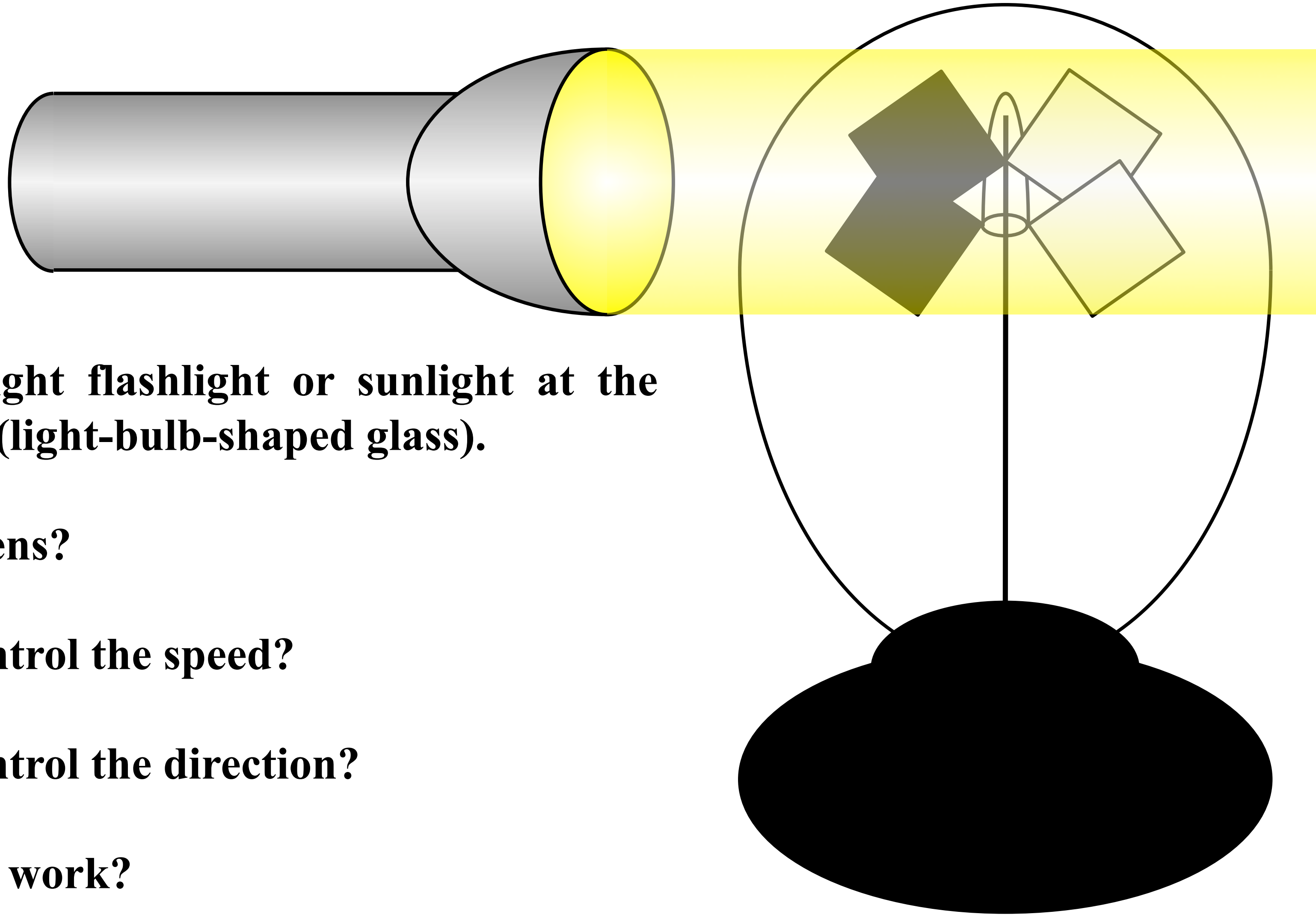
Radiometer (Front)

Explanation on back



Shine a bright flashlight or sunlight at the radiometer (light-bulb-shaped glass).

What happens?

Can you control the speed?

Can you control the direction?

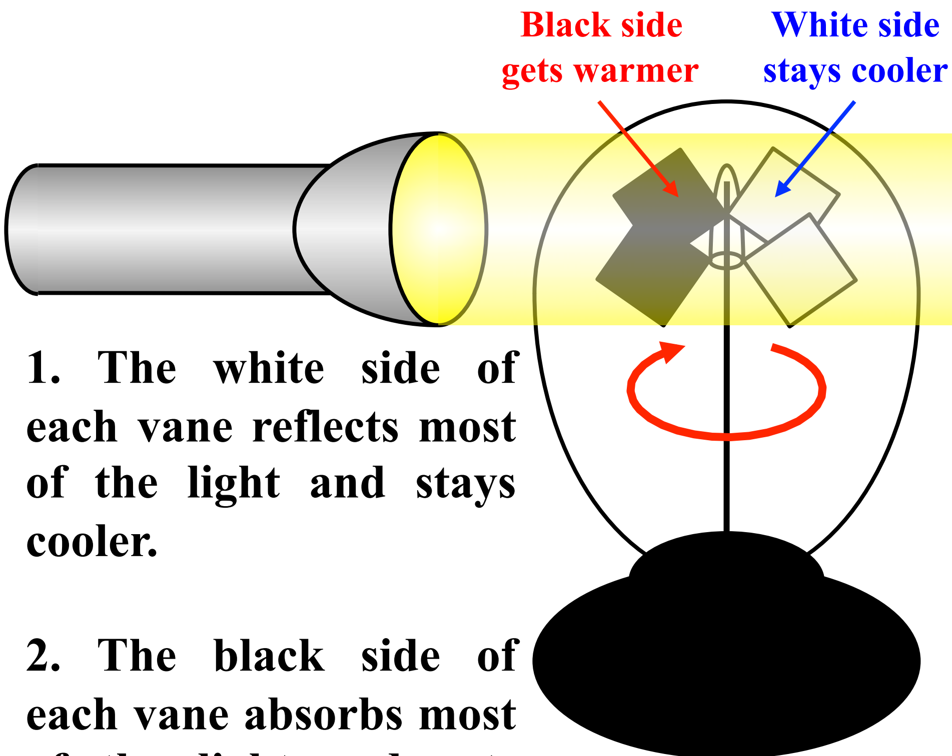
Why does it work?

Do not look at the sun, bright flashlight bulbs, or other bright lights!

Radiometer (Back)

Questions on front

How Does It Work?



1. The white side of each vane reflects most of the light and stays cooler.

2. The black side of each vane absorbs most of the light and gets warmer.

3. The warmer black side of the vane heats the air next to it.

4. The heated air expands and pushes on the black side of the vane.

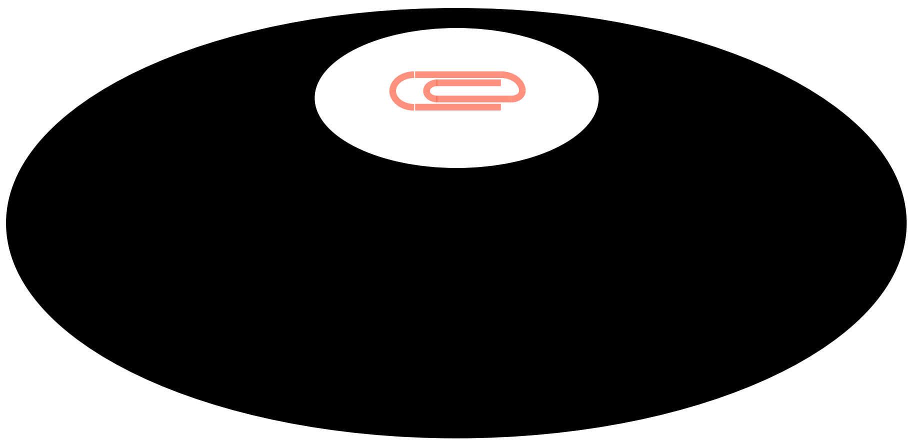
Why Is It Important?

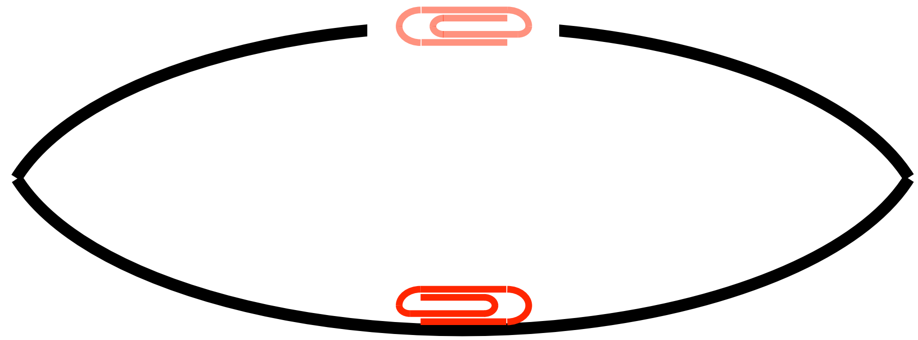
Sunlight heats different areas as the earth rotates daily and orbits annually, which helps to create winds in the atmosphere and currents in the ocean.

The radiometer experiment shows that light carries energy. Energy from sunlight can be utilized to heat water, or it can be converted to electrical energy by solar panels.

Mirage Maker (Front)

Explanation on back





Do not get fingerprints or scratches on the mirrored surfaces!

Put a small object in the center of the bottom of the mirage maker.

Do you see the object at the top of the mirage maker?

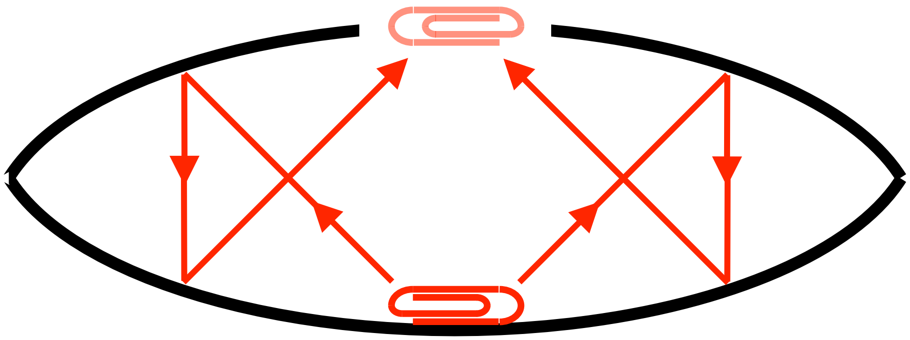
What happens if you change the position of the object at the bottom?

What happens if you put a larger or smaller object at the bottom?

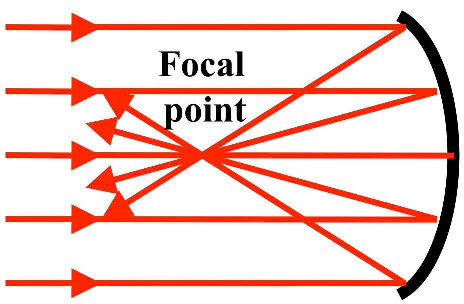
Mirage Maker (Back)

Questions on front

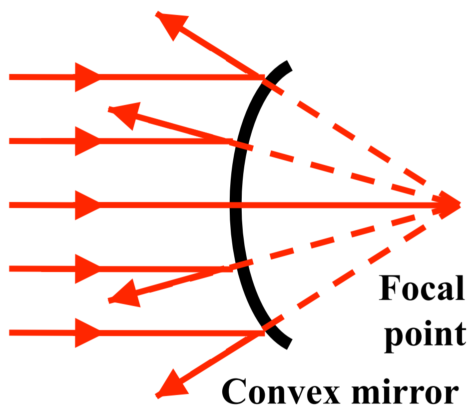
How Does It Work?



Light from an object at the bottom of the mirage maker bounces off the curved mirrors to create an image of the object at the top of the mirage maker



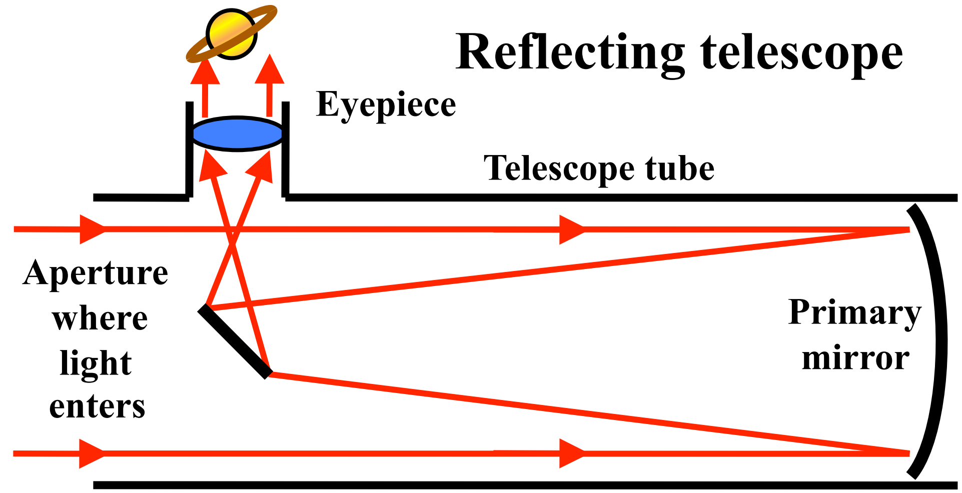
Concave mirror (remember that it "caves" in)



Convex mirror ("vexes" you trying to remember which way it curves)

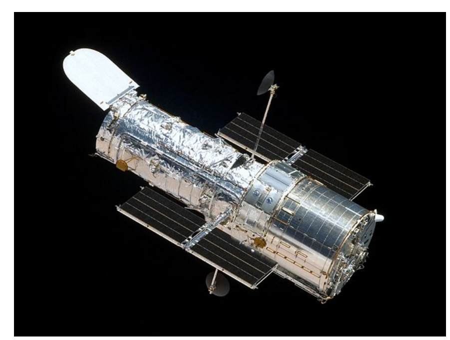
Why Is It Important?

Reflecting telescope



Curved mirrors can be used (just as lenses can be) to create magnified images in telescopes and microscopes. Large mirrors are cheaper and lighter than large lenses.

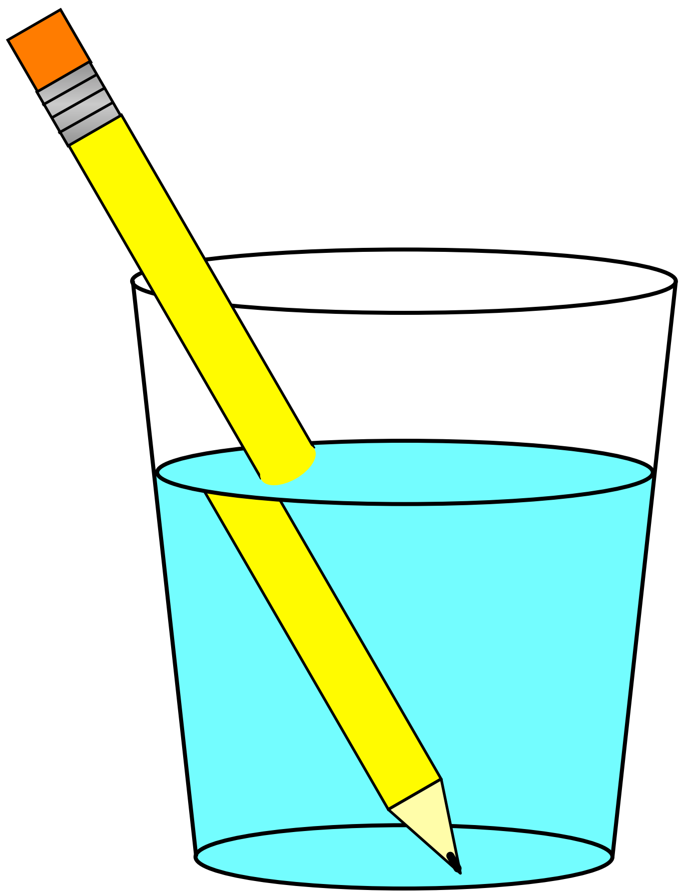
Hubble Space Telescope



Refraction (Front)

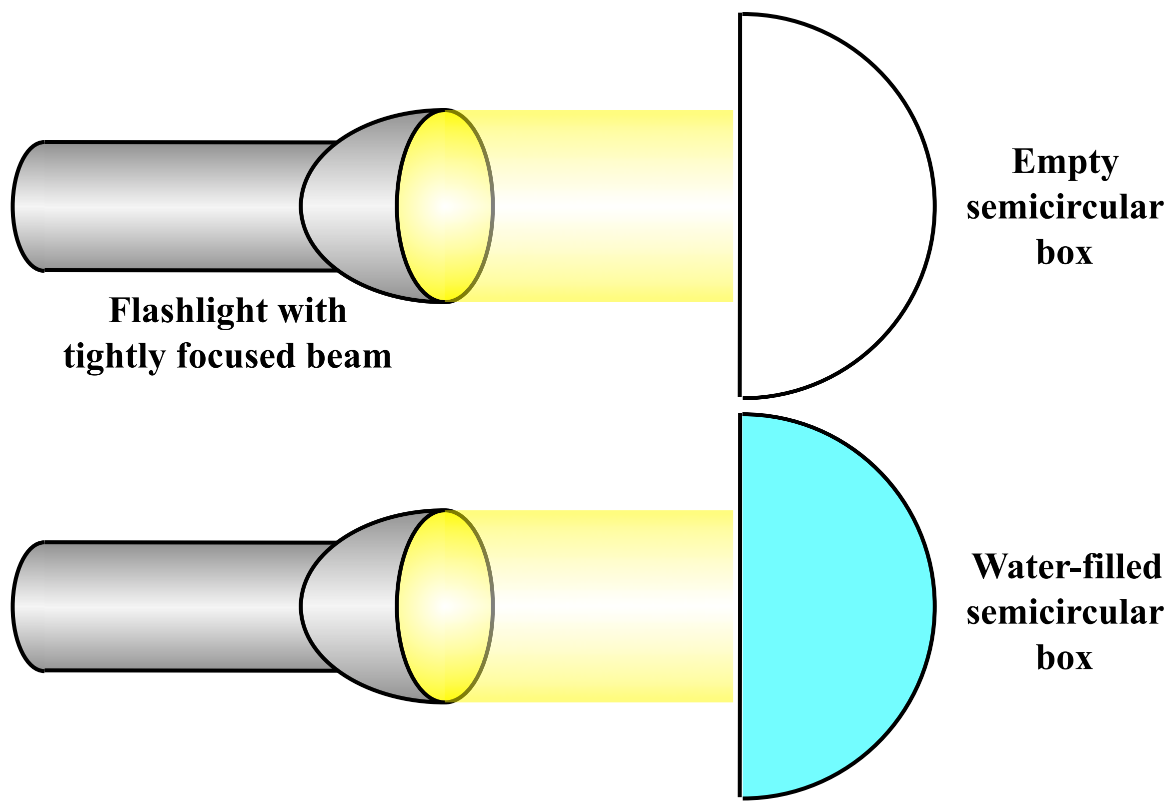
Explanation on back

Does a whole pencil look broken when you put it in a cup of water? Try it! Why does that happen?



Focus a flashlight to make a very narrow beam shining along the surface of the table. What does an empty semicircular box do to the beam?

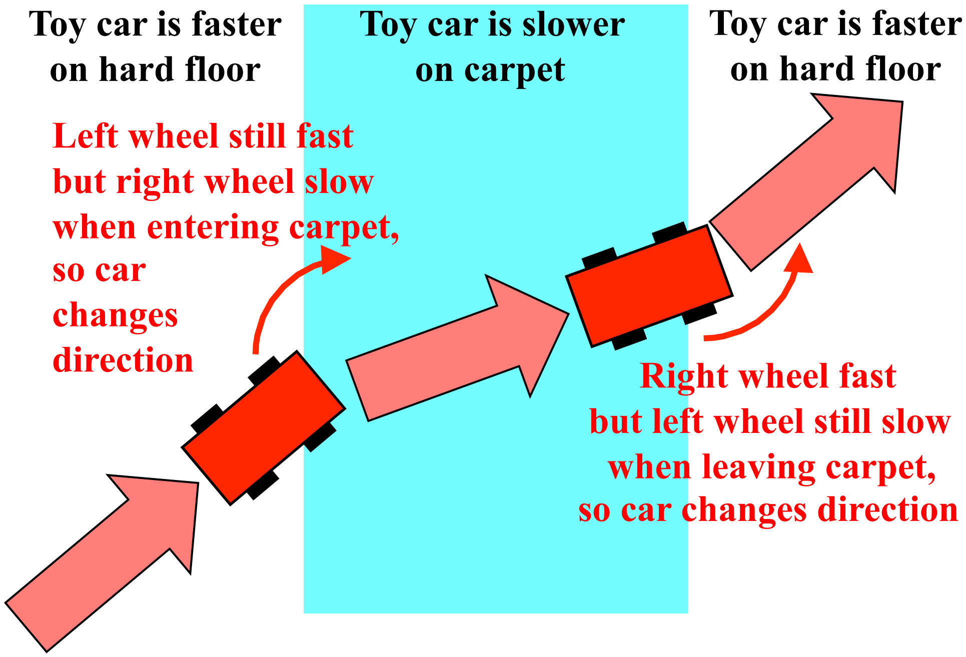
What does a water-filled semicircular box do to the beam? Why?

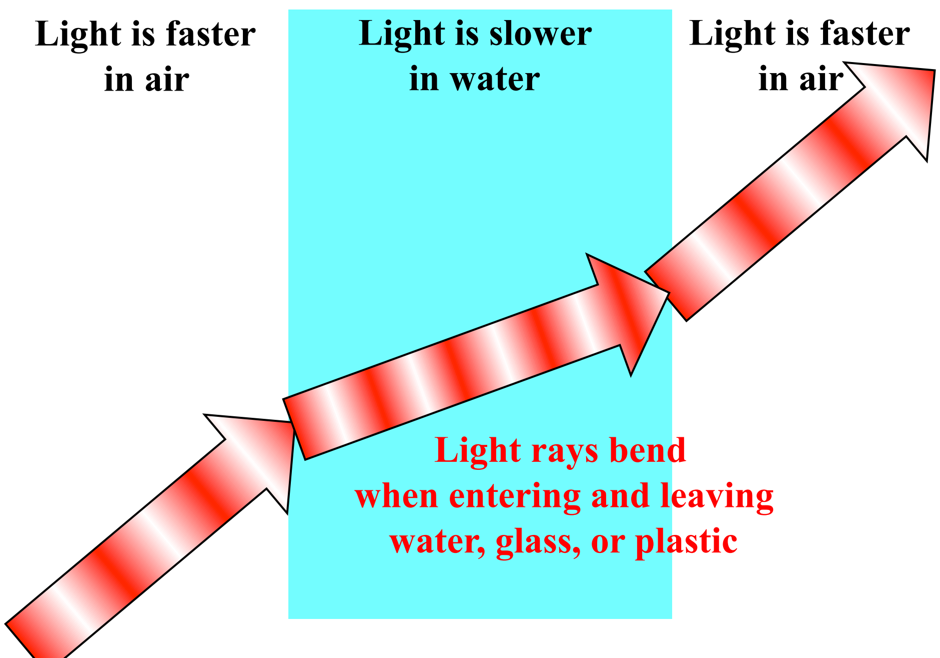


Refraction (Back)

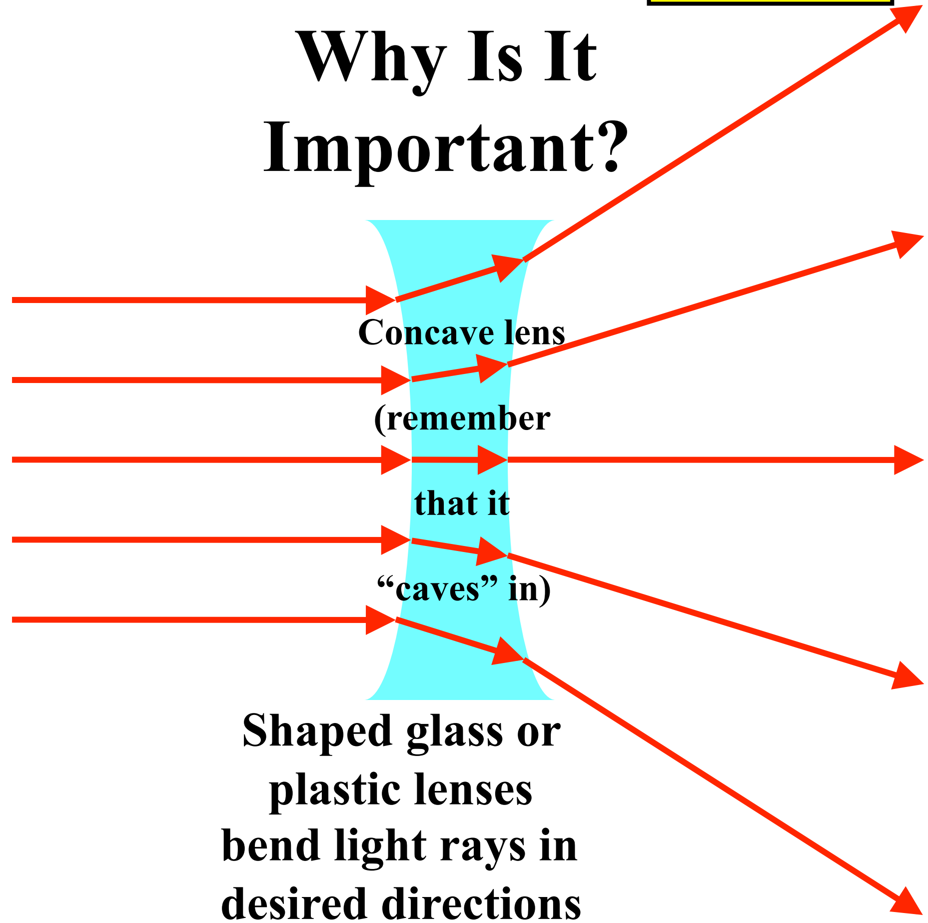
Questions on front

How Does It Work?

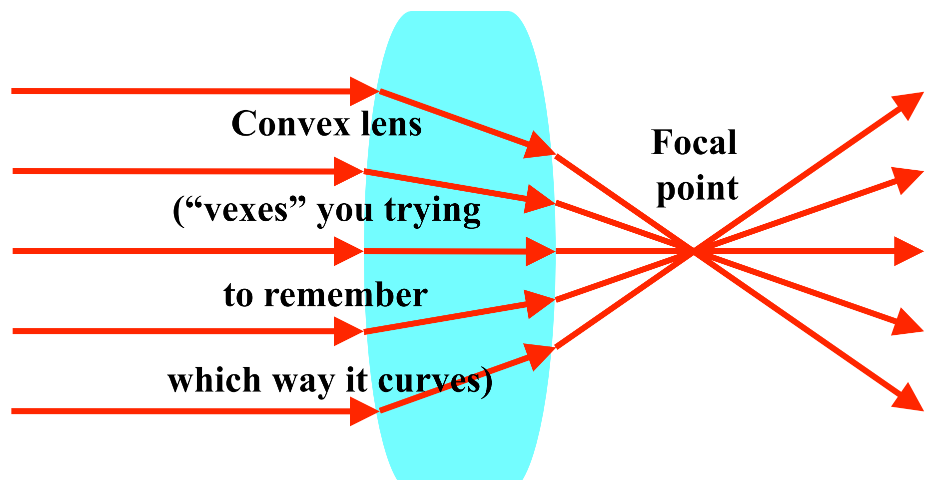




Why Is It Important?



Shaped glass or plastic lenses bend light rays in desired directions



Lenses (Front)

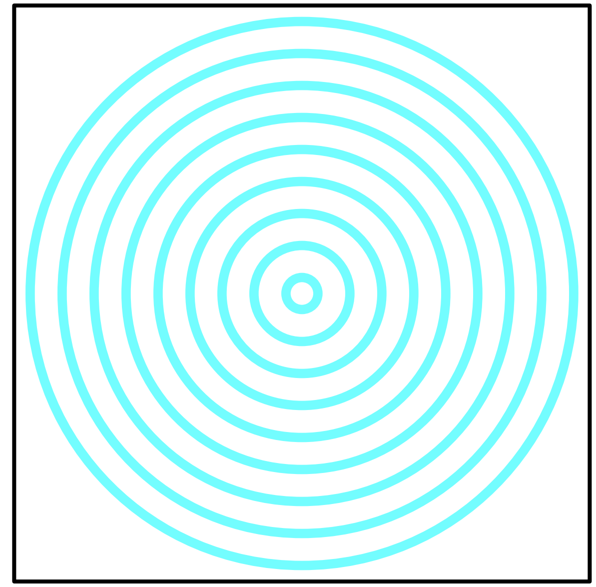
Explanation on back

Single concave lens | **Double concave lens** | **Mostly concave lens**

(“cave” in & defocus light)

Single convex lens | **Double convex lens** | **Mostly convex lens**

(“vex” you & focus light)



Fresnel lens

(side view)

Look through a concave lens at a written page or a distant object. How does it affect the image? Do things appear closer or further? Larger or smaller?

Look through a convex lens at a written page or a distant object. How does it affect the image? Do things appear closer or further? Larger or smaller?

Look through a Fresnel lens at a written page or a distant object. How does it affect the image? Does it act like a concave or convex lens? Why?

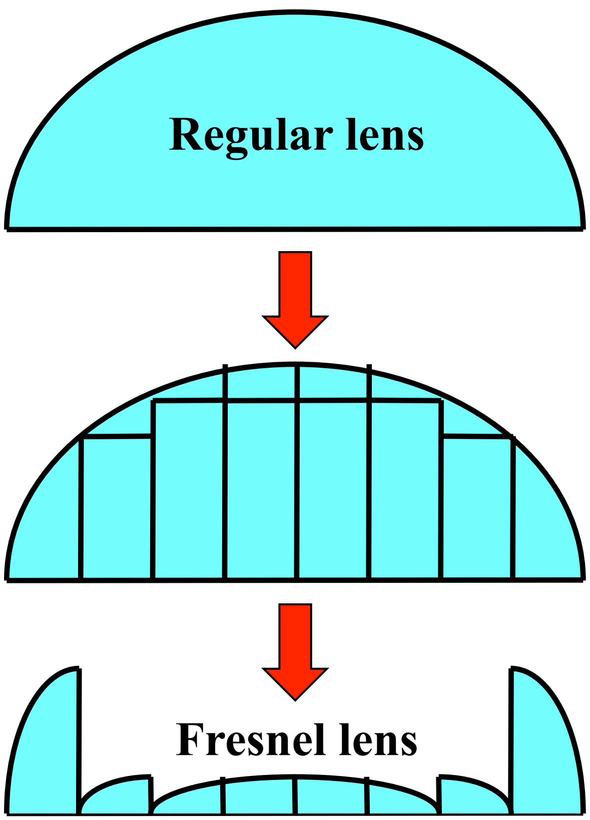
Try looking through two lenses. Can you adjust the distance between the lenses to see a clear image? Try different combinations of lenses.

Questions on front

Lenses (Back)

How Does It Work?

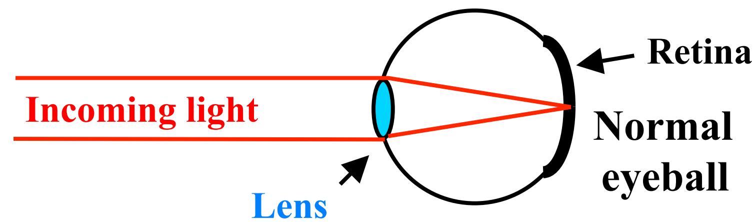
The surface curvature of a lens is more important than its thickness. Multiples of the light wavelength may be "cut out" from the thickness of the lens.



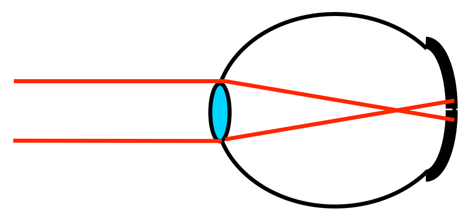
A Fresnel lens (with concentric circles) is flatter and lighter than a regular convex or concave lens.

Why Is It Important?

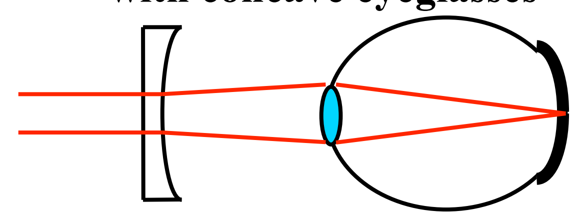
Your eye has a natural lens that focuses an image on your retina, which sends the signal to your brain. A nearsighted eyeball is too long, but a concave lens can correct the image. A farsighted eyeball is too short, but a convex lens can correct the image.



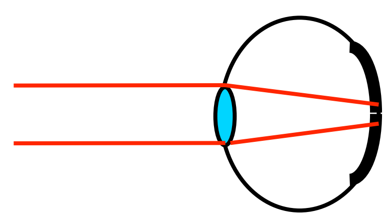
Nearsighted eyeball



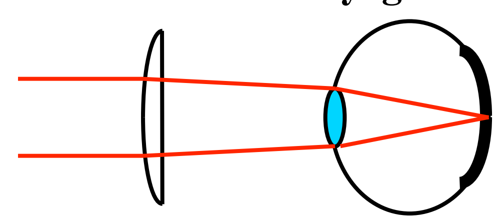
Nearsighted eyeball with concave eyeglasses



Farsighted eyeball

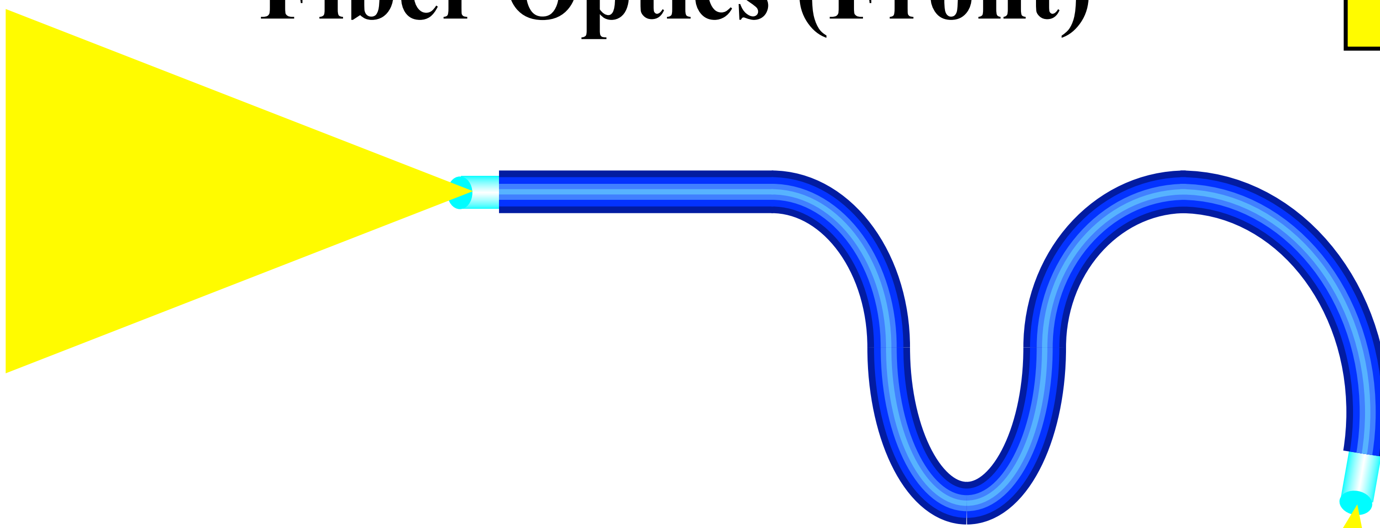


Farsighted eyeball with convex eyeglasses

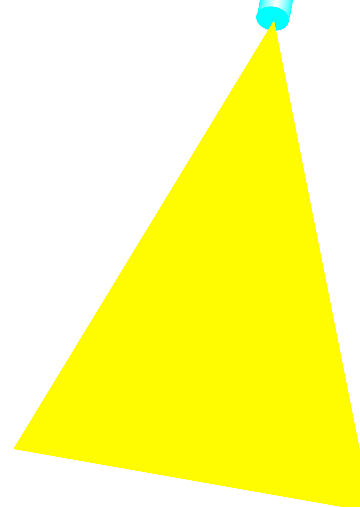


Fiber Optics (Front)

Explanation on back



Shine a flashlight into one end of an optical fiber (looks like blue fishing line or fibers) and bend the fiber into a gentle U shape so that you can look into the other end. What do you see? Why?

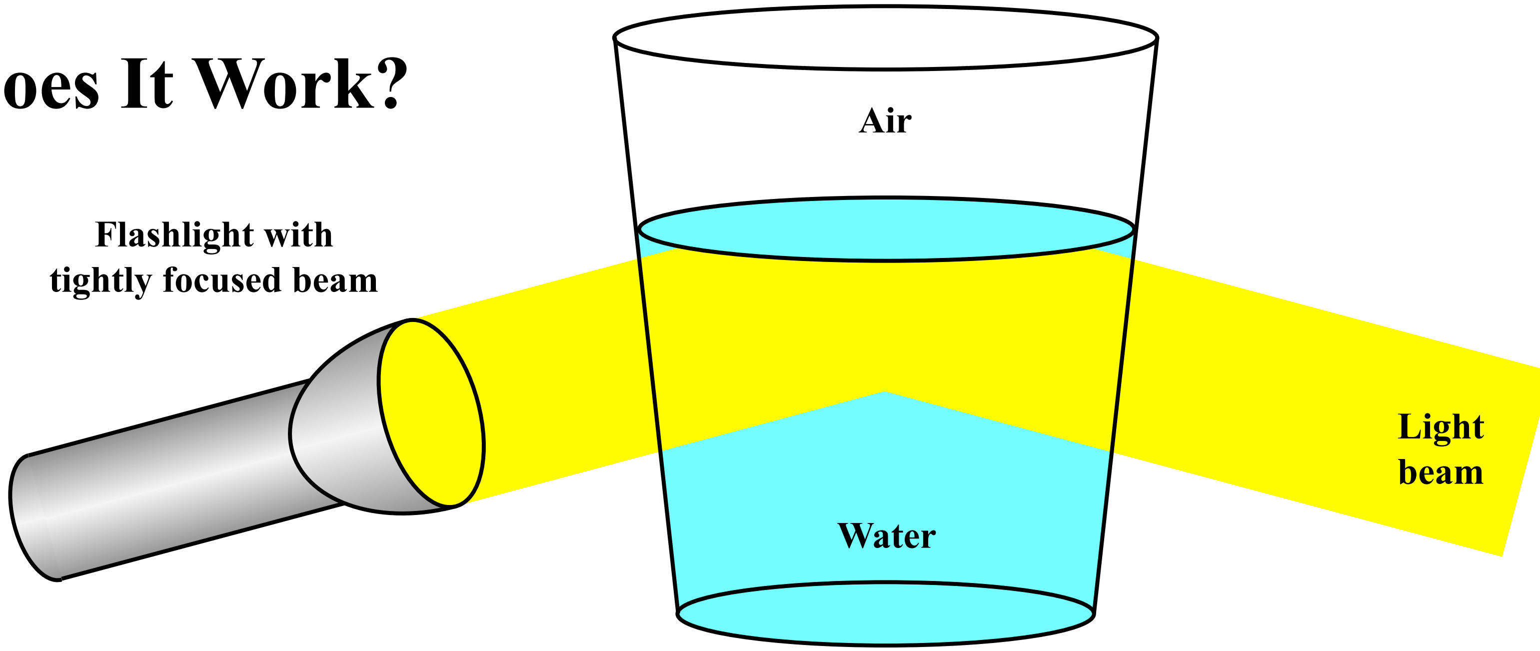


Keep shining the flashlight into one end of the optical fiber, but now bend the fiber into a sharper V shape in its middle. What happens to the light coming out of the end? Does any light escape at the V shape? An optical fiber can channel light around corners, but only if the fiber doesn't bend too sharply.

Fiber Optics (Back)

Questions on front

How Does It Work?



Fiber optics work because of <u>total internal reflection</u>. When light traveling through water bounces at a shallow angle off the surface between water and air, the light prefers to stay in the water, where it can travel more slowly. However, if the light beam angles upward more, it will escape to the air, not bounce back into the water.

Likewise, inside the optical fiber, light hitting the wall at a shallow angle is bent back into the fiber. But if the fiber is kinked into a V shape, light can hit the surface at more of an angle and escape out into the air.

Why Is It Important?

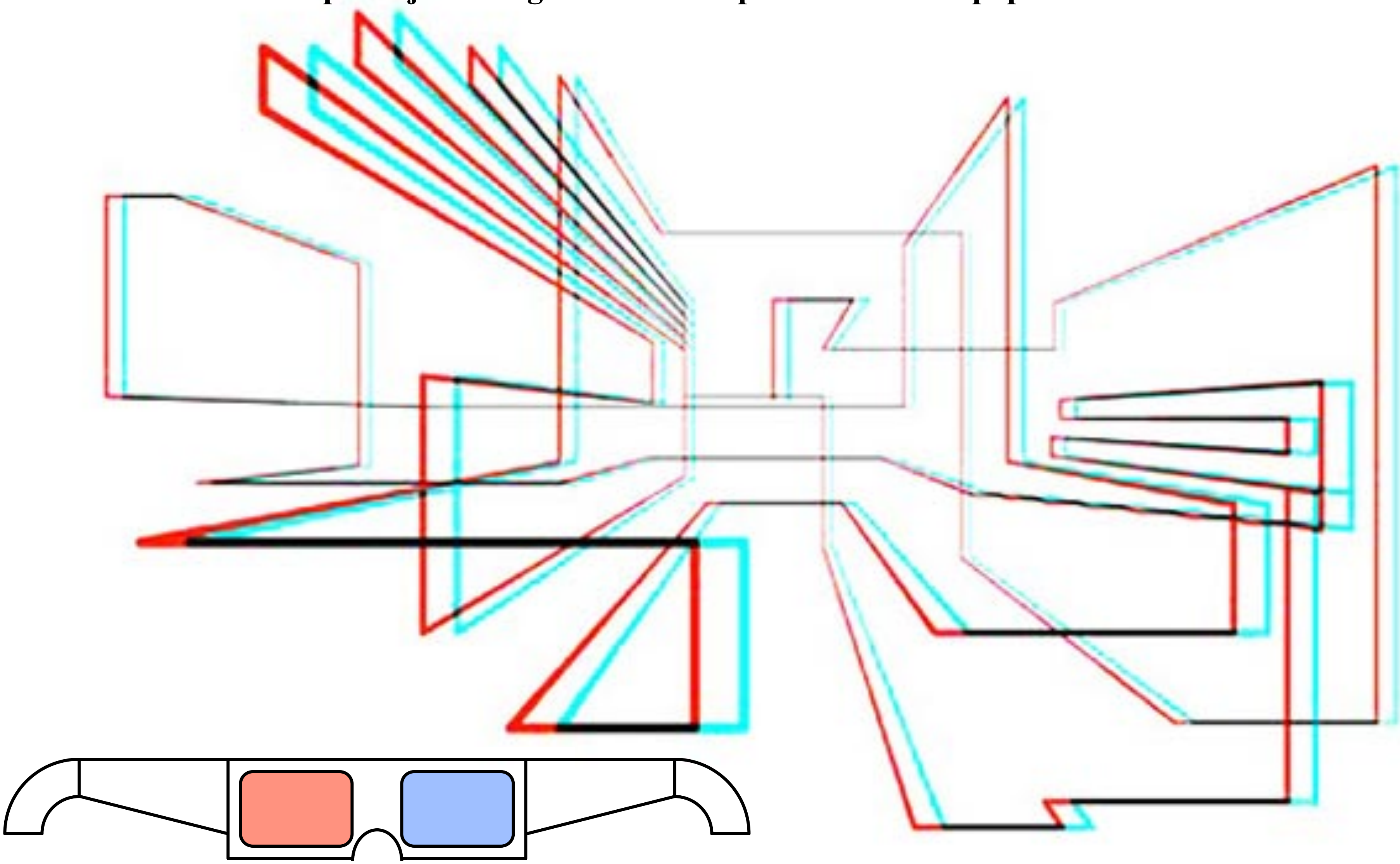
Optical fibers act like pipes for light, carrying light long distances and around corners. Many computer and phone networks use fiber optics to transmit data in the form of laser pulses.

Red and Blue Glasses (Front)

Explanation on back

Use the red and blue 3D glasses to view this image, with red for your left eye and blue for your right eye. Now try it again but with blue for your left eye and red for your right eye. Which works better and why?

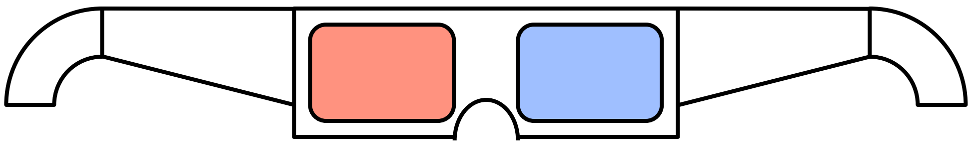
Make your own red and blue 3D images (or "anaglyphs") by drawing overlapping, slightly different views of the same simple object using red and blue pencils on white paper.

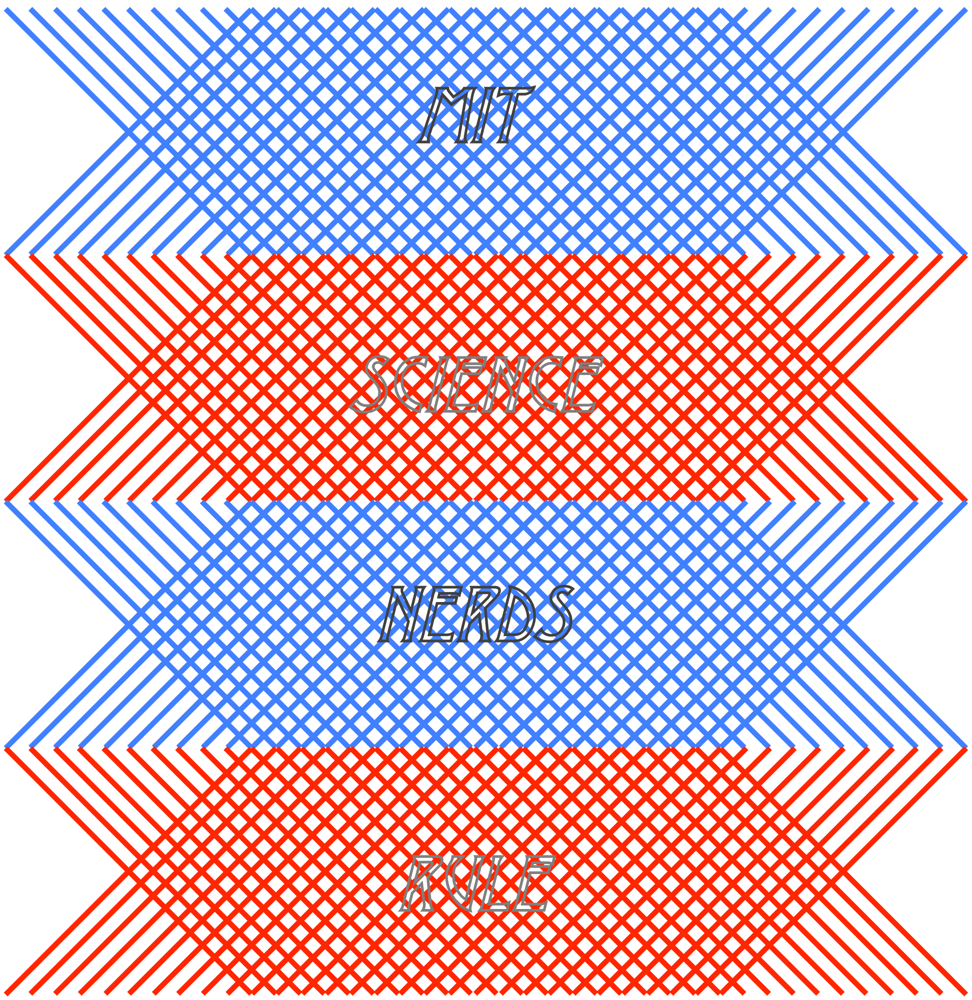


Red and Blue Glasses (Back)

Questions on front

How Does It Work?





The red filter of the glasses makes all the white areas red, so you don't notice red lines, but blue lines do not reflect much red light, so they appear very dark. Likewise the blue filter makes you ignore blue lines but makes red lines seem dark. Each eye sees different lines, and your brain tries to interpret those as the same lines seen from two different perspectives, or a 3D image.

Why Is It Important?

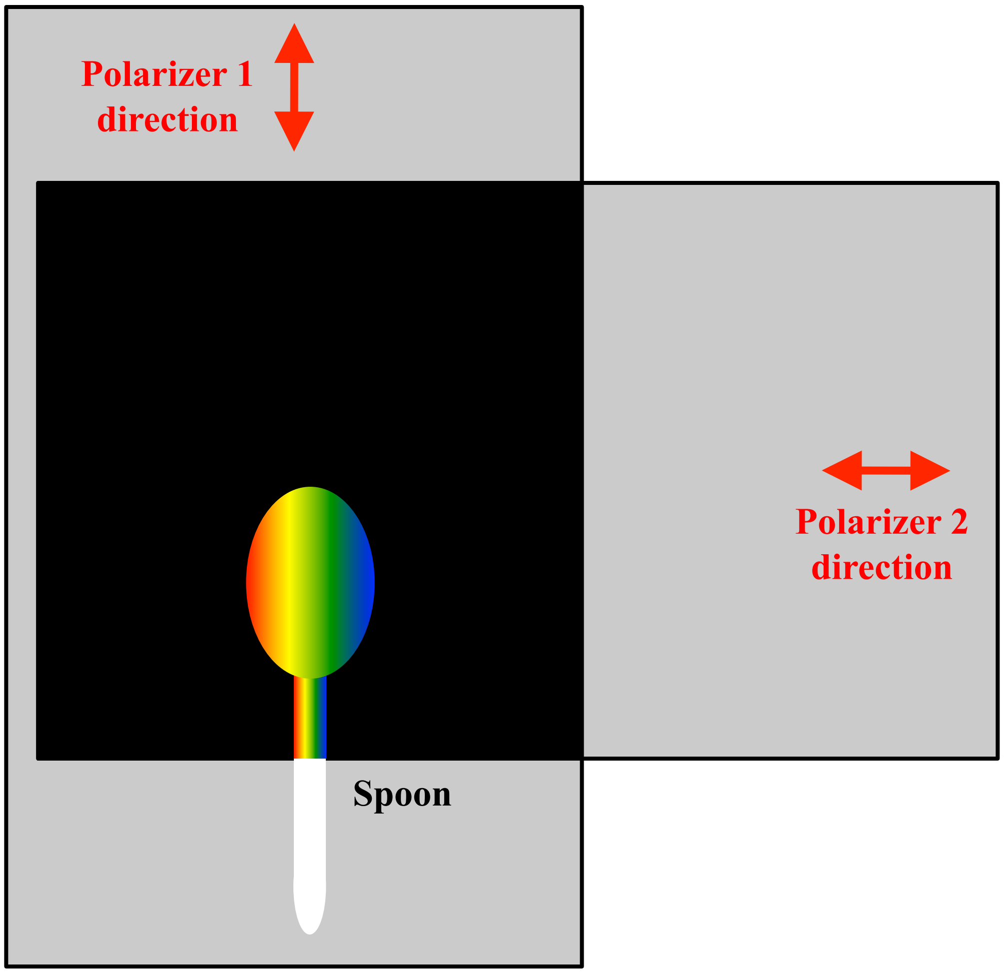
When looking at anything from planets to DNA samples, filters can be used to screen out unwanted colors and noise and focus on the most important signal.

View this image through the red or blue filter of the glasses. Which color makes it easier to see which words? Why?

Write a secret message on white paper using a black pencil, then scribble over it with a colored pencil (just one color). Decode the message by viewing it through the appropriate color filter.

Polarization (Front)

Explanation on back



Look through a polarizer. How much dimmer does it make things appear? Why?

Look through two stacked polarizers aligned in the same direction. How dim do things look? Why?

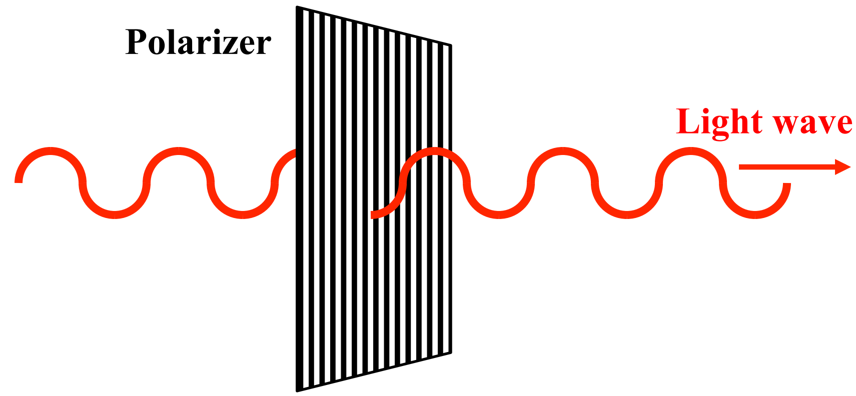
Look through two stacked polarizers rotated by 90° relative to each other. How dim do things look? Why?

Put a clear plastic spoon or fork between two stacked polarizers. How does the spoon or fork look? Why?

Polarization (Back)

Questions on front

How Does It Work?



A light wave has electric and magnetic fields wiggling side-to-side or up-and-down. Polarizers are covered with parallel lines (even closer together than the lines on diffraction gratings). If a light wave's electric field wiggles in the same direction as the lines in a polarizer, the light can squeeze through the polarizer. But if the light wave's electric field wiggles in the wrong direction, it runs into the lines and the polarizer stops the light. Two polarizers aligned in the same direction let some light through, since their little lines all go the same direction. Rotating one polarizer 90^o blocks all light, since light wiggling the right way to pass through one polarizer will be wiggling the wrong way to pass through the other polarizer.

If you put a clear plastic fork/spoon between two polarizers, you should see colors in the plastic item, especially in areas where the plastic is bent. When plastic is stretched, its long molecules can line up in parallel and act somewhat like a polarizer, rotating the polarization of light. The rotation affects different wavelengths (colors) of light differently, so you see colors in areas of the plastic that were stressed during the manufacturing process.

Why Is It Important?

Many (but not all) sunglasses use polarizers. Hold a polarizer over sunglasses and rotate it to see if the lenses are polarizers or just plain darkened plastic.

Many (but not all) LCD screens emit polarized light. Hold a polarizer over an LCD watch, calculator, phone, computer screen, or TV screen. Turning the polarizer the right way may make the screen go dark or block some colors on the screen.

The polarizers showed stress patterns in the plastic spoon or fork. Sometimes engineers use similar but fancier techniques to analyze stress patterns in materials to make sure things won't break unexpectedly.

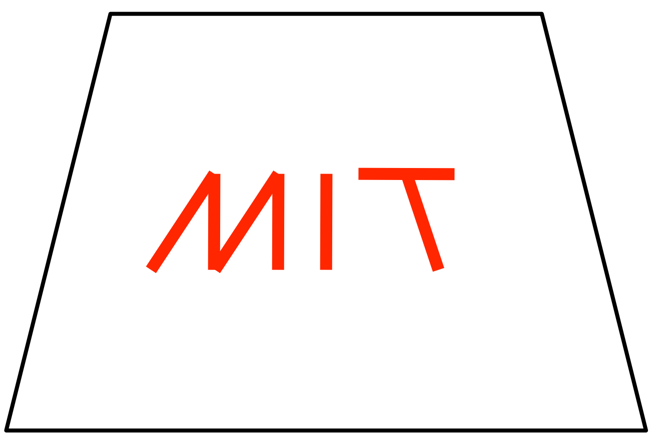
Birefringence (Front)

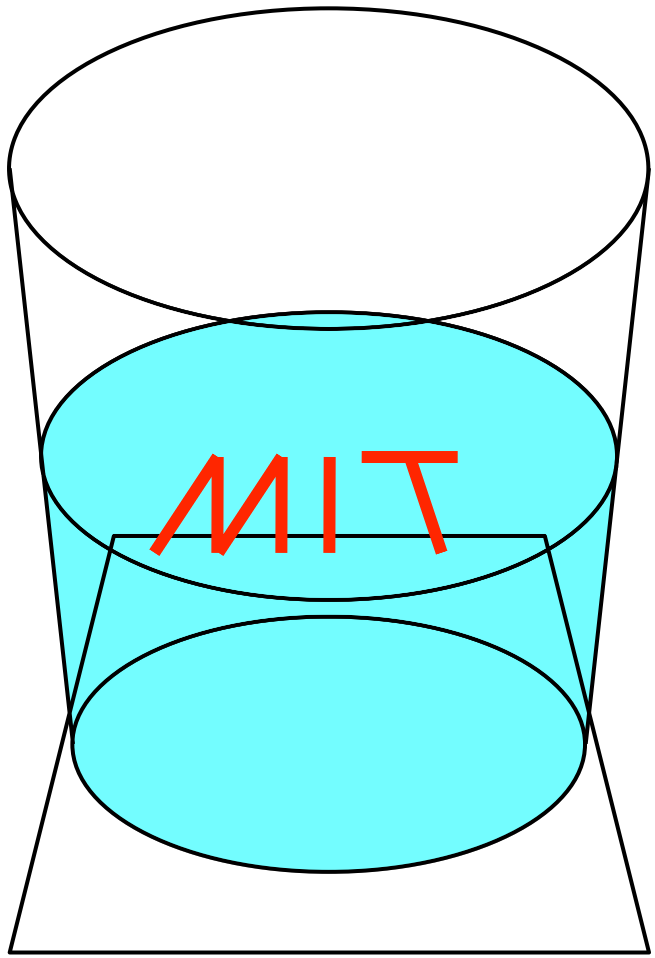
Explanation on back

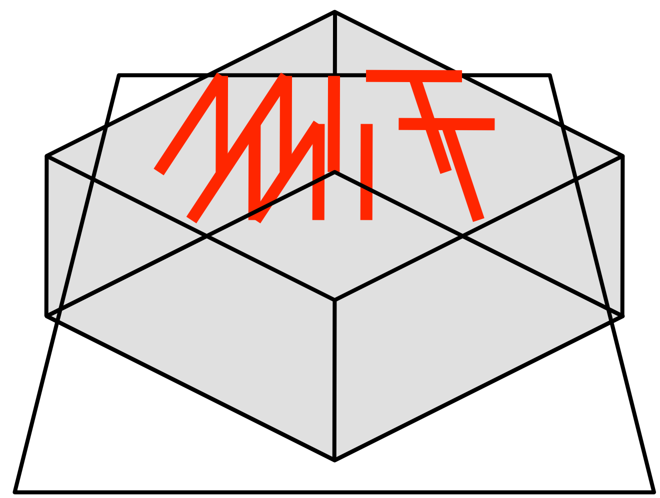
Put a cup of water on top of some text and look down through it. Do the letters appear higher, lower, or at the same height as the paper actually is?

Do not get the calcite crystal wet! It will dissolve!

Put a calcite crystal on top of some text and look down through it. How do the letters look? What happens if you rotate the crystal?







Birefringence (Back)

Questions on front

How Does It Work?

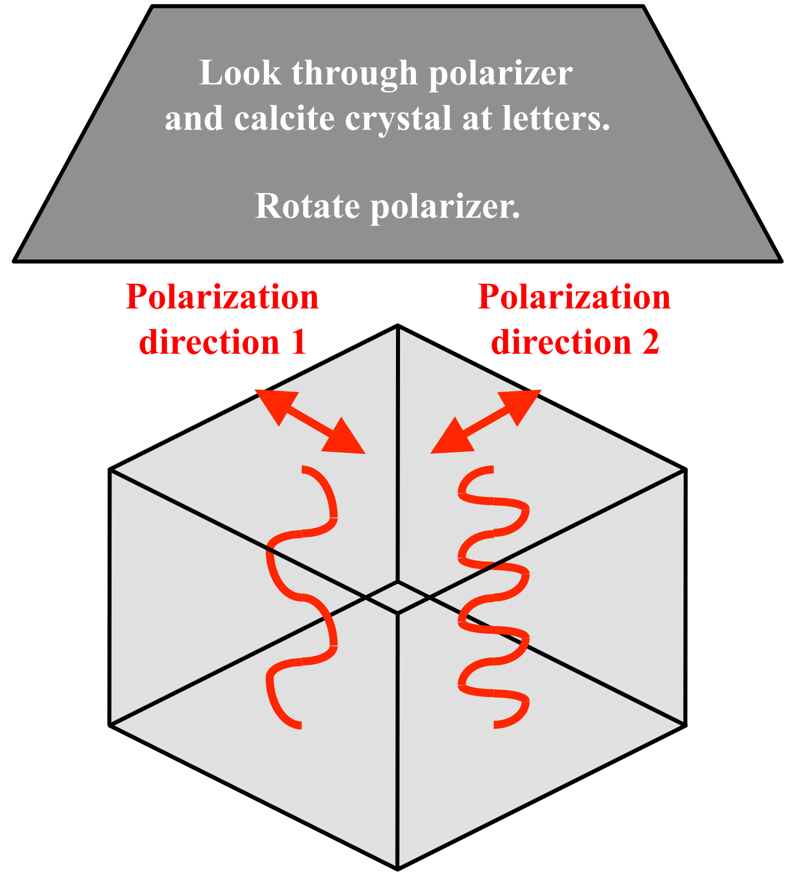
The index of refraction is the factor by which a substance slows down light (and thus can bend the light rays).

Polarization is which way the electric field component of a light wave is wiggling (up-and-down or side-to-side).

Water and most other substances have the same index of refraction regardless of how light is polarized. That bends light from the letters and make them appear to be at some height other than the actual page.

The calcite crystal has two different indices of refraction (birefringence)—one for light waves polarized one way, and another for light waves polarized the other way.

Test that yourself by putting one polarizer above the calcite and rotating the polarizer.



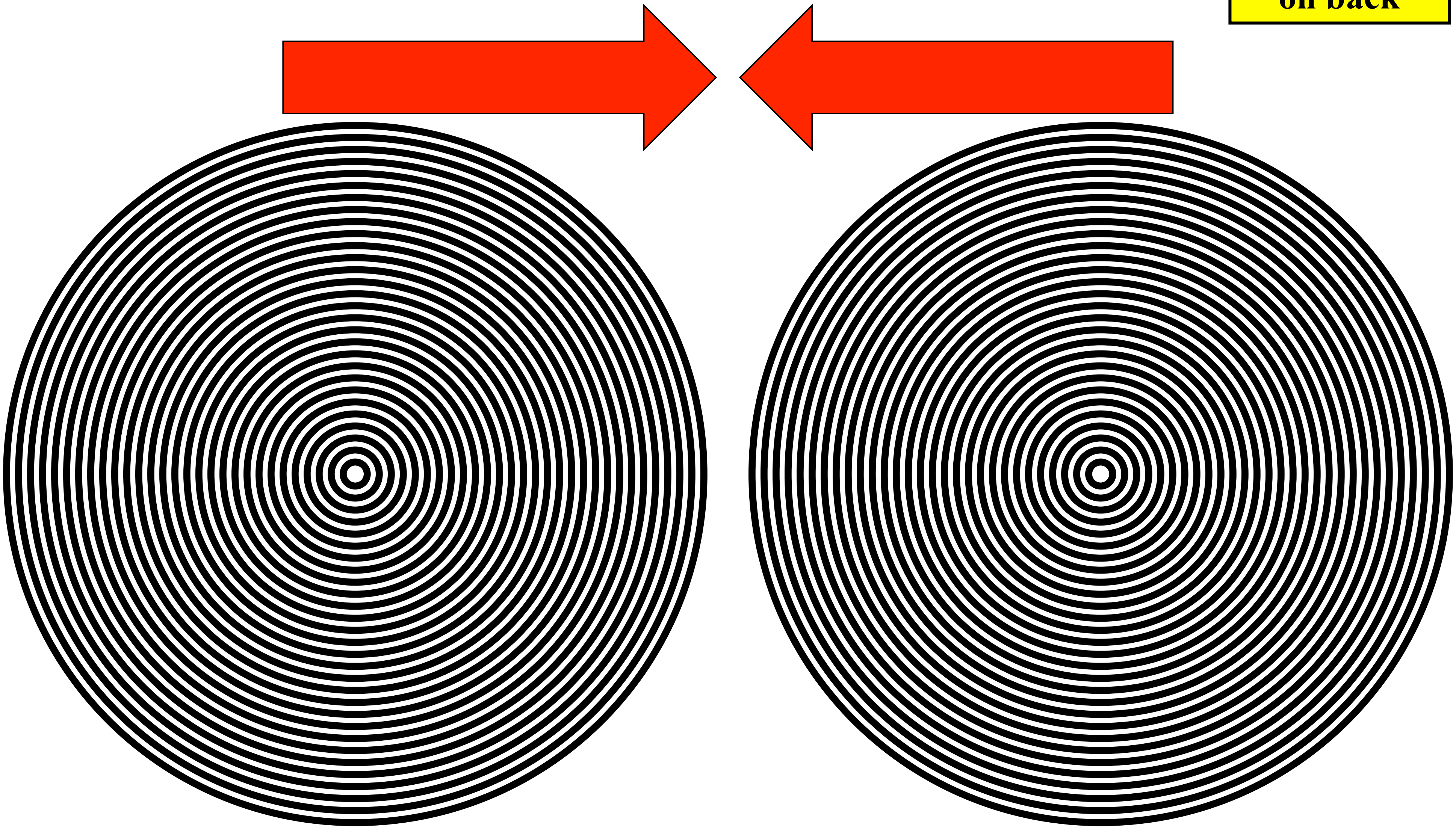
Why Is It Important?

Birefringence can be useful for:

- Liquid crystal displays for electronic devices
- Polarized microscopes
- Visualizing stress in materials

Interference (Front)

Explanation on back



Overlap two transparencies that have concentric circles. Slowly slide one transparency past the other. What happens?

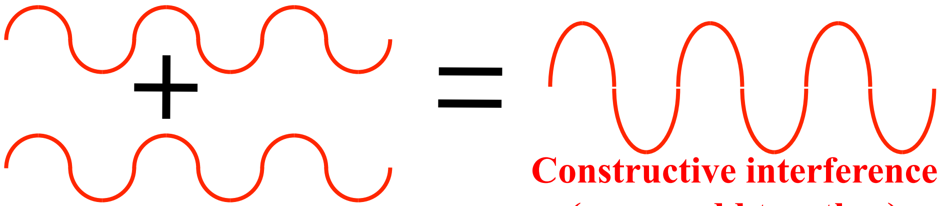
How does the position of the transparencies affect what you see?

Why does this effect happen?

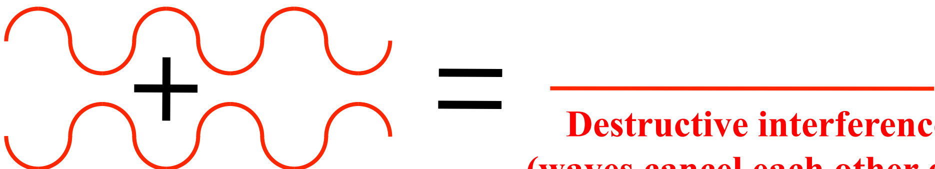
Interference (Back)

Questions on front

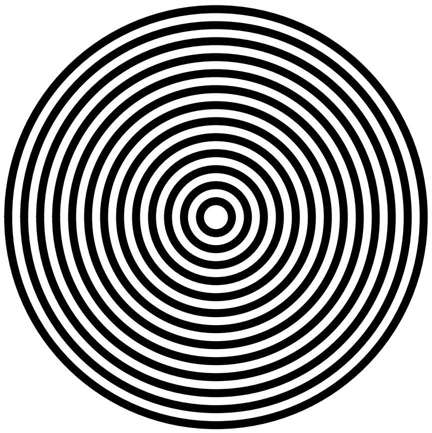
How Does It Work?



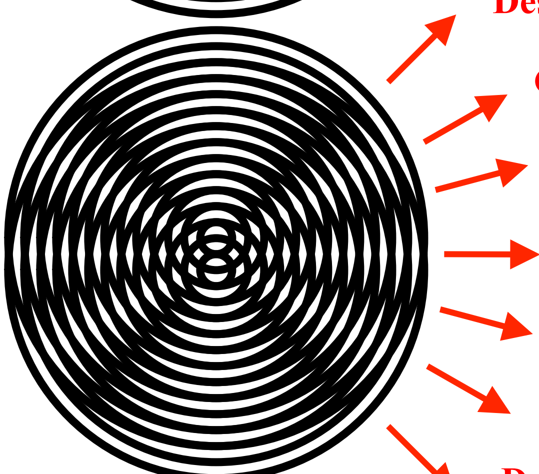
Constructive interference
(waves add together)



Destructive interference
(waves cancel each other out)



Overlapping two sets of concentric circles creates a Moiré pattern of interference



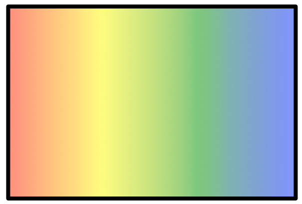
Why Is It Important?

Constructive and destructive interference can be used to direct radar beams, laser beams, or sound waves in particular directions but not in others.

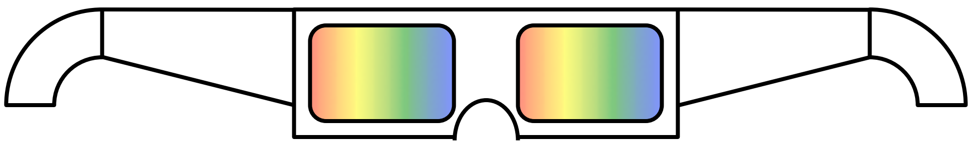
Diffraction (Front)

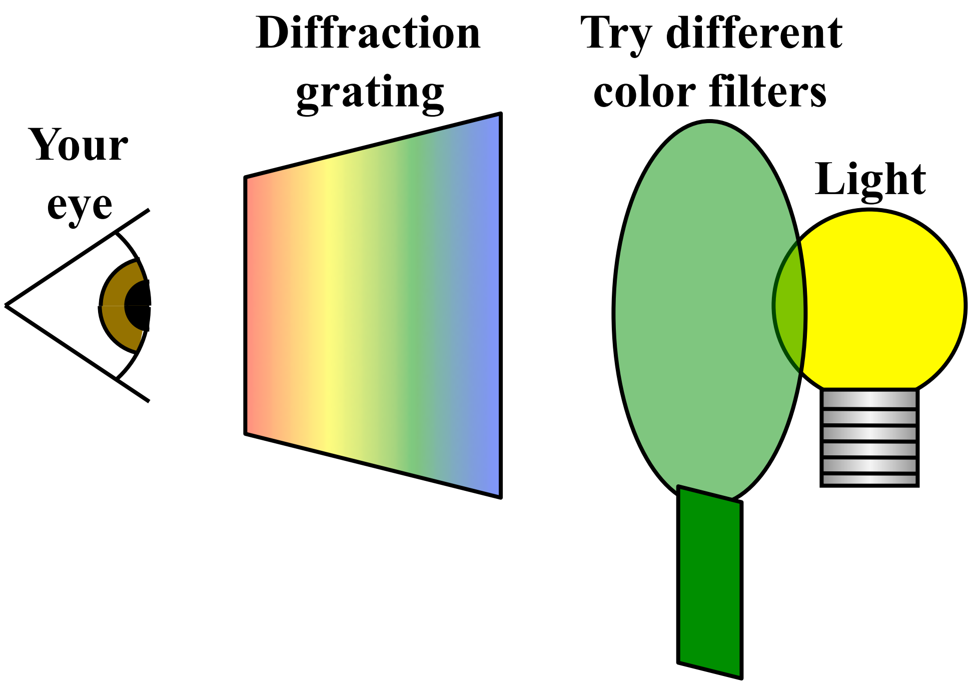
Explanation on back

Diffraction grating



Rainbow glasses





Do not look at the sun, bright flashlight bulbs, or other bright lights, either with or without a diffraction grating!

A diffraction grating looks like clear plastic, but makes you see rainbows if you look through it. Try it! Why does it work?

Try the rainbow glasses. How are they similar to or different from the single diffraction grating?

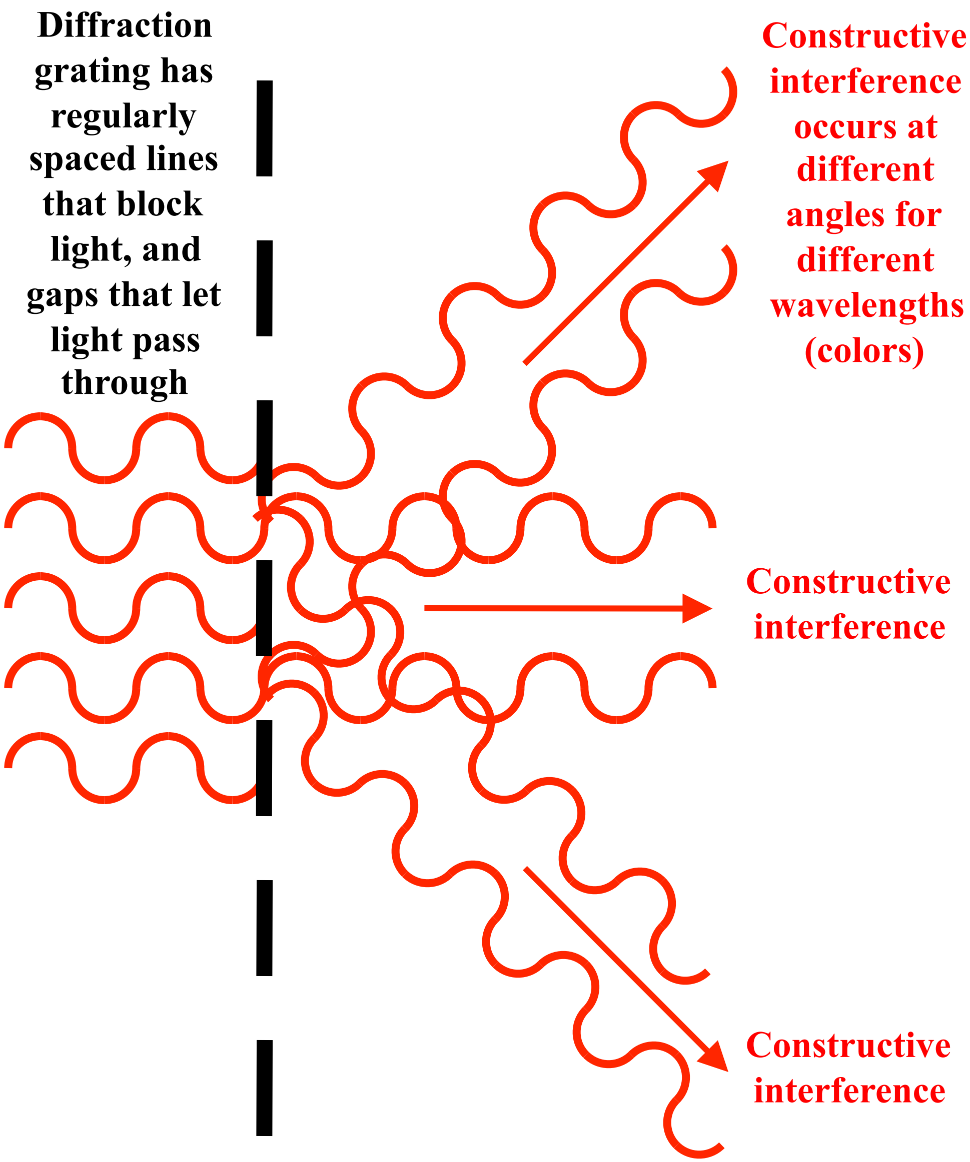
Use the diffraction grating or the rainbow glasses to examine light from different sources. Sources that emit white light produce all the colors. Other sources may only produce one or a few colors. Try different color filters together with the diffraction grating.

Use the rainbow glasses to examine or make a drawing with different colors.

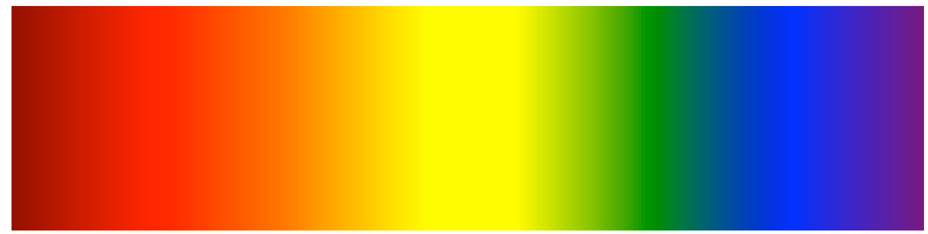
Diffraction (Back)

Questions on front

How Does It Work?



Why Is It Important?



A diffraction grating can separate light into its component colors like a glass prism, but it is cheaper and lighter.

Different substances absorb or emit different wavelengths (colors), so a diffraction grating can be used to identify substances, even in distant stars.

The regularly spaced lines in a diffraction grating form a simple rainbow, but the more complex lines in a holographic film can form the image of a whole object. (See the hologram security seals.)