REFLECTION AND VIRTUAL IMAGES

When you look at yourself in the mirror, your reflection is called a virtual image. When something is virtual, it appears to be real, but isn't actually - your reflection looks just like you, standing in front of you, but you're not really there! Virtual images created by plane mirrors, or flat mirrors, follow very strict rules. These virtual images are always as far from the mirror as the real object being reflected,

and horizontally reversed - left and right are swapped around. They're also the same size as the original object!

HOW PEPPER'S GHOST WORKS

One of the ways that Pepper's Ghost was created was with a special stage, shown in *Figure 1*. The stage consisted of two parts: the visible stage (in pink), and a room to one side, hidden from the audience's view (in blue). The hidden room was called the "blue room", and this is where the person dressed as a ghost would stand. The blue room was painted a dark color; usually black.

A sheet of glass was placed at a 45° angle between the stage and blue room. When the blue room was dark and the stage well-lit, the stage seemed empty - think about when you stand in front of a window when it's sunny outside. Can you see your reflection? No, only the objects outside!

Then, when the stage lights were dimmed and a spotlight lit over the man in the blue room, his reflection became visible in the glass. Since the audience couldn't see the glass or the real man, it appeared as though a ghost was floating on the stage!
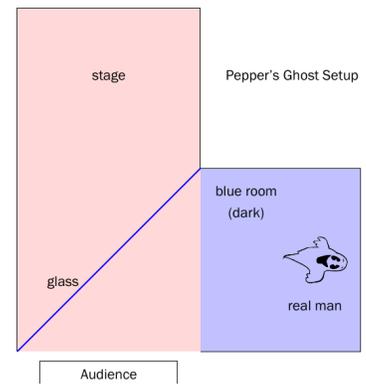

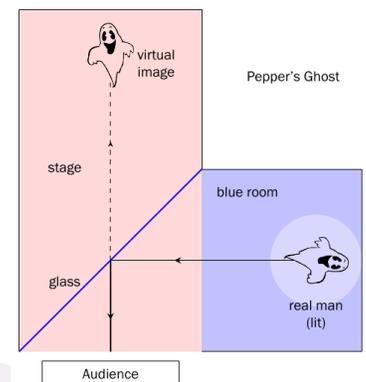Figure 1: Setup of Pepper's Ghost

Figure 2: Pepper's Ghost in Action

PEPPER'S GHOST IN REAL LIFE: DISNEYLAND'S HAUNTED MANSION

The ballroom of Disneyland's Haunted Mansion is one of the largest examples of Pepper's Ghost in action. As guests travel through the haunted room, they're actually looking down into an empty ballroom covered by a gigantic sheet of glass.

Hidden from the guests' view, robotic "ghosts" dance and dine in a black recreation of the ballroom. As they're lit in the fake ballroom, they appear dancing in the real ballroom, and disappear just as quickly when they move away from the lights.

ACTIVITY SHEET: PEPPER'S GHOST

We're now going to create an old-fashioned Pepper's Ghost. For these activities, you'll want to darken the room you're working in as much as possible - the darker the room, the clearer the images!

1. Place the printed picture on a flat surface. The surface should either be at eye level, or you should be able to crouch down so that it is.

2. Hold the Reflect View over the picture at a slant. Rest the top end of the Reflect View on the table just below the picture. Make sure the bevelled (stepped) edge of the Reflect View is facing towards you.

3. Shine the LED onto the picture. Hold it about 10-20 cm from the picture, and be careful not to shine the light through the Reflect View. You want to get as little glare as possible on the picture.

4. Look directly into the Reflect View. You should be low enough that you don't see the picture on the table.

What do you see? Think about how far the virtual image of the picture appears behind the Reflect View, and how it compares to the original picture.

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You should notice that the virtual image appears to be the same distance from the Reflect View as the original picture. The virtual image is also reversed, or swapped around.

Replace the picture and LED with a video played on the smartphone. Something like a candle with a black background works best. What do you see now? Is it different to when you used the printed picture?

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This proves what we know about virtual images - the candle floats the same distance behind the Reflect View as the smartphone, and it's swapped around! What could you do to make the candle appear further away than it does now? Use what you know about virtual images!

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To move a virtual image further away from the reflective surface, you need to move the object being reflected. We could do that by moving the Reflect View further from the smartphone, or making the Reflect View bigger and using a bigger screen!

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
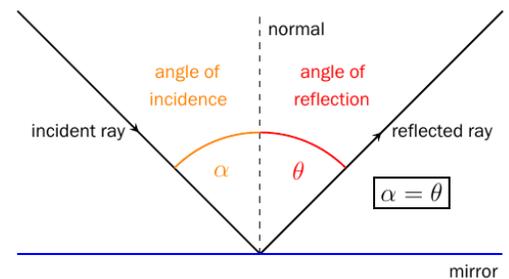

Figure 1: The Law of Reflection

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.
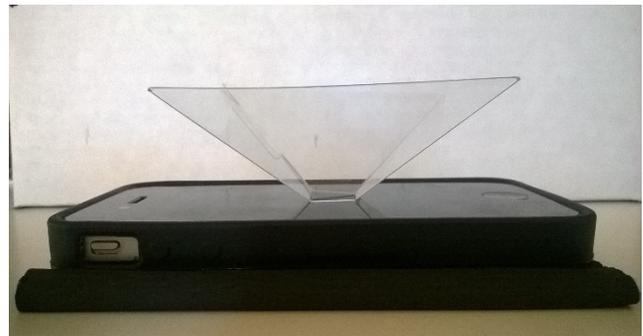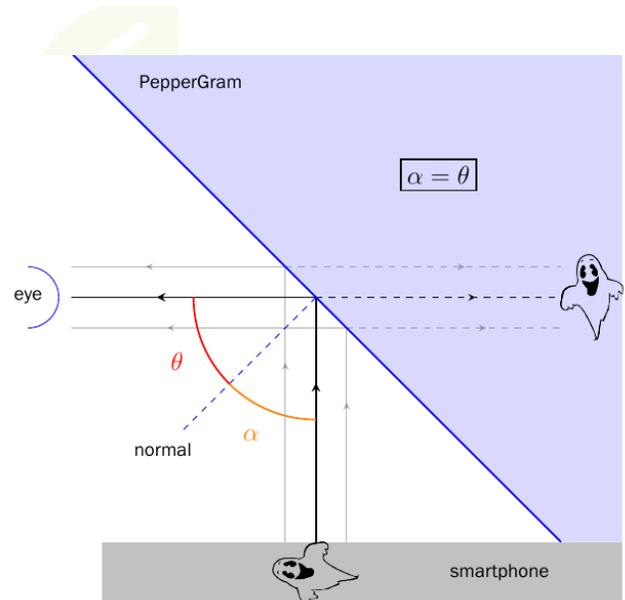

Figure 2: The PepperGram Setup

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=WFvlnYxEJGU. 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!