This section provides you information about the instructional objectives of the exhibit or what the exhibit is teaching. To maximize the learning from this exhibit, please have all staff involved in working with children and families including volunteers interact with the exhibit, making sure they understand the learning objective at each table.

Overview of Exhibits by Theme

Lenses & Refraction

Look Through Lenses
What's Up

The Rainbow Effect*
Refraction in Action*

Color

Color on Color*
Color Shadows*

Spinning Disks
Now You See It

Reflection

Periscope
Mouse Multiplier

Cheek to Cheek
Block Out/Pink Pig

Sources of Light

Look-a-Lights*
Instant Lighting*

Light within a Light*
What's in a Light Bulb?*

Holograms & Vision

Holograms on Parade*
Do You See What I See

* denotes exhibit that requires electricity

Lenses & Refraction

A lens is a transparent device through which light passes and is refracted or bent.

Look Through Lenses

OBJECTIVE: To let visitors experience looking through different types of plastic “lenses.”

METHOD: A variety of lenses and light-refracting devices are available.

EXPLANATION: This is one exhibit purely “for fun:” to engage the visitor in manipulating light and watching what happens.

What’s Up

OBJECTIVE: To present the visitor with a lens puzzle.

METHOD: The visitor slides a board beneath two round lenses. At first glance the lenses appear alike: actually the left side is hollow plastic and the right is solid plastic. Some of the words appear to flip over and some do not; the puzzle is to find out why.

EXPLANATION: Refraction is the bending of light as moves through different materials. Thus as light moves through the plastic into the air it is bent. The light refracts differently going through the solid and hollow plastic tubes. The light going through the solid tube bends in such a way that it makes the words appear “upside down”. Visitors are encouraged to look at the lens table (Refraction in Action) to see how light rays are refracted through a round lens.

What’s Up? Exhibit Copy

What happens to the words on each side of the board when viewed through the clear plastic?

The rod on the **left** is *solid* plastic. This solid, rounded material acts like a lens. When a word is viewed through the rod the image appears upside-down. Can you find another lens in the Light and Color exhibit that works the same way?

The rod on the **right** is a *hollow* plastic tube. When a word is viewed through this hollow tube the light rays passing through it are refracted (bent) slightly by the thin walls of plastic. The image appears slightly smaller as a result of this refraction.

Refraction in Action

OBJECTIVE: To demonstrate how light interacts with different lenses.

METHOD: The solid plastic lenses are in a variety of different shapes. The visitor is invited to the lenses to manipulate light.

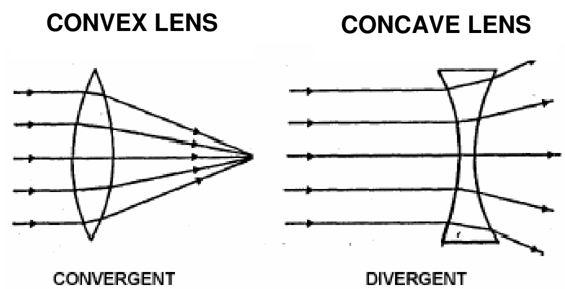
EXPLANATION: When light passes from air into another material, it is refracted or bent. This is because light travels more slowly in certain materials than in others.

Imagine you are pushing a two-wheeled cart along the sidewalk. You want to cut across the lawn. As you turn onto the lawn, the wheel, which strikes the lawn first, begins to slow down, while the wheel on the sidewalk remains traveling at the same speed. This causes the cart to turn in towards the lawn. The same thing happens to light when it passes through a dense material. This bending of light is called refraction. Generally, the denser the material, the greater the degree of refraction. The light is bent again as it leaves the dense material, just as the cart turns again as it gets back on the sidewalk.

Convex and Concave Lenses

The convergent (or convex) lens is thicker in the middle. Light rays passing through it come together (converge) to a point on the other side.

The divergent (or concave) lens is thinner in the middle (curves inward like the wall of a cave). Light rays passing through it spread apart (diverge) on the other side.

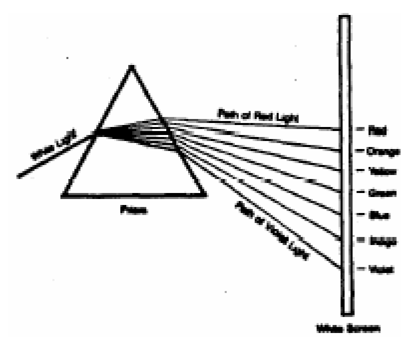


The Rainbow Effect

OBJECTIVE: To demonstrate how white light can be split into all the colors of the rainbow.

METHOD: A mounted prism is set so that it disperses white light into the colors of the rainbow. The prism can be rotated to manipulate the dispersion.

EXPLANATION: Dispersion, the splitting of light rays, is a topic for further exploration all its own.



<u>The Rainbow Effect</u>

What happens to white light when it passes through a prism?

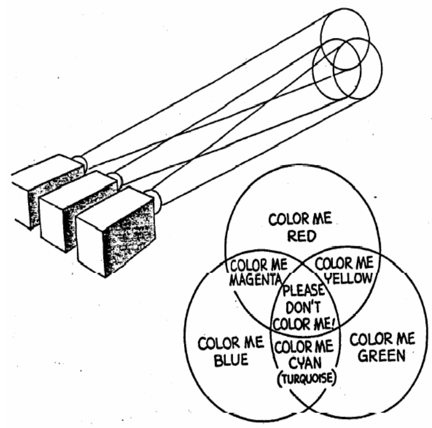
Light striking a prism which is a type of lens fans out its colors like a peacock spreading its feathers. This is called dispersion. The “rainbow” you see is the visible color spectrum. (See illustration below.)

For another view of light being bent by a solid, look at the “Refraction in Action” exhibit.

Color

Color is a result of light and how the eye (and by extension the brains) see this light.

Color on Color



Hewitt: Conceptual Physics

OBJECTIVE: To demonstrate that when the primary colors of light are added to one another the resulting colors are always the same.

METHOD:

1. Red, green and blue light are overlapped to show the secondary colors, and the three added together make white (see illustration below).
2. The visitor can hold up color filters to investigate how different colors blend.
3. The visitor can block the different colors of light and see what results.

EXPLANATION: See diagram to the right and exhibit copy. It's interesting to note that the adding of colored lights is very different from the adding of colored paints or pigments. (See Spinning Disks.) Try mixing red, green and blue paint; you won't get white!

<u>Color on Color Exhibit Copy</u>

What happens when colored lights overlap? Try viewing the lights through a colored filter and then try looking through two filters!

When colored lights overlap, they ADD UP to a different color. You see the sum of their colors. When all three colored lights are equally bright, they can be added together to make white light.

RED + GREEN + BLUE = WHITE

What's so special about red, green and blue?

These are the primary colors of light. In different proportions, these three colors can be combined to make all the colors of the rainbow.

RED + GREEN = YELLOW

RED + BLUE = MAGENTA

GREEN + BLUE = CYAN

When you view the lights through a colored filter.

Each colored filter SUBTRACTS (absorbs) all the other colors and lets only light of the same color through. When you look through the RED filter, for example, it blocks out blue and green light (absorbs them), and lets only RED light through.

Color Shadows

OBJECTIVE: To demonstrate that the shadow of an object will vary depending on the color(s) of light cast onto it and which color(s) the object blocks.

METHOD: The three primary colors of light (red, green and blue) are projected from different angles so that when a hand (or other object) interrupts the light a colored shadow is cast.

EXPLANATION: Not all shadows are black! As stated in the exhibit copy, when your hand (or another object) blocks one of the lights shining from above, the two unblocked colors combine to form another color. A variety of different colored shadows can be made this way.

<u>Color Shadows Exhibit Copy</u>

How many different colored shadows can you make by placing your hand under the lights?

The white light that you see on the back of your hand is made from a combination of the red, blue f and green lights shining from above. When your hand casts a shadow it is BLOCKING one, two, or all three of the colored lights from above. When only one color is, blocked, the two remaining colors ADD together to form another color.

So, how many different colored shadows did you make?

Spinning Disks

OBJECTIVE:

To demonstrate that the primary colors of pigment are different from the primary colors of light.

To demonstrate that the eye can visually combine colors to create a new color.

METHOD: Several disks, each painted in two colors, can be spun on the lever. The rapid spinning of the disk is similar to mixing colored paints together: the eye sees the mixture of, for example, blue and yellow (green).

EXPLANATION: There are many ways to see a color. You can see yellow, for example, if your eye is stimulated with light from the yellow portion of the spectrum. Your eye doesn't have yellow receiver cells (it only has blue, green and red), but it does see yellow where the red and green receptors overlap.

You can also see yellow if the red and green receptors are stimulated by red and green light. In this case, there are no yellow wavelengths, yet you perceive yellow just the same. This is the effect of watching the spinning disks: your eye combines the colors and your brain perceives a new color. (The San Francisco Exploratorium: Facets of Light.)

Spinning Disks Exhibit Copy

What do you see when you spin the different multi-colored disks?

Change the disk by pulling it off and exchanging it with another disk.

When the disk is spinning fast, your eyes see a combination of the two colors. The color that you see is similar to one you can create by mixing two pigments (colors) of paint. The mixing of paints and dyes is an entirely different process from the mixing of colored lights. Pigments reduce their colors by absorbing and reflecting certain wavelengths of light. For example, when blue and yellow paints are mixed, together they absorb all the colors in the light spectrum except green. Since green light is the only wavelength of light reflected, that's the color our eyes see.

Benham's Disk: Black and White = Color?!

OBJECTIVE: To demonstrate that a black and white patterned disk (Benham's Disk) can actually "trick" the eye into seeing color.

METHOD: The disk is spun rapidly on a lever: depending on the viewer's eyesight and speed of the disk, the viewer may see alternating flashes of blue, green, brown, violet or gray.

EXPLANATION: The original Benham's wheel was a spinning black-and-white top. As it twirled, it produced colors in the eye of the beholder. Presumably, Benham's wheel was named after one of the eight people who discovered the effect. (It was "rediscovered" eight times.)

Which colors appear depends on who is looking, how fast the disk is spinning and in which direction. If you reverse the direction of the spin, the colors interchange. If you spin the disk too fast, the colors may fade out, but if you spin it too slowly, they may not appear at all. Nobody knows for sure why the colors appear.

The color-sensitive cells in your retina seem to respond to different rates of stimulation and persist in their response for various lengths of time. Thus, the various spacing of black and white could somehow trigger the perception of various colors. However, the perception of color from black and white also seems to depend on the presence of sharp edges, which means the effect might somehow be related to lateral inhibition. Benham's Disk appears in color even on a black-and-white TV set. Facets of light.)

Benham's Disk Exhibit Copy

While the disk is spinning, watch it and notice what happens.
What do you see when the disk is still?

Different people see different amounts of yellow, red, green, purple and blue on this spinning disk. Just why is not fully understood, but the illusion must involve the color vision cells in your eye. These cells come in three varieties: some are most sensitive to red light, some to green light, and some to blue light. When you gaze at one place on the spinning disk, you are looking at alternating flashes of black and white. You see white only when all three-color sensors respond to a flash of light. If one type of color sensor (green, for example) responds at a different rate than the others, you see an illusion of the color green.

Now You See It…

OBJECTIVE: To show that blackness is actually the absence of light.

METHOD: The visitor looks into a box with an eyehole in the lid trying to see what color the inside of the box is painted. (It appears black.)

The visitor opens the box to discover that the inside is actually painted white.

EXPLANATION: Color we see is actually the light reflected from the surface of an object. In the absence of light, color cannot be seen. (All cats are gray in the dark!) It wouldn't matter if the inside of the box were red or purple or cyan blue: it would still appear black without light.

Now You See It… Exhibit Copy

When you look inside this closed box, what color do you see? Now open the box.

Surprise! Did you think the inside of the box was black? That's because without light, there is no color. COLOR that we see is actually the LIGHT reflected by the object we're looking at. When the box is opened, light enters and is reflected from the inside surface. Your eye can see that it is actually white!

Reflection

Reflection occurs when light waves bounce off the mirror.

Mouse Multiplier

OBJECTIVE: To show that the number of images that can be created by two mirrors is variable depending on what angle the mirrors are to each other.

METHOD:

Two mirrors are hinged together so that their angles to one another are adjustable. A small toy is placed between the two mirrors to observe what happens to the image when the mirrors are moved.

EXPLANATION: There is actually a mathematical equation that relates the angle of a mirror to the number of images that you see. A 360-degree circle divided by 90 degrees is four; thus you see four images when the angle between the mirrors is 90 degrees.

Similarly, 360 divided by 60 is six, so you get six images at 60 degrees. (The mirrors on this exhibit are at 90 degrees when they are opened to the stopper). If the mirrors are parallel, then the angle between them is zero. Anything divided by zero is infinity -- which is why two parallel mirrors always look into infinity. The closer you get to parallel, the more images you see.

Mouse Multiplier Exhibit Copy

Adjust the mirrors while looking at the toy mouse.

The number of images that you see depends on the angle of the mirrors. When the mirrors are set at 90 degrees (opened to the stopper), you see four mice. One is the real toy mouse and three are reflections. Two of the reflections are direct mirror images of the mouse and the third reflection is made by light bouncing from one mirror to the other and then to your eye, so it is actually a reflection of a reflection!

The smaller the angle between the two mirrors, the more the light bounces back and forth between them before going to your eye. The more the light bounces, the more images your eye sees.

Cheek to Cheek

OBJECTIVE: To show what happens when two mirrors are positioned at 90 degrees to one another and then rotated.

METHOD: See Objective

EXPLANATION: This exhibit is similar to the effect in the Mouse Multiplier, but demonstrates a different aspect of angled mirror reflection. Because the two mirrors inside the drum are placed at right angles to each other, the viewer's image (or reflection) appears flipped: the right side of his/her face looks like it's on the left side and vice versa.

This is most easily noted when the viewer places his finger on his cheek to note which side is which -- most of us wouldn't automatically realize that our reflection is reversed. This is also why we placed the flat mirror on the exhibit, to compare your "normal" Image to this, reversed one.

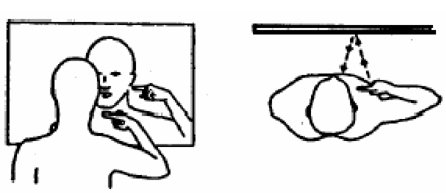
Likewise, when the mirror is rotated, the image turns so that the viewer's chin is where his forehead should be. This is simply the same principle from a slightly different angle. Keep turning the drum and the image rights itself again. As you turn, it looks like you're "screwing your head on."

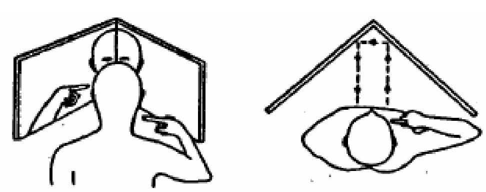
You'll note that in the Mouse Multiplier, the image is also reversed when the mirrors are set at 90 degrees to each other.

Cheek to Cheek Exhibit Copy

While looking into the mirror drum below, place a finger on your right cheek. What happens to the image? What happens when you turn the drum? Compare this with your reflection in the flat mirror above.

The two mirrors inside the drum are placed at 90 degrees to one another. Light strikes the first mirror and reflects to the second mirror, then bounces off of the second mirror to your eye, so you see your right cheek on the left side, and vice versa, And when you turn the mirror, you see your chin where your forehead should be!





Block Out/Pink Pig

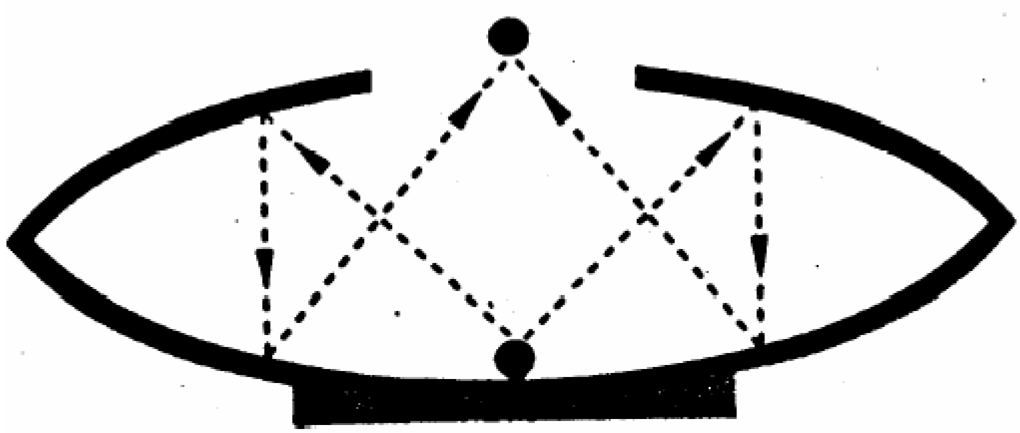
OBJECTIVE: To demonstrate that a reflected image is simply the light given off by the red object.

METHOD: A curved mirror is used to project an image of a green block into open space. (See Illustration below.)

EXPLANATION: Block Out demonstrates a scientific phenomenon called a three-dimensional real image. There are two types of images: real and virtual. A real image is one in which the light rays actually come from the image. In a virtual image, they appear to come from the image reflected, but do not. In a flat mirror, for instance, the virtual Image of an object is behind or "inside" the mirror, but light rays do not come from there.

The light rays from the real green block are reflected off of the curved surfaces of the concave mirrors inside the pedestal in such a way that the rays come to a single point and recreate the image of the block.

(See illustration below.) Yes, it's a tricky one!



<u>Block Out</u>

What happens when you pick up the green block?

The green block that you see is actually a three-dimensional reflection. The real object is inside the pedestal. The entire surface inside the pedestal is mirrored so that light reflecting from surface to surface creates an image that appears to "float" in mid-air.

Up Periscope

OBJECTIVE: To demonstrate to visitors that mirrors can be used in different ways to view the world around them.

METHOD: Two mirrors are mounted inside the periscope: one near the top and one near the bottom. The viewer looks into the low mirror and can rotate the upper mirror to see a view from the upper mirror's height.

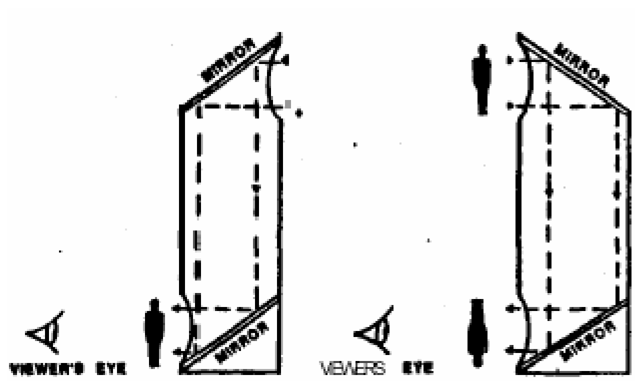
When the top mirror is rotated the images that are seen will change orientation (appear upside down, or right themselves).

EXPLANATION: See exhibit copy. Note that the effect is similar to the "Cheek to Cheek" exhibit; also using mirrors attached at a 90 degree angle to each other to reverses the sides of an image.

<u>Up Periscope Exhibit Copy</u>

What happens 'when you look through the periscope and turn the top?

When the periscope is directed forward, the mirrors at the top and the bottom are both at the same angle and the reflected image is right side up. When you turn the periscope to see behind you, the top mirror turns so it is at a 90-degree angle to the bottom mirror. This causes the image to flip (rotate 180 degrees), so everything appears upside -down! (This effect is similar to the "Cheek to Cheek" exhibit.)



Sources of Light

The source of light has an impact on the properties and quality of that light.

Instant Lighting

OBJECTIVE: To demonstrate that when electricity passes through a gas, it stimulates the molecules enough to cause them to emit light.

METHOD: A spark generator, i.e. a rod that can be moved to create a spark like a Jacob's Ladder, is used.

EXPLANATION: This is one exhibit, which can get very complicated very fast! The briefest explanation is in the exhibit copy: nitrogen atoms in the air are being stimulated by the electrical current, causing them to give off a purplish light. Visitors interested in learning more about this phenomenon may be encouraged to look up how lightning is formed.

Instant Lightning Exhibit Copy

Move the lever and notice the spark that jumps through the air. "Regular air" is composed mainly of -nitrogen and oxygen atoms. The purple spark you see is produced by the electric current stimulating the electrons of these atoms.

What's In A Light Bulb?

OBJECTIVE: To demonstrate that heat is one source of light. This principle is called incandescence.

METHOD: A variable rheostat (dimmer switch) is used to control a very large, unfrosted light bulb. The filament is a tungsten wire (used in nearly all incandescent light bulbs), which glows when it is heated, giving off light.

EXPLANATION: See Method.

What's in a Light Bulb? Exhibit Copy

Find out where the light in a light bulb comes from by turning the knob.

As electricity passes through the filament (wire) in a light bulb, the metal heats up and glows, giving off light. This is an example of *an incandescent* (glowing from heat) light bulb. Use the rainbow glasses to discover how many colors there are in the light this bulb gives off.

Light Within A Light

OBJECTIVE: To demonstrate the effect phosphor coating has on light emitted from a fluorescent light tube.

METHOD: Both a coated and an uncoated fluorescent tube are on display. (The uncoated tube is on the left and the coated tube is on the right.)

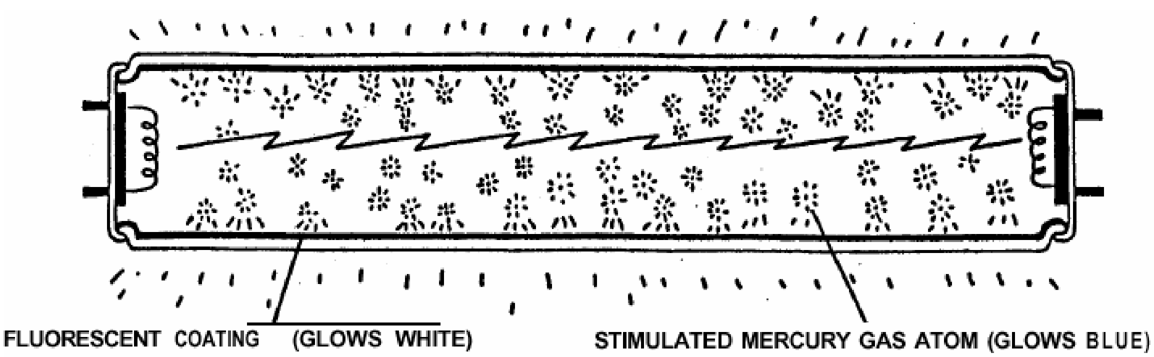
EXPLANATION: See exhibit copy.

Light Within a Light Exhibit Copy

Recognize this light source?

The light given off by, a fluorescent lamp is produced by a two-step process. The first step is electricity passing through the mercury gas in the tube, creating a bluish light. The light is blue because stimulated mercury gas gives off light in the blue end of the rainbow spectrum. It also gives off light in the invisible ultraviolet range. (Check out the uncoated tube with your rainbow glasses.). The second step occurs when this ultraviolet light hits the phosphor coating on the walls of the tube. This coating then fluoresces (glows), producing the white light that we see. (Check out the coated tube with your rainbow glasses.)

COATED FLUORESCENT LIGHT TUBE



Look A Lights

OBJECTIVE: To demonstrate that gasses stimulated by electricity give off a specific color.

METHOD: A glowing neon-filled tube and a glowing argon-filled tube are placed side by side so viewers can see the difference in their colors.

EXPLANATION: The spectroscope glasses permit viewers to see that neon only gives off color in the red color range. Argon only gives off color in the blue range.

Look-a-Lights Exhibit Copy

These two lights may look alike when turned off,
but when turned on it's a different story!

These lights have electricity passing through them, which stimulates the gases in the tubes and makes them emit (give off) light. Each type of gas gives off its own color of light. Neon gas emits a red light and argon gas emits a blue light. View them with your rainbow glasses to compare them to white light.

Rainbow Glasses

OBJECTIVE: To demonstrate how different sources of light show differing portions of the rainbow or electromagnetic spectrum.

METHOD: Visitors look at different light sources through the "rainbow glasses".

EXPLANATION: Only white light shows the full electromagnetic spectrum of Red, Orange, Yellow, Green, Blue, Indigo and Violet. If a light source does not produce white light, only a portion of the spectrum will be visible.

Holograms

Holograms on Parade

OBJECTIVE: To demonstrate what reflection holograms look like and to stimulate visitor interest in holograms.

METHOD: View a variety of reflection holograms.

EXPLANATION: See exhibit copy for a brief explanation. For more information on this complex topic, *The Complete Book of Holograms* (Joseph Kasper, Stephen Feller. John Wiley & Sons. 1987) is highly recommended. Encourage visitors to explore holograms more fully on their own!

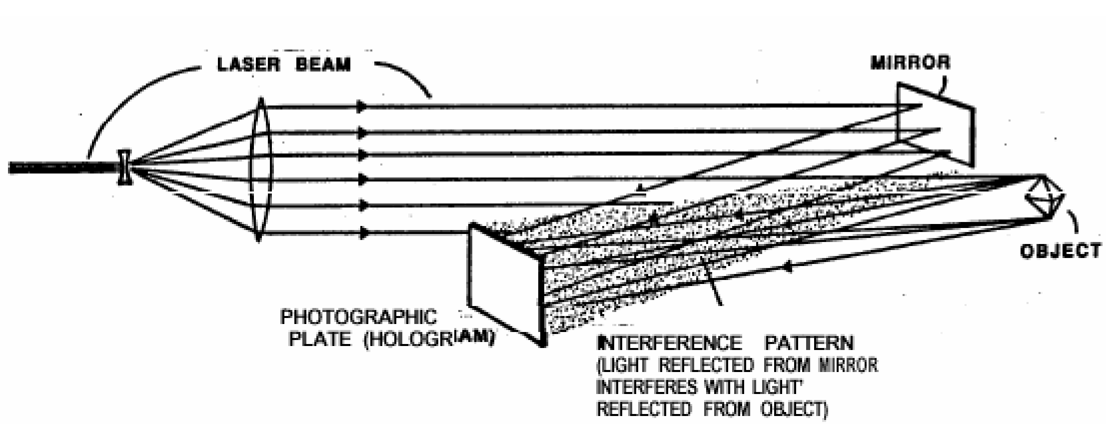
Holograms on Parade Exhibit Copy

Can you see the 3-D effect in these holograms?

Holograms are made using laser light. A beam of laser light is split so that part of it hits a piece of photographic film and part of it is reflected from the object (see illustration below). These two beams interfere with each other and create a pattern (like ripples intersecting in a pond), which is recorded on the film. This film is then developed in a process similar to developing regular photographs. Once developed, if the photographic plate is viewed by illuminating it with light from a specific angle, the image appears as an exact duplicate of the original object.

These particular holograms are examples of a reflection hologram. This type of hologram is viewed by light reflected from a light source on the viewer's side of the photographic plate into his or her eyes.

ILLUSTRATION OF A REFLECTION HOLOGRAM



Color Vision

Why Do We See Color

OBJECTIVE: To give visitors the opportunity to test their color vision.

METHOD: View sample plates from A Test for Color-Blindness by Shinobu Shihara, M.D., a color vision testing method commonly used by ophthalmologists.

EXPLANATION: See exhibit copy. A Xerox of the explanation from the Ishihara manual is also included. This is another topic that visitors will enjoy exploring on their own.

Why Do We See Color? Exhibit Copy

Light strikes the retina, the light-sensitive membrane in our eyes, which contains different types of rods and cones that send signals to our brain. Rods perceive all light as white, while cones are sensitive to specific wavelengths of light. In the same way that a color television set uses red, green and blue fluorescent dyes to create all the colors of objects seen on the screen, the retina contains three types of cones. Red, green, and blue cones in the eye along with perceptual centers in the brain integrate information about the wavelength of light coming from an object and provide us with the sensation of color.

Do You See What I See? Exhibit Copy

There are several ways to test color perception.

On this display are sections from a pseudoisochro-matic booklet, the “color dot test,” with the correct answers supplied below. Test your own color vision!

A. If you have normal color vision, you will see an “8;” if you have red-green deficiencies; you’ll see a “3.”

B. If you have normal color vision, you will see a “74;” if you have red-green deficiencies; you’ll see a **"21."**

C. If you have normal color vision, you can hardly read it, but if you have red-green deficiencies, you can probably see a “2.”

D. If you have normal color vision, you can probably see the **"16,"** but if you have red-green deficiencies, you probably cannot.

Source: Ishihara’s Tests for Color-Blindness, Kaneharat & Co., © 1980

Dichroic (die-CROW-ick) Sculpture

What is Dichroism?

In the 1950's the laser industry developed interference light filters. Technicians vaporize titanium oxide and quartz in a vacuum chamber, alternating thin layers of each mineral onto glass. The result produces a transparent yet highly reflective color surface. The various layers of minerals interfere with light passing through the coatings, so only selected wave lengths of color can pass through and the remaining wave lengths of color reflect back off the surface.

"Dichroic" means a two color system; one color goes through the glass and one color is reflected. The thickness of each layer determines the color.

Dichroism uses this special glass to create art.

About the Sculptor:

Ray Howlett, the father of Dichroism, was born in Lincoln, Nebraska, in 1940. When he was 25 years old he moved to Los Angeles. His breath was taken away when he saw the large, spacious ocean reflecting the infinite sky spotted with the lights of Hollywood. Many technical advances were being made in Southern California that affected his exploration into this new style of art. The illusions created by Artist M.S. Escher and Victor Vasarely motivated him to experiment. He also incorporates the concepts of James Turell, who we study in the Art History portion.

Before and after his move in the mid-1960's to Los Angeles, he painted contrasting light and space. Then he was exposed to mind expanding philosophies like metaphysics. Eventually he moved away from images so the viewer would not get stuck on "isn't that a pretty flower", losing the essence of the perceptual experience. In 1973 he was intrigued when he started to play with structural optics and electric light that produced many reflections. Thus began Dichroism.

His sculpture is recognized all over the world as an art movement. As of 1999, there were two thousand artists doing dichroism throughout the U.S.A.

The Dichroic movement also overlaps internationally recognized art movements in glass, electric light, mixed media, California light and space, The Los Angeles Look, illusionism, art & technology, kaleidoscope art, structuralism, infinity art, kinetic art, interactive art and the 4th dimension in art as seen in cubism, ect.

The optical chamber we are looking at is an example of Dichroism as it uses the special glass. In this sculpture, you will see an image that could reflect back for infinity when there are only 12 inches of box (physical space). This creates a visual time delay between the spaces reflected. This is a piece of art where everyone needs to participate with the sculpture. Without the viewer, the art does not move. The longer you look the more depth you will see and the more variety of compositions you will create. This is known as the 4th dimensional aspect. It is an exercise in perception like Cubism.

Ray Howlett now makes his home in Nebraska and travels regularly to South Dakota. He had an art show in 1999 at the Dahl Arts Center in Rapid City and during the summer of 2005 he had a show in Mitchell. We are proud of the fact that he feels a connection with the South Dakota family and wanted all of you to see what an original Dichroic sculpture looks like.