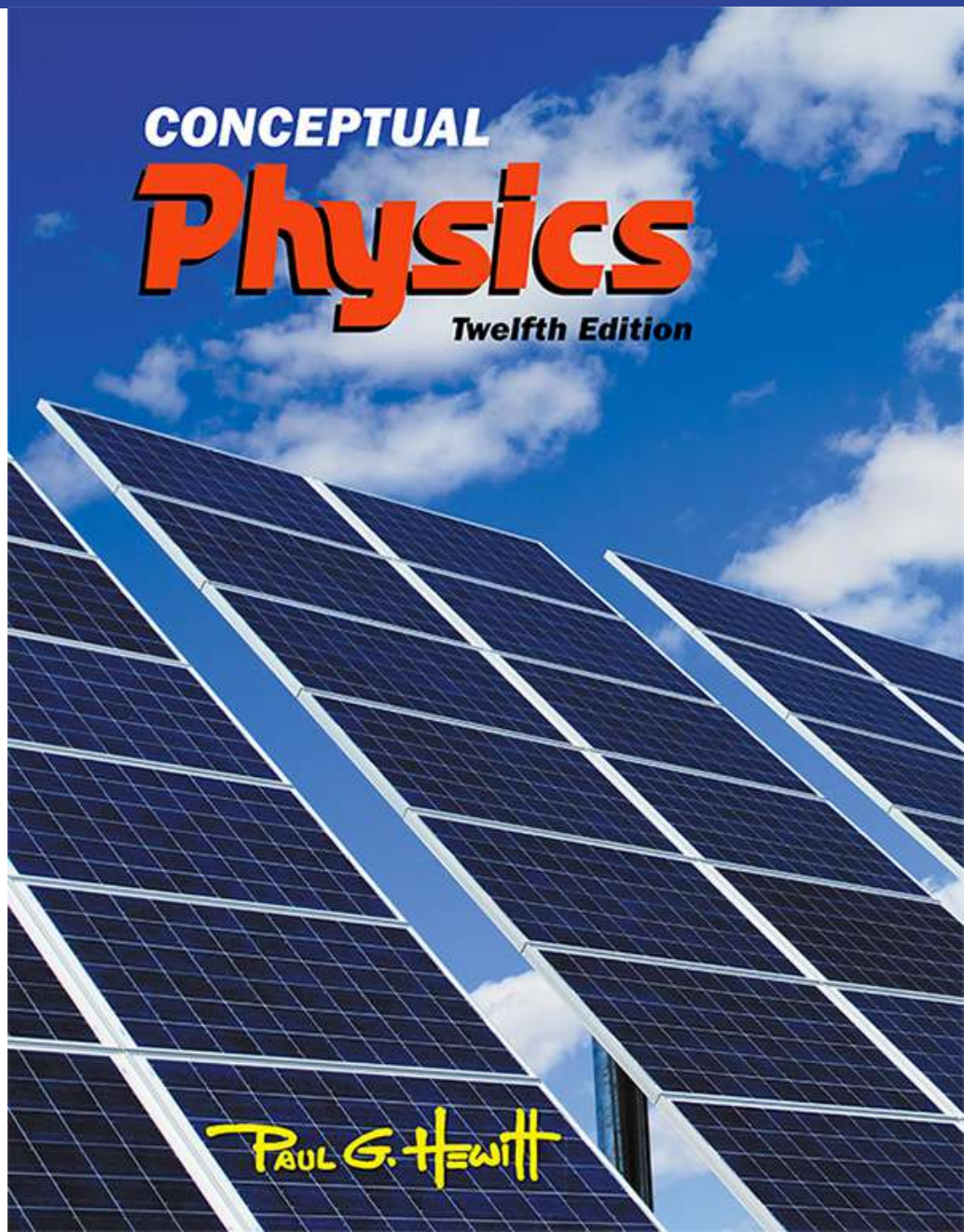
Lecture Outline

Chapter 28: Reflection and Refraction



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This lecture will help you understand:

- Reflection
- Principle of Least Time
- Law of Reflection
- Refraction
- Cause of Refraction
- Dispersion
- Rainbows
- Total Internal Reflection
- Lenses
- Lens Defects

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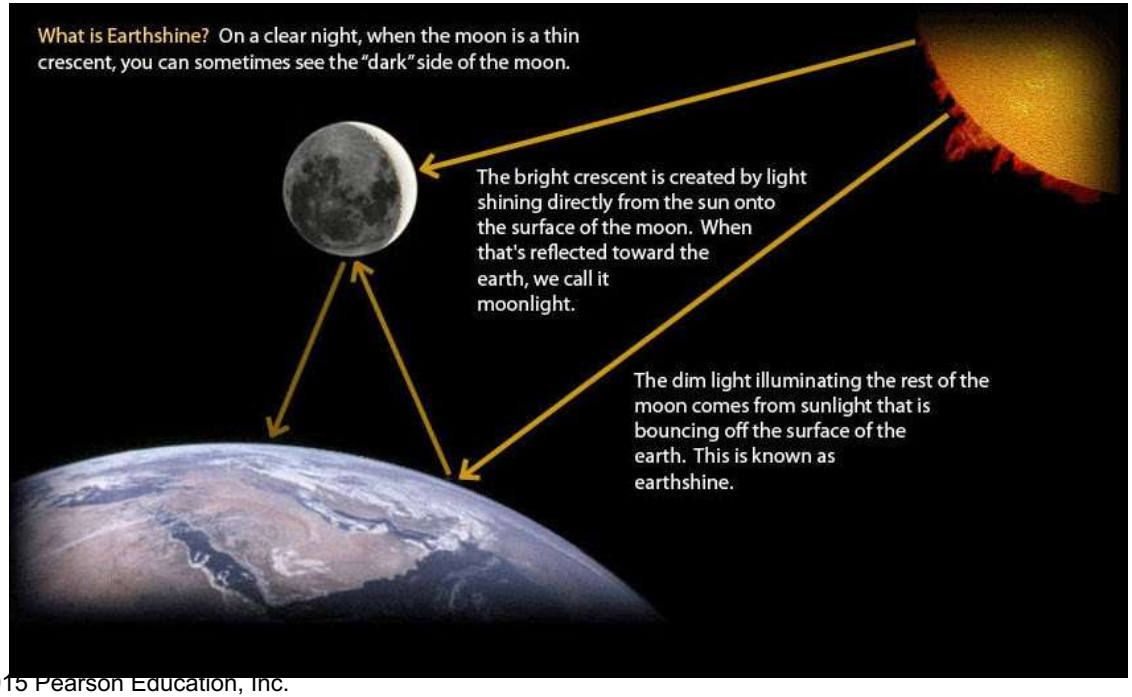
Earthshine:

During a crescent moon, light reflected from Earth lights up the rest of the Moon. This is called *earthshine*.



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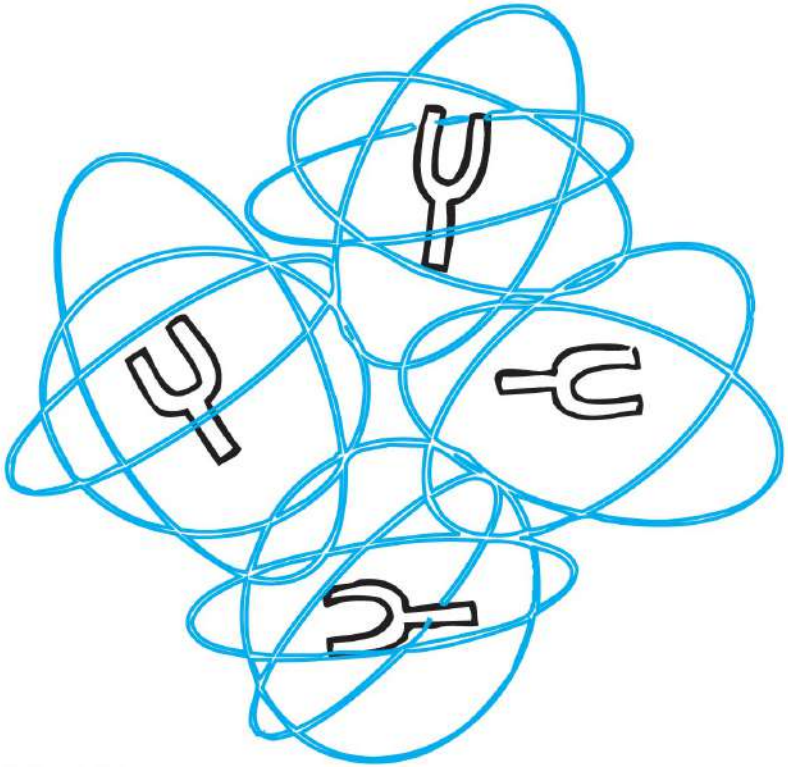
Reflection

- We say light is *reflected* when it is returned into the medium from which it came—the process is **reflection.**
- When light illuminates a material, electrons in the atoms of the material move more energetically in response to the oscillating electric fields of the illuminating light.
- The energized electrons re-emit the light by which you see the material.



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Principle of Least Time

- The idea that light takes the quickest path in going from one place to another is called **Fermat's principle of least time.**

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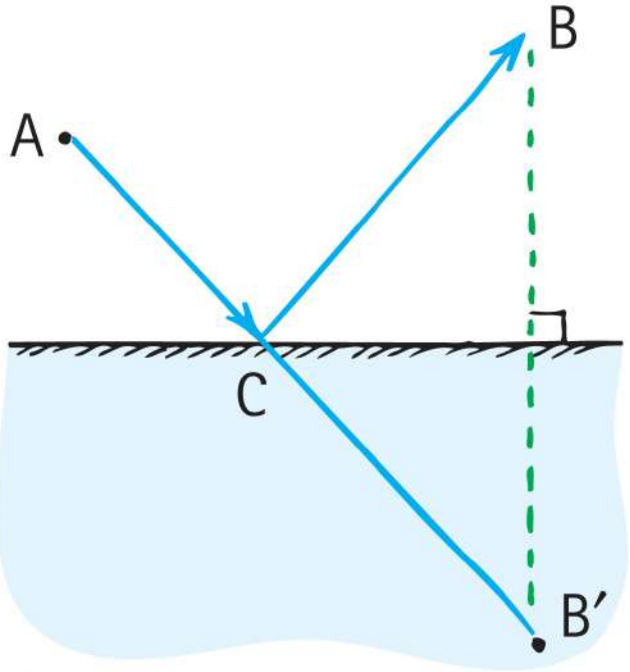
Principle of Least Time, Continued

- Finding the shortest time for light to go from A to B by reflecting off the mirror
- Construct, on the opposite side of the mirror, an artificial point, which is the same distance "through" and below the mirror as the point B is above the mirror.
- The shortest distance between A and this artificial point is a straight line.
- This straight line intersects the mirror at a point C, the precise point of reflection for least time from A to B.



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Law of Reflection

- Angle of incidence
  - Angle made by the incoming ray and the perpendicular
- Angle of reflection
  - Angle made by the reflected ray and the perpendicular
- Normal
  - Imaginary line perpendicular to the plane of the reflecting surface
  - Lies in the same plane as the incident and reflected rays

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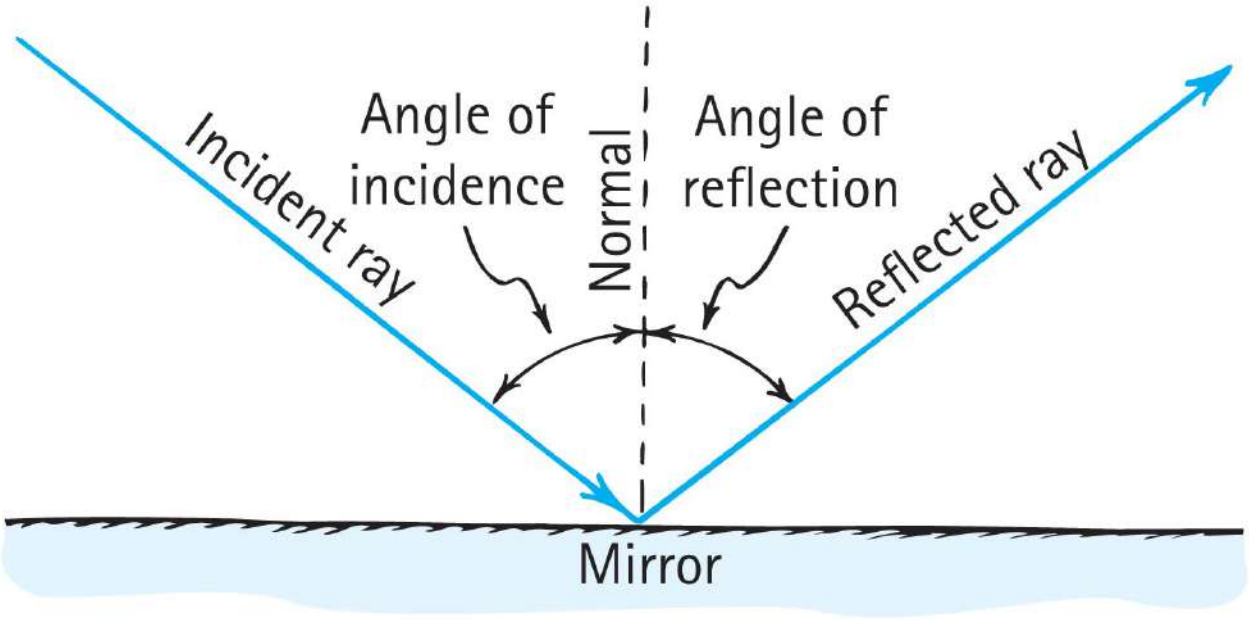
Law of Reflection, Continued

- Law of reflection
  - The angle of reflection equals the angle of incidence.



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Law of Reflection
CHECK YOUR NEIGHBOR

The law of reflection applies to

A. light.
B. sound.
C. Both A and B.
D. None of the above.

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Law of Reflection
CHECK YOUR ANSWER

The law of reflection applies to

C. Both A and B.

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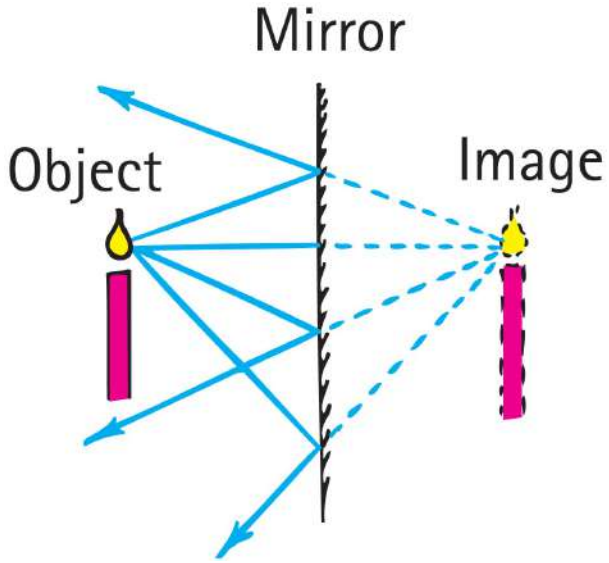
Law of Reflection, Continued-1

- Virtual image
  - is same size as object, formed behind a mirror, and located at the position where the extended reflected rays converge.
  - is as far behind the mirror as the object is in front of the mirror.



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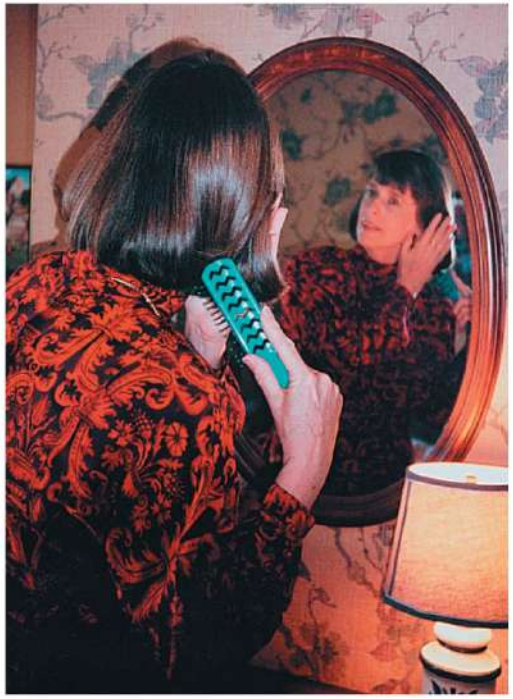
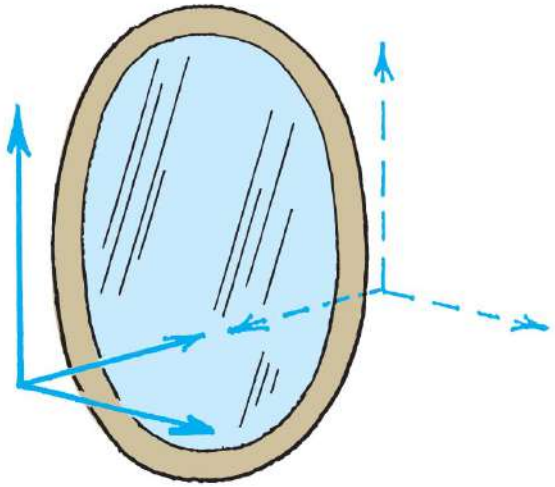
Law of Reflection, Continued-2

- Plane mirror
  - Note: the only axis reversed in an image is the front-back axis.





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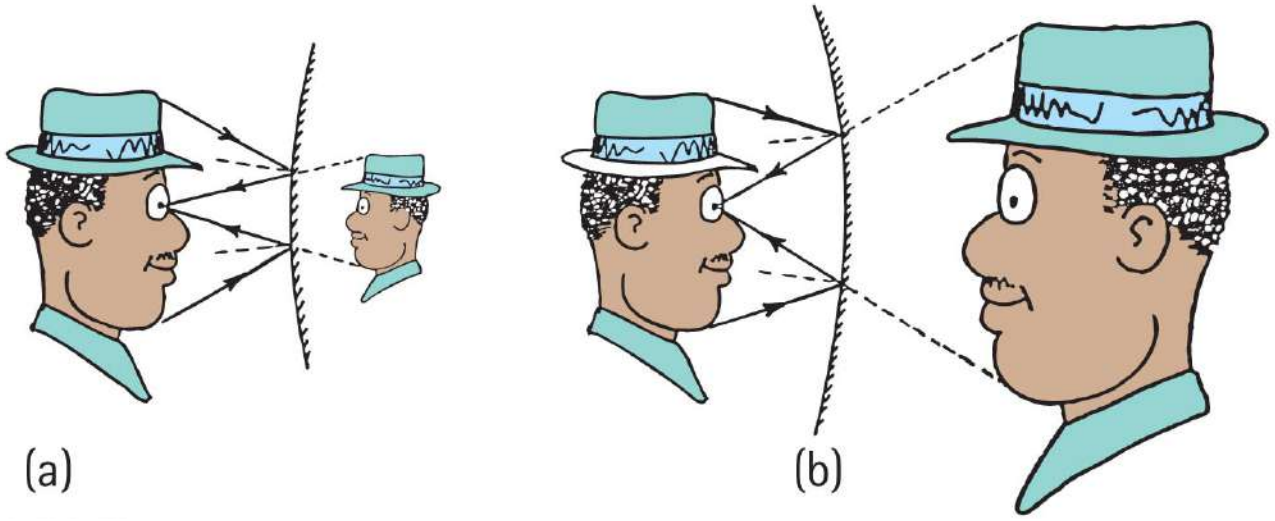
Law of Reflection, Continued-3

- Shape of mirror forms a different virtual image.
  - Convex mirror (that curves outward): virtual image is smaller and closer to the mirror than the object.
  - Concave mirror (that curves inward): virtual image is larger and farther away than the object.



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Law of Reflection
CHECK YOUR NEIGHBOR, Continued

Light reflecting from a smooth surface undergoes a change in

A. frequency.
B. speed.
C. wavelength.
D. None of the above.

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Law of Reflection
CHECK YOUR ANSWER, Continued

Light reflecting from a smooth surface undergoes a change in

D. None of the above.

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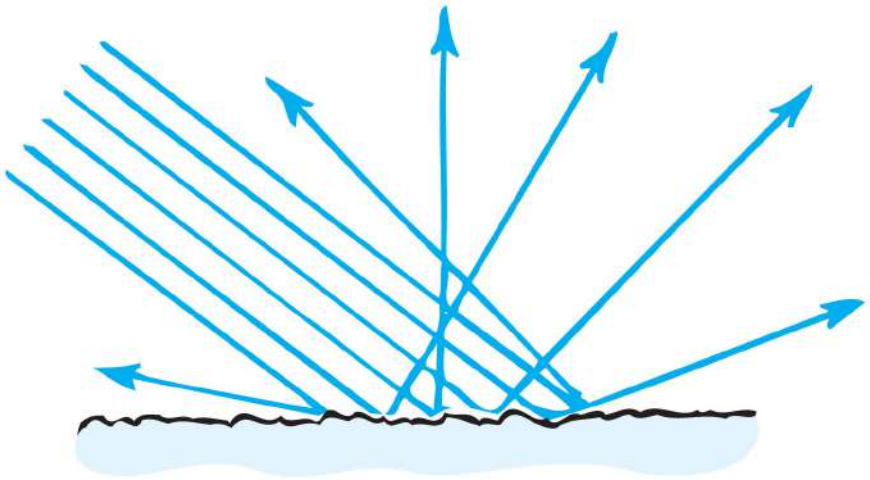
Law of Reflection, Continued-4

- Diffuse reflection
  - When light strikes a rough or irregular surface and reflects in many directions
  - An undesirable circumstance is the ghost image that occurs on a TV set when TV signals bounce off buildings and other obstructions.



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Law of Reflection, Continued-5

- Different road surfaces determine amount of diffuse reflection
  - Rough road surface—because of diffuse reflection, see road ahead of car at night.
  - Wet road surface is smooth—because of less diffuse, reflection, difficult to see.

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Law of Reflection
CHECK YOUR NEIGHBOR, Continued-1

Diffuse reflection occurs when the sizes of surface irregularities are

A. small compared with the wavelength of reflected radiation.
B. large compared with the wavelength of reflected radiation.
C. Both A and B.
D. None of the above.

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Law of Reflection
CHECK YOUR ANSWER, Continued-1

Diffuse reflection occurs when the sizes of surface irregularities are

B. large compared with the wavelength of reflected radiation.

Explanation:

Diffuse reflection occurs for rougher surfaces.

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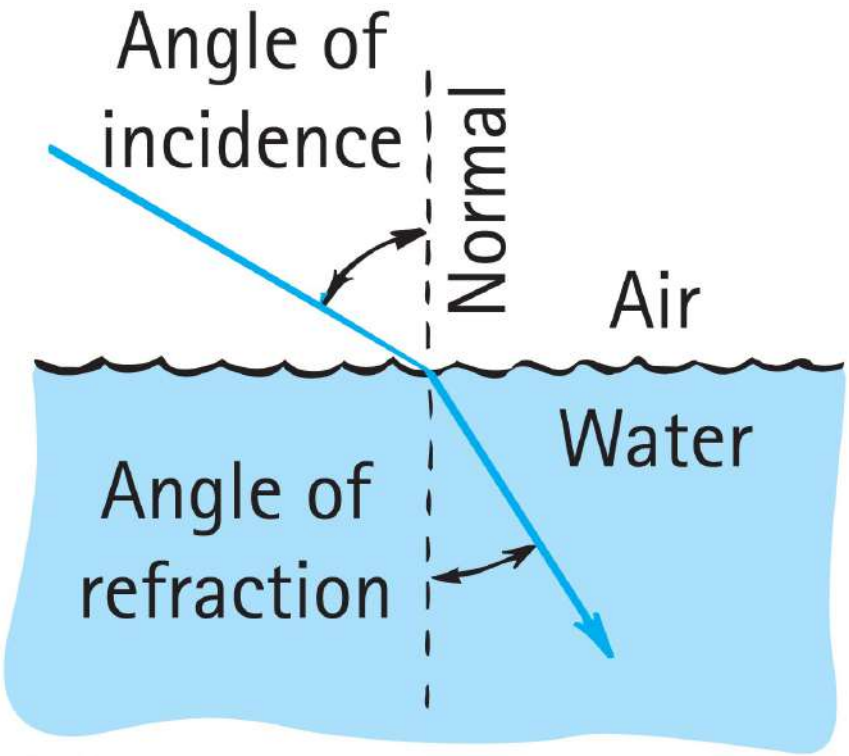
Refraction

- When light bends in going obliquely from one medium to another, we call this process refraction.



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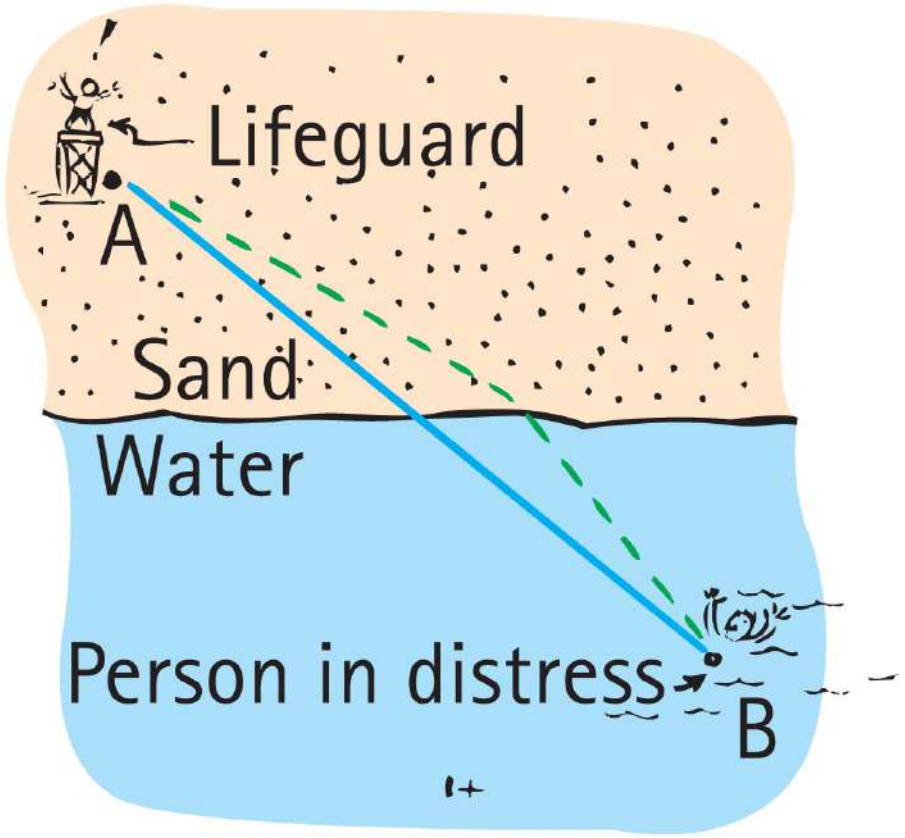
Refraction, Continued

- Refraction occurs to minimize the time taken by light to travel from A to B.

- Just as if you wanted to save someone from drowning, the quickest path would not be a straight line – it would be the dashed path shown.



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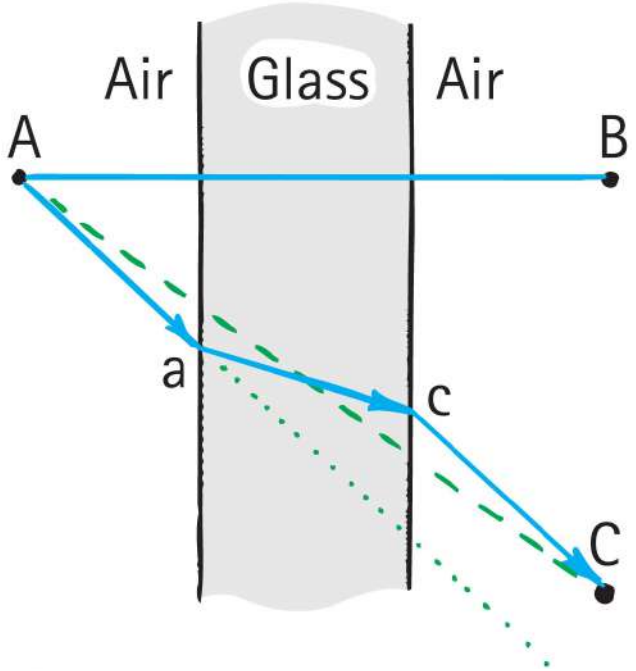
Refraction, Continued-1

- Light follows a less inclined path in the glass.
  - Light travels slower in glass than in air, so it minimizes the time it spends in the glass.



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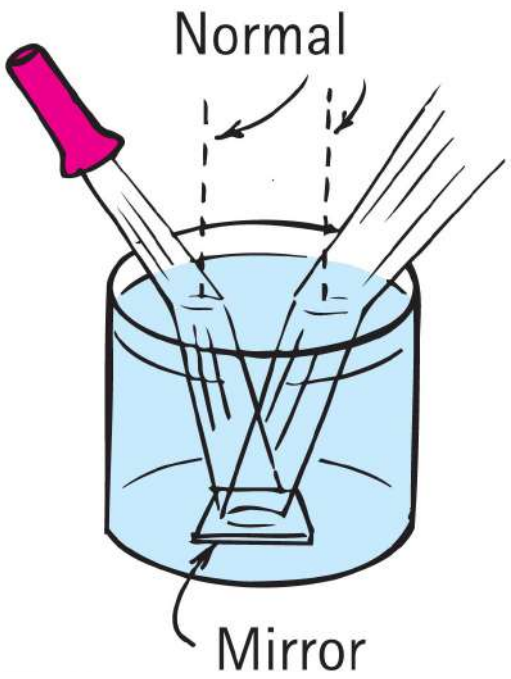
Refraction, Continued-2

- Light rays pass from air into water and water into air.
  - Pathways are reversible for both reflection and refraction.



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Refraction, Continued-3

- Refractive index:
- Index of refraction, *n*, of a material
  - indicates how much the speed of light differs from its speed in a vacuum.
  - indicates the extent of bending of rays.
  - ratio of speed of light in a vacuum to the speed in a material.

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Refraction, Continued-4

- Refractive index (continued):
  - In equation form:

$$n = \frac{\text{speed of light in vacuum}}{\text{speed of light in material}}$$

  - Medium with a high index means high bending effect and greatest slowing of light.

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Refraction
CHECK YOUR NEIGHBOR

Refracted light that bends toward the normal is light that has

A. slowed down.
B. sped up.
C. nearly been absorbed.
D. diffracted.

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Refraction
CHECK YOUR ANSWER

Refracted light that bends toward the normal is light that has

A. slowed down.

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Refraction
CHECK YOUR NEIGHBOR, Continued

Refracted light that bends away from the normal is light that has

A. slowed down.
B. sped up.
C. nearly been absorbed.
D. diffracted.

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Refraction
CHECK YOUR ANSWER, Continued

Refracted light that bends away from the normal is light that has

B. sped up.

Explanation:

This question is a consistency check with the question that asks about light bending toward the normal when slowing.

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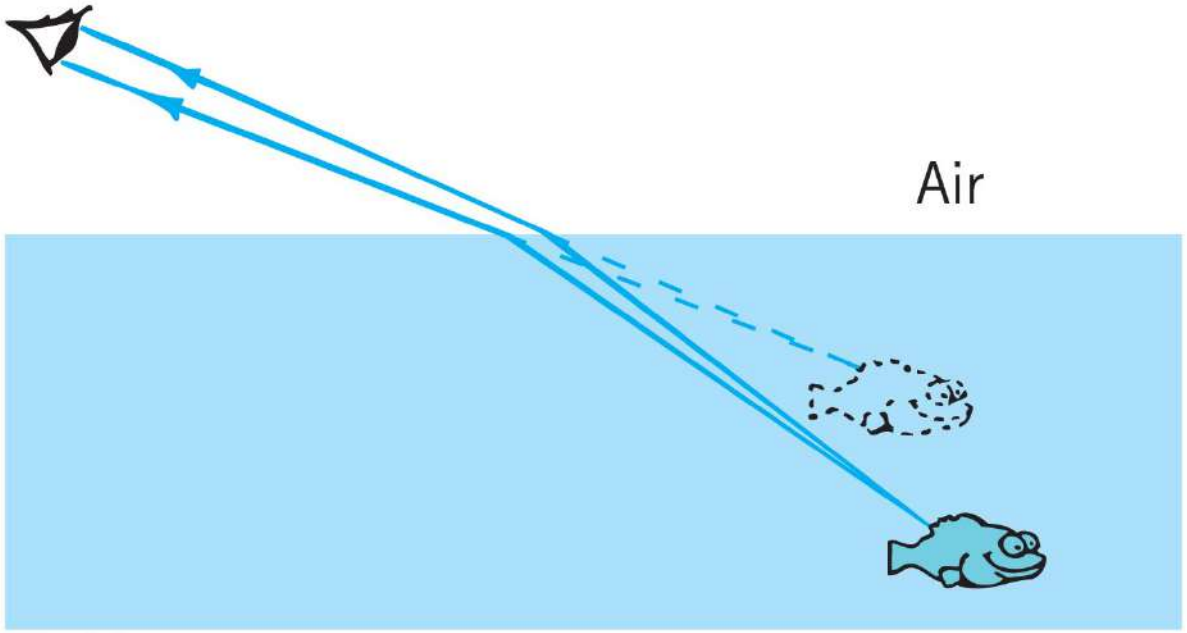
Refraction, Continued-5

- Illusions caused by refraction



  - Objects submerged in water appear closer to the surface.

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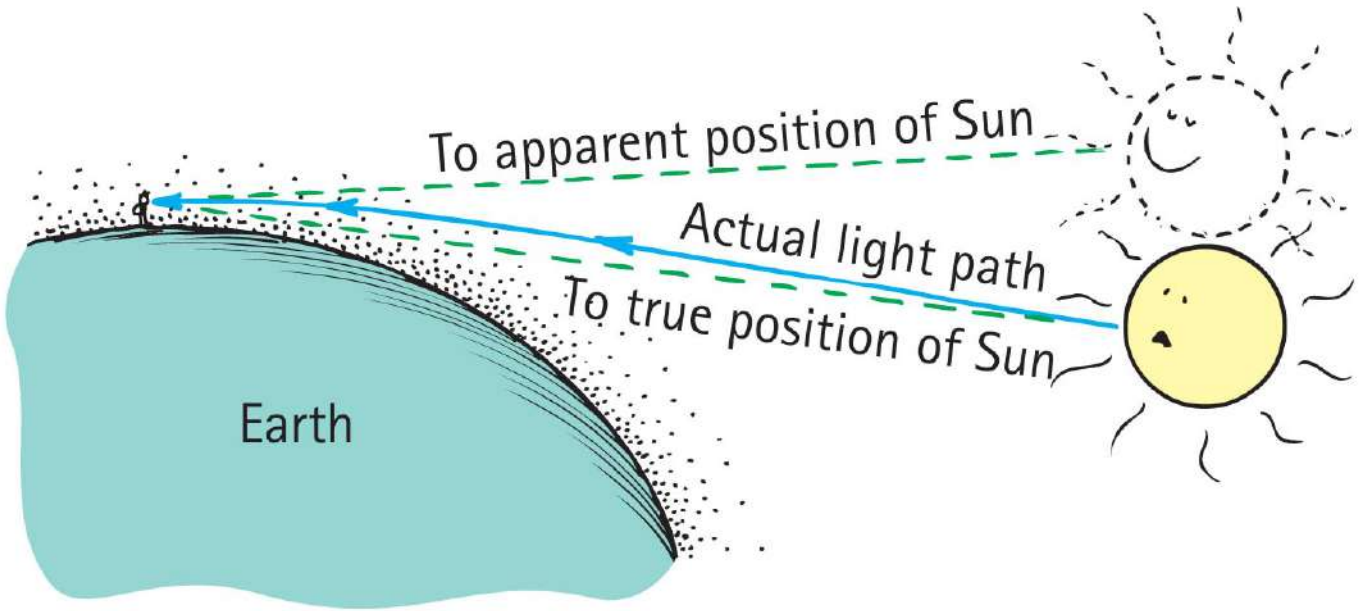
Refraction, Continued-6

- Illusions caused by refraction (continued)



  - Objects such as the Sun seen through air are displaced because of atmospheric refraction.

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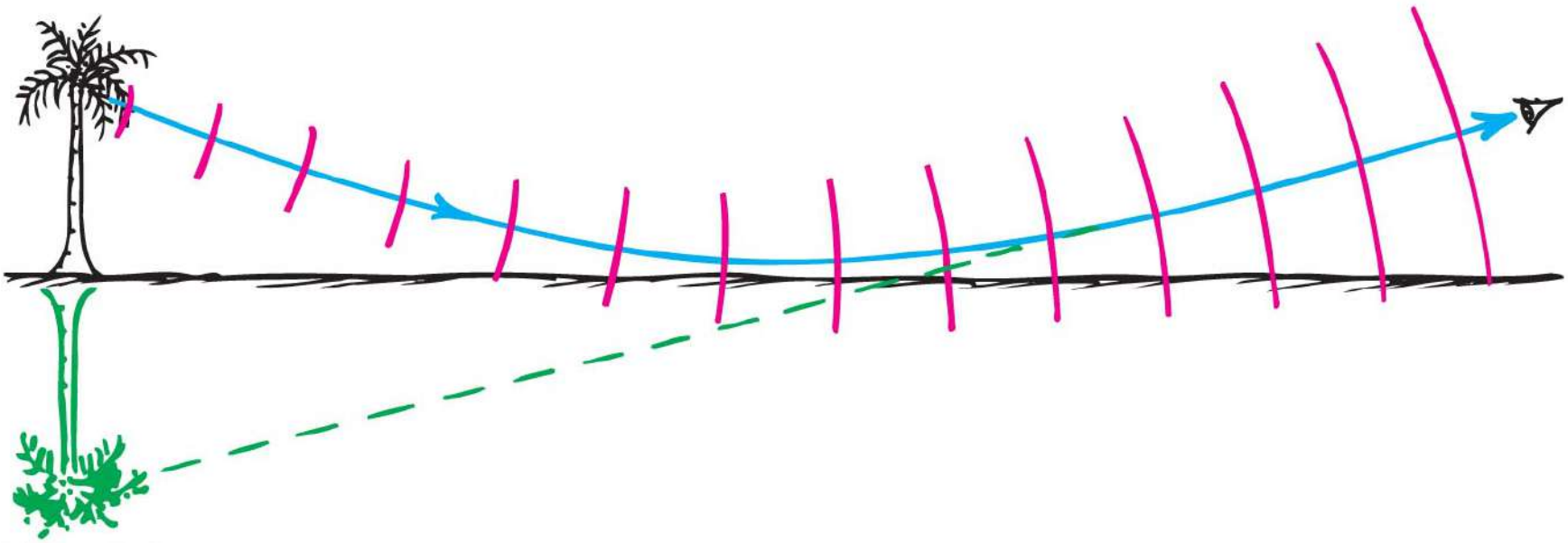
Refraction, Continued-7

- Illusions caused by refraction (continued)



  - Atmospheric refraction is the cause of mirages.

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Refraction
CHECK YOUR NEIGHBOR, Continued-1

When light travels from one medium to another and changes speed in doing so, we call the process

A. reflection.
B. interference.
C. dispersion.
D. refraction.

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Refraction
CHECK YOUR ANSWER, Continued-1

When light travels from one medium to another and changes speed in doing so, we call the process

D. refraction.

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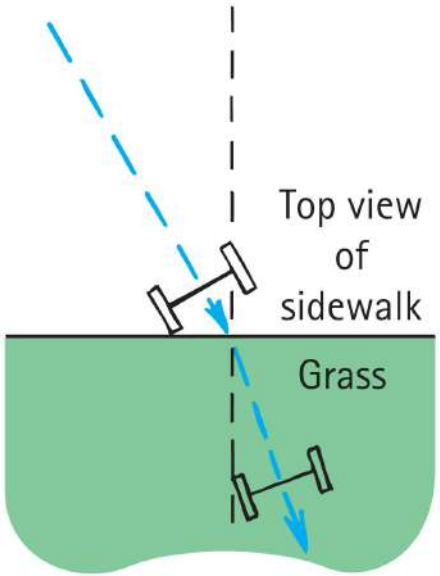
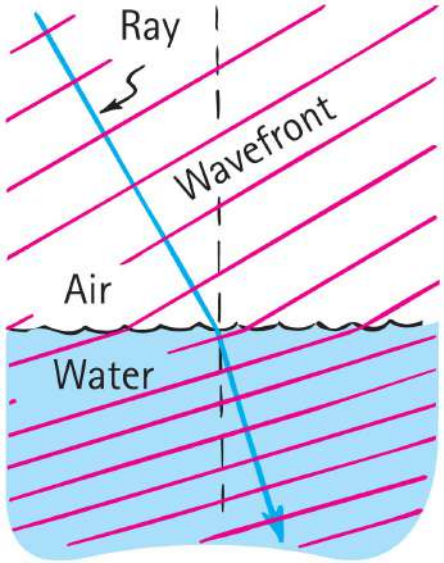
Cause of Refraction

- Refraction
  - Bending of light when it passes from one medium to another
  - Caused by change in speed of light





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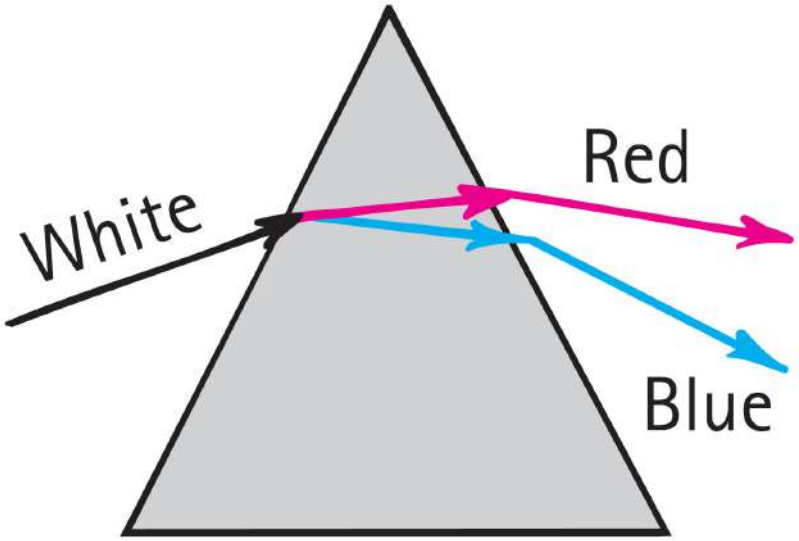
Dispersion

- Dispersion
  - Process of separation of light into colors arranged by frequency



  - Components of white light are dispersed in a prism (and in a diffraction grating).

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Dispersion
CHECK YOUR NEIGHBOR

When white light passes through a prism, green light is bent more than

A. blue light.
B. violet light.
C. red light.
D. None of the above.

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Dispersion
CHECK YOUR ANSWER

When white light passes through a prism, green light is bent more than

C. red light.

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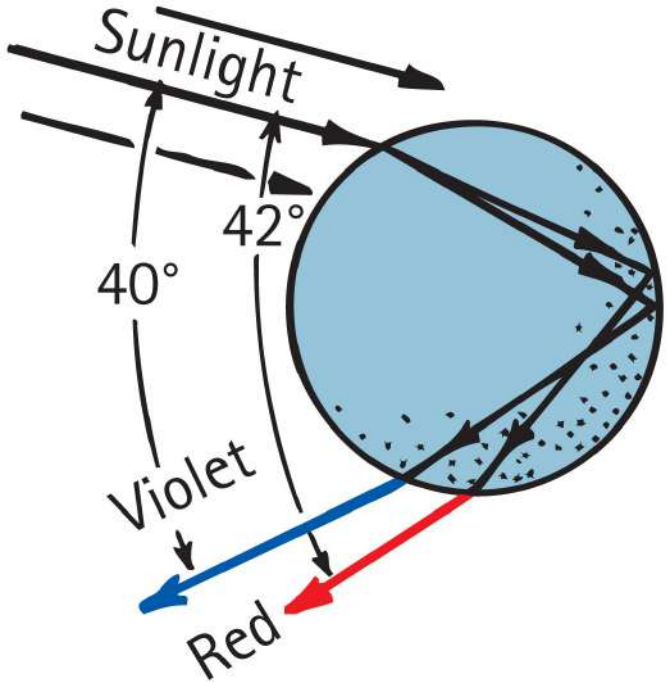
Rainbows

- Rainbows are a result of dispersion by many drops.
  - Dispersion of light by a single drop



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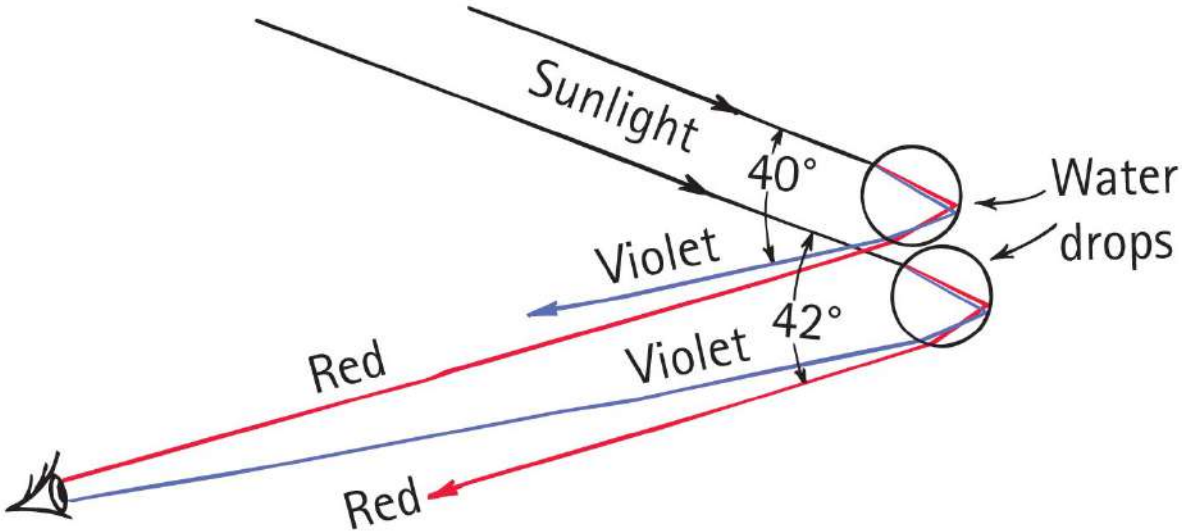
Rainbows, Continued

- Sunlight incident on two sample raindrops, as shown, emerges from them as dispersed light.
- The observer sees the red light from the upper drop and the violet light from the lower drop.
- Millions of drops produce the whole spectrum of visible light.



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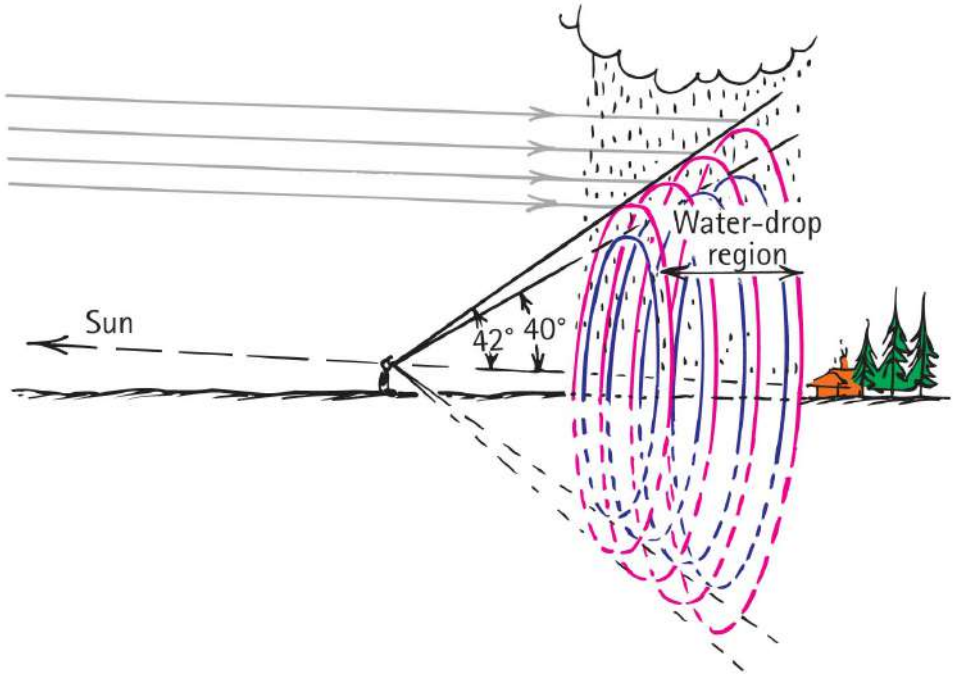
Rainbows, Continued-1

- When your eye is located between the Sun (not shown off to the left) and a water drop region, the rainbow you see is the edge of a three-dimensional cone that extends through the water drop region.



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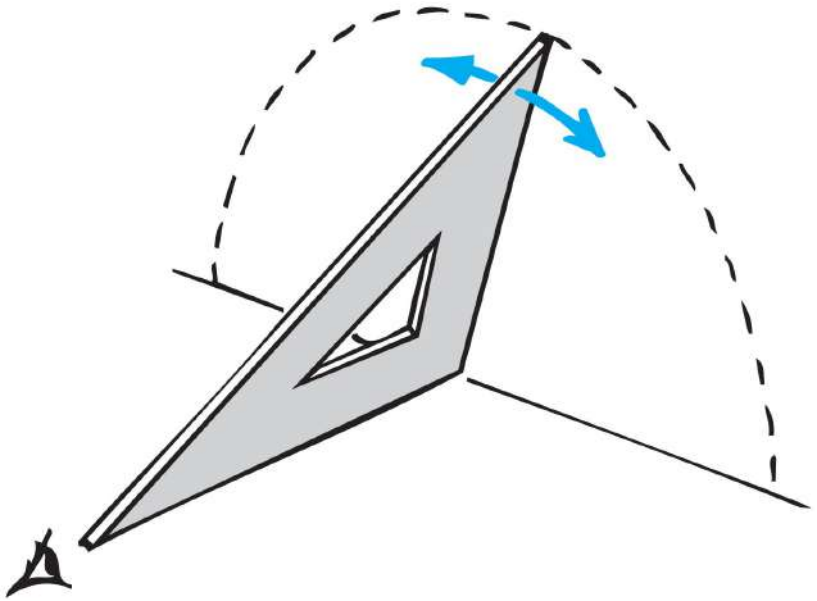
Rainbows, Continued-2

- All the drops that disperse the rainbow's light toward *you* lie in the shape of a cone—a cone of different layers with drops that disperse red to your eye on the outside, orange beneath the red, yellow beneath the orange, and so on, all the way to violet on the inner conical surface.
- The thicker the region containing water drops, the thicker the conical edge you look through, and the more vivid the rainbow.
- Only raindrops along the dashed line disperse red light to the observer at an angle; hence, the light forms a bow.



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Rainbows, Continued-3

- Rainbow facts
  - An observer is in a position to see only a single color from any one droplet of water.
  - Your rainbow is slightly different from the rainbow seen by others.
  - Your rainbow moves with you.
  - Disk within the bow is brighter because of overlapping of multiple refractions (which don't occur outside the disk).

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Rainbows, Continued-4

- Rainbow facts (continued)
  - Secondary rainbow is fainter (due to two internal reflections and refracted light loss).
  - Secondary bow is reversed in color (due to the extra internal reflection).

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Rainbows
CHECK YOUR NEIGHBOR

Compared with the primary rainbow, the secondary bow

A. is dimmer.
B. has colors reversed.
C. is caused by two internal reflections.
D. All of the above.

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Rainbows
CHECK YOUR ANSWER

Compared with the primary rainbow, the secondary bow

D. All of the above.

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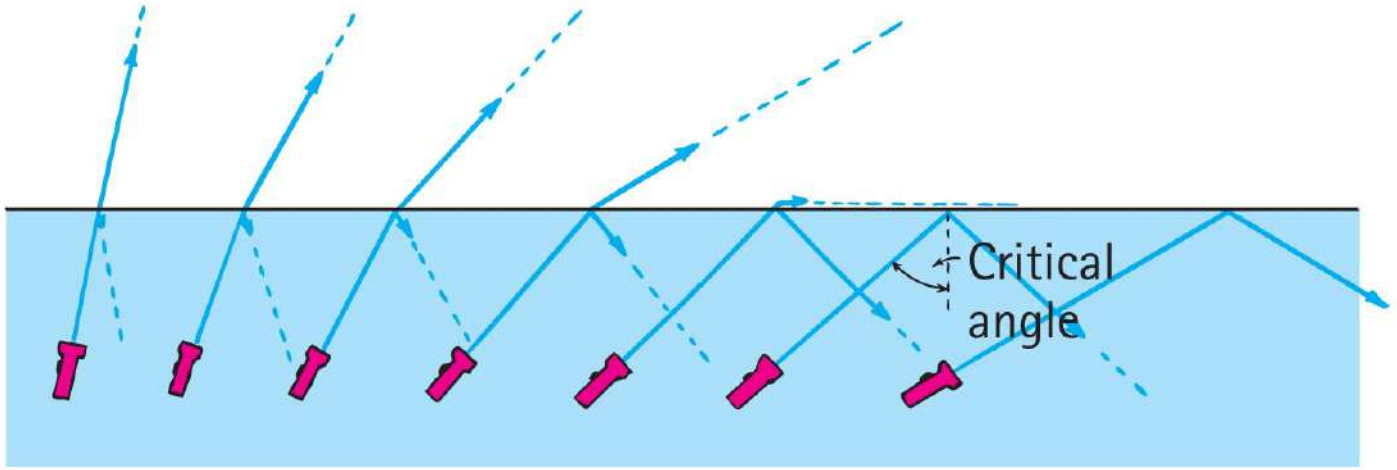
Total Internal Reflection

- Total internal reflection
  - Total reflection of light traveling within a medium that strikes the boundary of another medium at an angle at, or greater than, the critical angle



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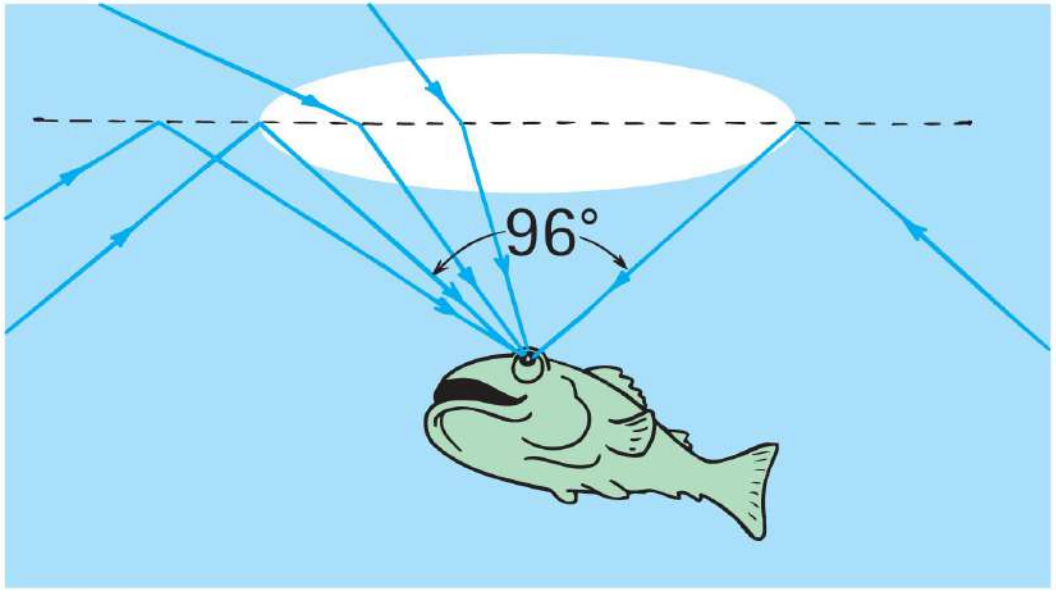
Total Internal Reflection, Continued

- Critical angle
  - Minimum angle at which beam of light no longer emerges into the air above the surface; varies for different materials



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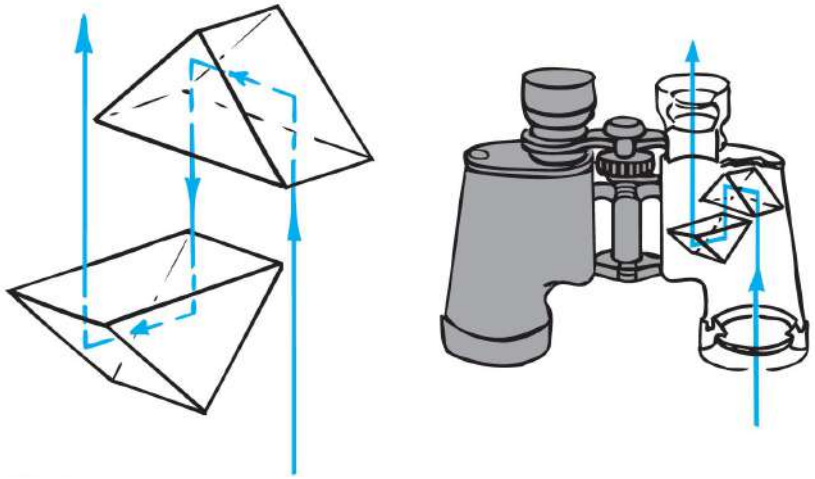
Total Internal Reflection, Continued-1

- Advantages of glass prisms
  - Internally reflect 100%, which is the principal reason for use in many optical instruments
  - Lengthen the light path between lenses, thus eliminating the need for long barrels in binoculars
  - Reflection by prisms reinverts the image in binoculars



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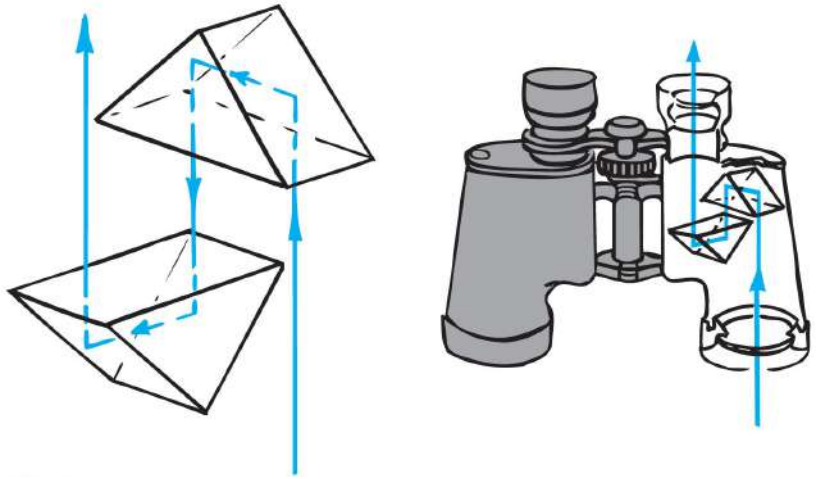
Total Internal Reflection, Continued-2

- Optical fibers or light pipes
  - Thin, flexible rods of special glass or transparent plastic.
  - Light from one end of the fiber is total internally reflected to the other end, resulting in nearly the same brightness of light.



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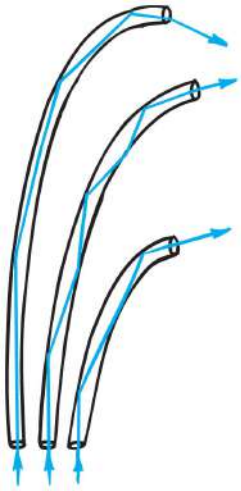
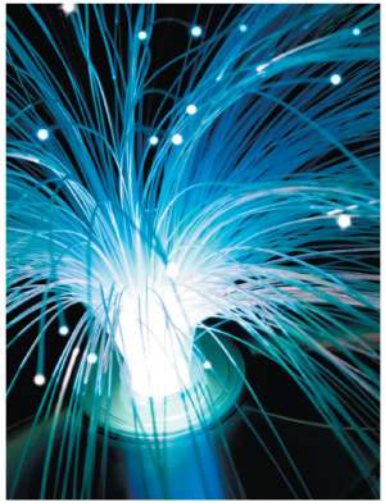
Total Internal Reflection, Continued-3

- Optical fibers or light pipes (continued)
  - Used in
    - illuminating instrument displays
    - concentrating light in dental procedures
    - viewing of inaccessible regions of organs and other devices
    - communications





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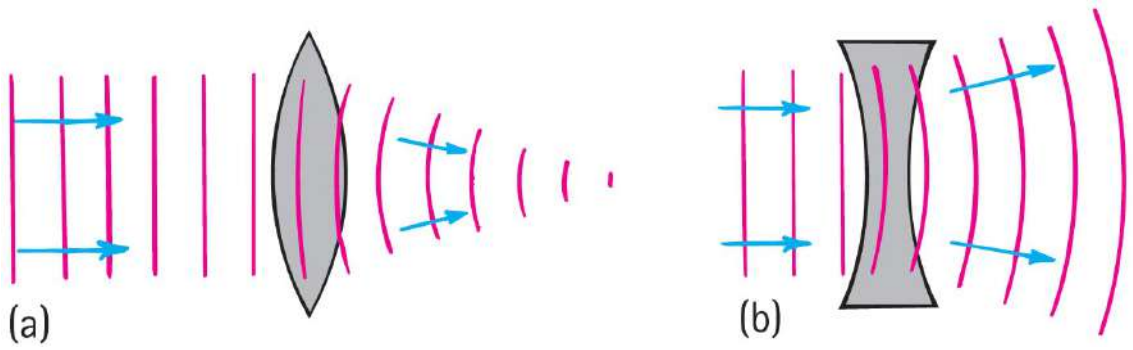
Lenses

- Lenses
  - Two common types:
    - Converging (convex) lens
      - thicker at the center than edges
      - converges light
    - Diverging (concave) lens
      - thinner at the center than edges
      - diverges light



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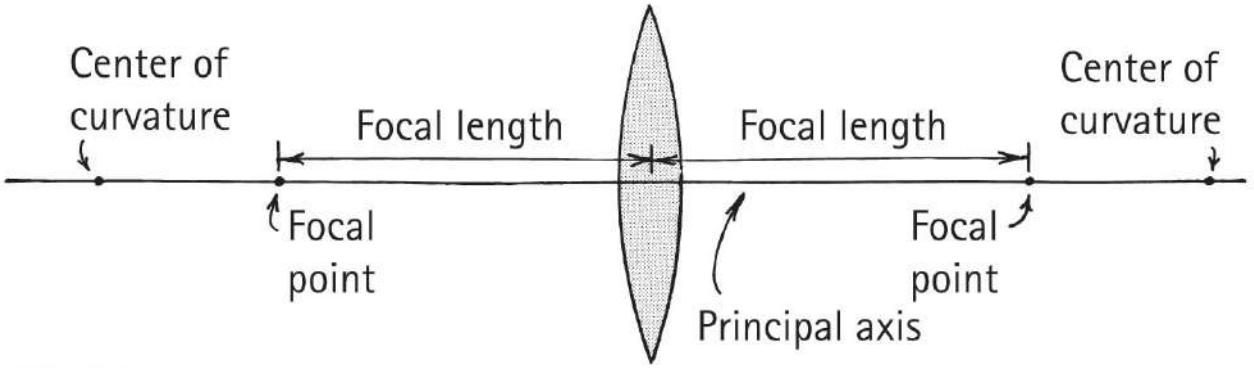
Lenses, Continued

- Key features of lenses
  - Principal axis
    - line joining the centers of curvature of the two lens surfaces
  - Focal point
    - point at which all the light rays come together
  - Focal length
    - distance between the center of the lens and either focal point



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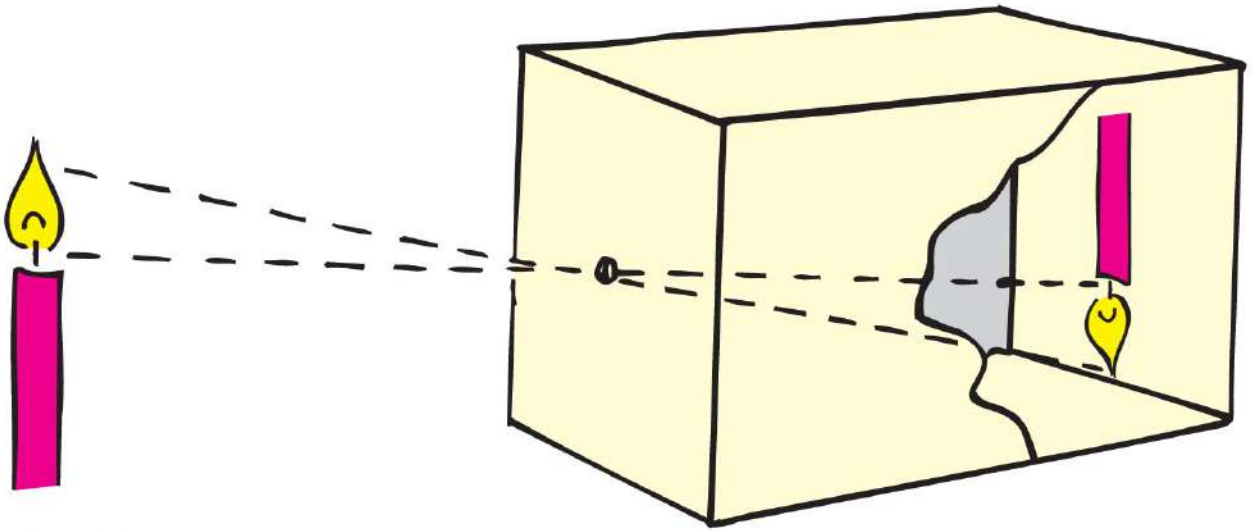
Lenses, Continued-1

- Image formation is a consequence of light traveling in straight lines.



- The first camera—the pinhole camera—illustrates this fact.

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Lenses, Continued-2

- Pinhole images are caused by small openings in the leaves above.

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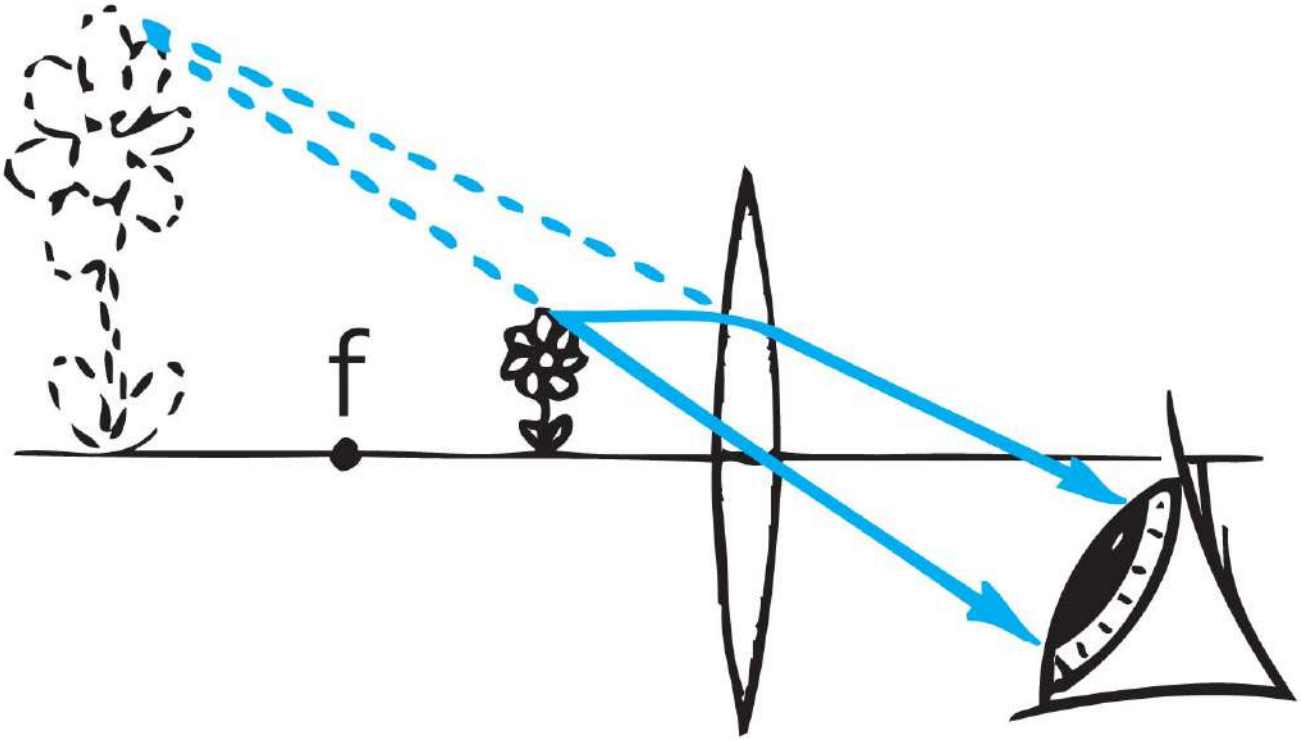
Lenses, Continued-3

- A lens nicely bends the straight-line paths of light.



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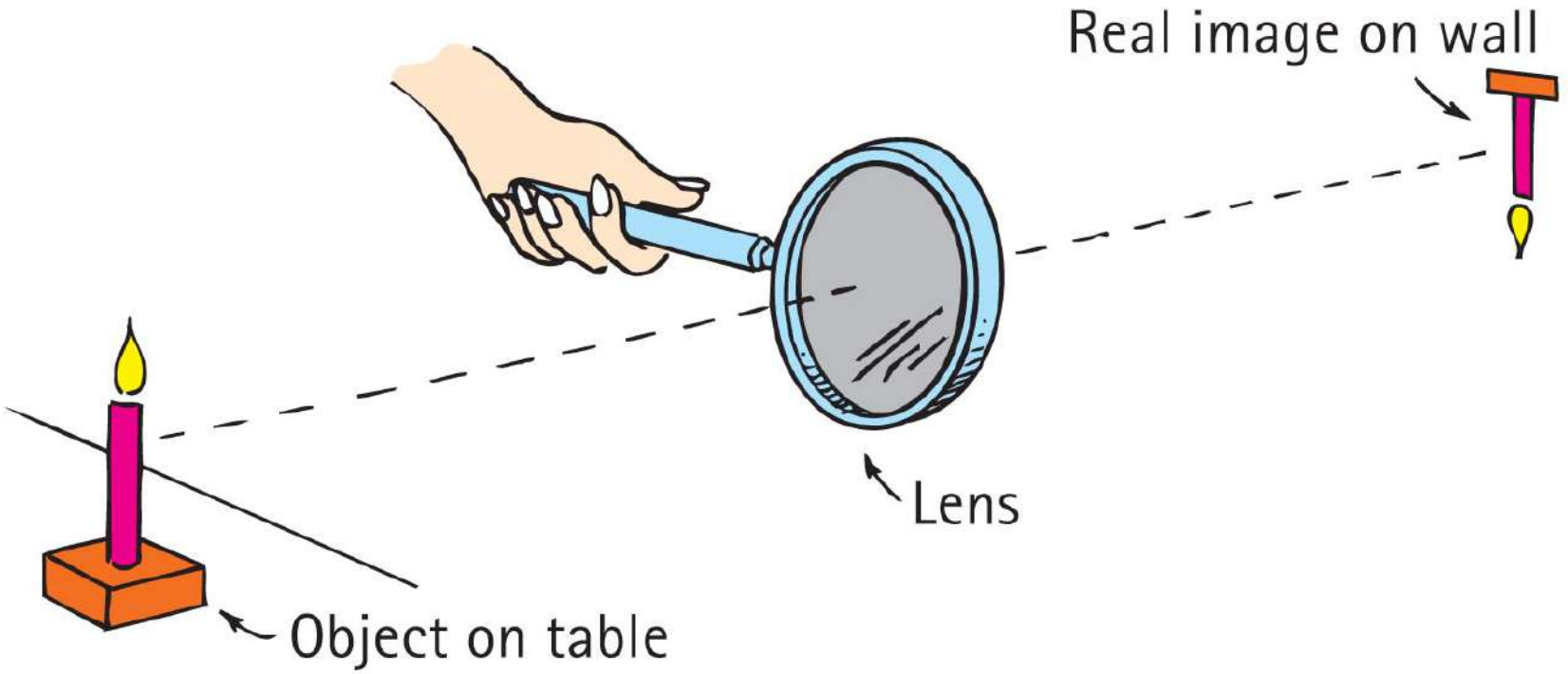
Lenses, Continued-4

- A converging lens can project an image.



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Lenses
CHECK YOUR NEIGHBOR

The action of lenses depends mainly on

A. reflection.
B. refraction.
C. Both A and B.
D. Neither A nor B.

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Lenses
CHECK YOUR ANSWER

The action of lenses depends mainly on

B. refraction.

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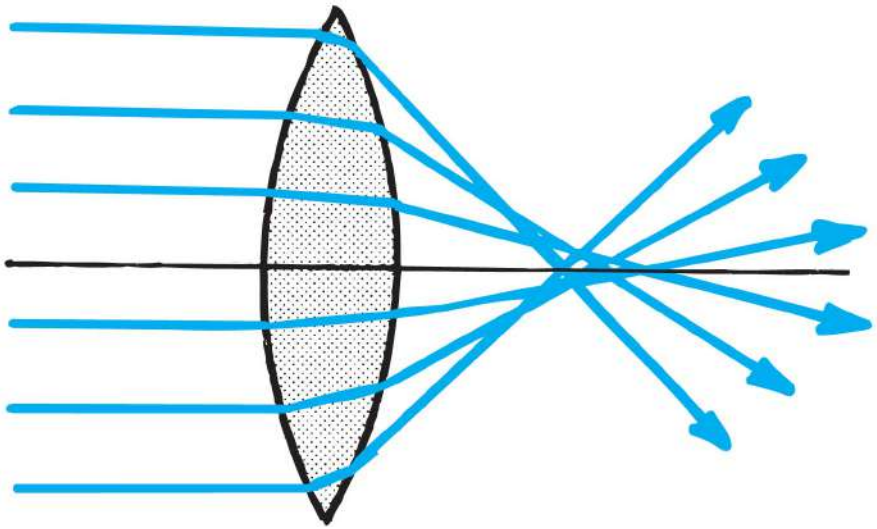
Lens Defects

- Aberration
  - distortion in an image
  - types of aberrations
    - Spherical aberration
      - result of light passing through the edges of a lens and focusing at a slightly different place from where light passing through the center of the lens focuses



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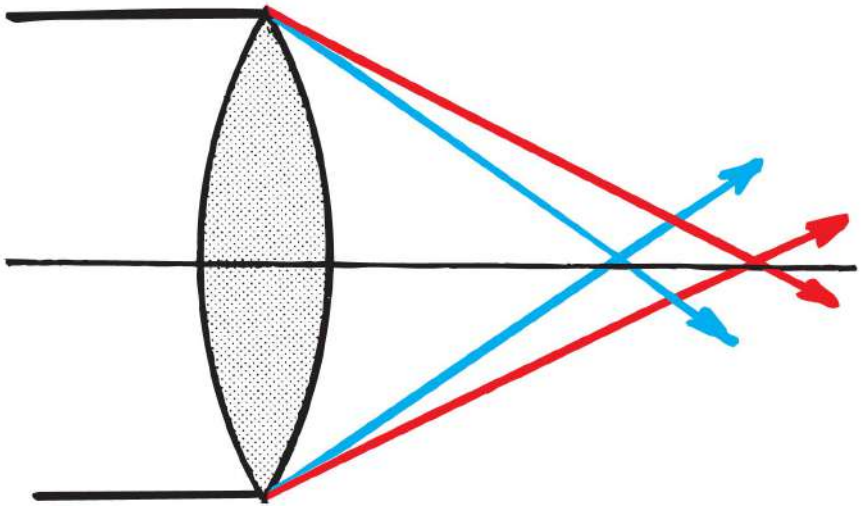
Lens Defects, Continued

- Aberration (continued)
  - Chromatic aberration
    - result of various colors having different speeds and different refractions in the lens
  - Astigmatism
    - front surface of the eyeball is unequally curved



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