Bent Light

When the path of a light ray is bent, the image of the light source becomes distorted. This is what happens when light is bent as it passes from the air into the lenses of eyeglasses, producing a magnified image. Likewise, when sunlight is deflected as it travels through different layers of the atmosphere, the Sun appears flattened. Another way that light paths can be bent is through the warping of space by a massive object such as a galaxy or galaxy cluster. The massive object acts as a gravitational lens that distorts the images of more distant background galaxies.

Q: Where can we observe images produced by bent light?
A: Here, there, and everywhere that a light wave is deflected by the medium it is traveling through.

Activity 1 – Playing with bending light

Core Concept: As a light ray passes from one transparent medium (such as air, glass, plexi, or water) into another its direction changes.

Exhibit connections: Lensing Panel 1

Materials: laser pointers, acrylic block, lenses (including visitor's eyeglasses), chalk-dust

Background:
"Refraction" is the bending of light as it passes from one medium into another. The amount of this bending depends both upon the angle of the incoming light and the nature of the medium. Understanding this idea led to the invention of lenses, eyeglasses, and telescopes!

Suggestions for introducing the activity:
Ask visitors if any of them wear glasses or contact lenses. They should know how important lenses are to everyday life! Eyeglasses and contact lenses bend light in just the right way to help us see the world perfectly. However, some lenses distort as they bend light. For example, if you were to wear glasses not designed for your unique eyes, the world would appear fuzzy and distorted. Each type of lens bends light in its own way. *(Safety note: be careful with the laser pointers to insure they cannot shine in visitors' eyes. You may decide not to allow visitors to handle these, but to keep this as a demonstration)*

Procedure:
Start with one red laser and aim it straight into the acrylic block, and then slowly change the angle of the incoming beam. Later you can hold both lasers perpendicular to each other and point them into the block. Have visitors closely examine the path of the laser beams as they pass from the air to block, and also as they pass through the lens. Tap the eraser filled with chalk dust to make the laser beams visible.

Discussion/Questions for visitors to consider:
What happens to the path of the beam as it enters the plastic block? How does the path change as you change the angle of incoming light? What happens as you shine 2 lasers into a lens? Why do you think one beam bends in one direction and one in the other?

Activity 2 - **Flattening the Sun**

Core Concept: Objects look different when viewed through a medium that bends the direction of light rays passing through. The atmosphere can alter the Sun's appearance at sunset. This activity encourages visitors to explore this process themselves using a ball and a square vase.

Exhibit connections: Lensing Panel 2

Materials: A square glass vase, yellow ball, image of sunset

Background:
The Sun is a sphere, not the misshapen oval that appears in this sunset picture. The distortion happens because the Earth's atmosphere is acting as a lens. Light from the bottom of the Sun is being bent more than from the top because the light must pass through more of the atmosphere the closer we look to the horizon. The effect is that the apparent location of the bottom of the Sun is raised more than the top, making the whole Sun look oval-shaped.

Suggestions for introducing the activity:
Ask visitors if they have ever watched a sunrise or sunset very closely. Have they ever noticed the flattened appearance of the Sun as depicted in the exhibit photograph? Do they have any theories for why this might happen? What's different when you see the Sun on the horizon vs. when you see it overhead? (You're seeing it through a lot more of Earth's atmosphere).

Procedure:
Viewing a ball through a vase can simulate the Sun setting through the atmosphere. Place the square vase at eye level and hold the yellow Sun behind and above the vase. (See photos)

Discussion/Questions for visitors to consider:
How does the shape of the ball change as you lower it so that you view it through the glass rather than through the air? How does it change as the ball moves from the middle of the vase to the bottom? Where the glass is thicker? The more material the yellow ball is viewed through, the more its image is distorted.

Activity 3 - Looking through a "black hole gravity lens"

Core Concept: A massive object such as a black hole bends space, and so bends the path of light that comes near it. A black hole distorting space acts as a lens.

Exhibit connections: Lensing Panel 3

Materials: Block stand with clip, black hole simulation lens, image of galaxies, image of lensing

Background: In the early 20th century, Albert Einstein realized that space can be significantly curved by an extremely massive object. Since light follows the curvature of space, a massive object can act as a gravitational lens. The acrylic lens for this activity was specially crafted to simulate the bending of light and image distortions that an observer might detect when viewing a background object through the warped space around a compact but massive black hole.

Suggestions for introducing the activity:
Ask visitors what they know about black holes. Most will say that they suck things in, and are incredibly massive and mysterious. Visitors may be surprised that black holes don't devour everything that comes near to it. One of the more observable qualities of a black hole is how it bends and distorts light that passes by.

Procedure:
Hold the black hole lens so that visitors can see what it looks like. Then, hold the lens up to an image of many galaxies, and compare it to an image of actual observed gravitational lensing. How does the lens distort light? Does it stretch, make doubles, or both? Try looking at many different things!

Discussion/Questions for visitors to consider:
Show visitors the image of gravitational lensing. Can they notice any similarities between looking at the image of galaxies through the black hole lens and the actual image of gravitational lensing? In the image, light from a few very distant galaxies passes through a cluster of galaxies in the foreground. The cluster in the foreground is so massive that it bends space, and so affects the light coming from the distant galaxies. Can your visitor use the lens to create an “Einstein ring” – a very thin ring around the center of the lens—by looking at the image through the lens and at just the right angle?