SLE123

Class 10

Ray Optics

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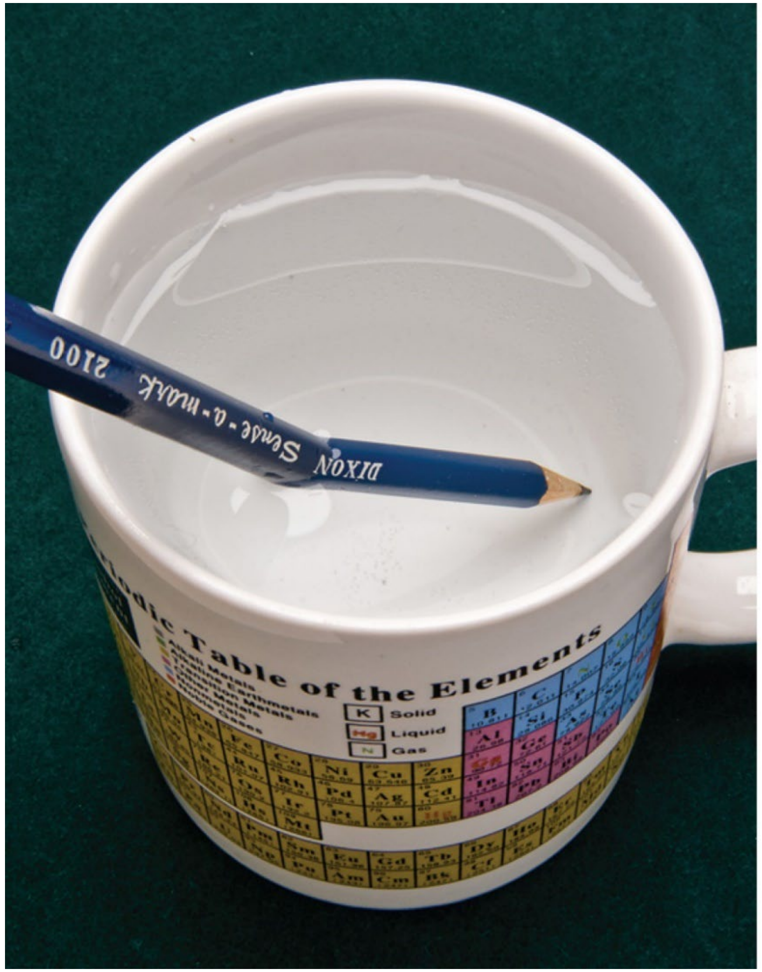
Reflection and Refraction of Light



Cengage Learning/Charles D. Winters

Topics

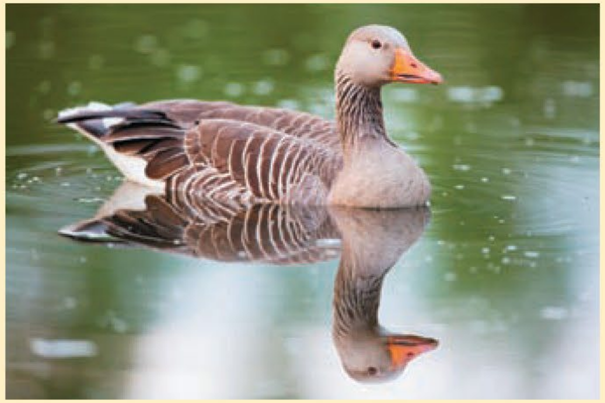
- The ray model of light
- Reflection
- Refraction
- Ray tracing for lenses

Why are there two images of this turtle in an aquarium, and why does each image appear to be a different size?

Looking ahead

Reflection

Light rays can bounce, or **reflect,** off a surface. Rays from the bird's head reflect from the water, forming an upside-down image.



You'll learn how the **law of reflection** can be used to understand image formation by mirrors.

Refraction

The two images of the turtle are due to **refraction,** the bending of light rays as they travel from one material into another.

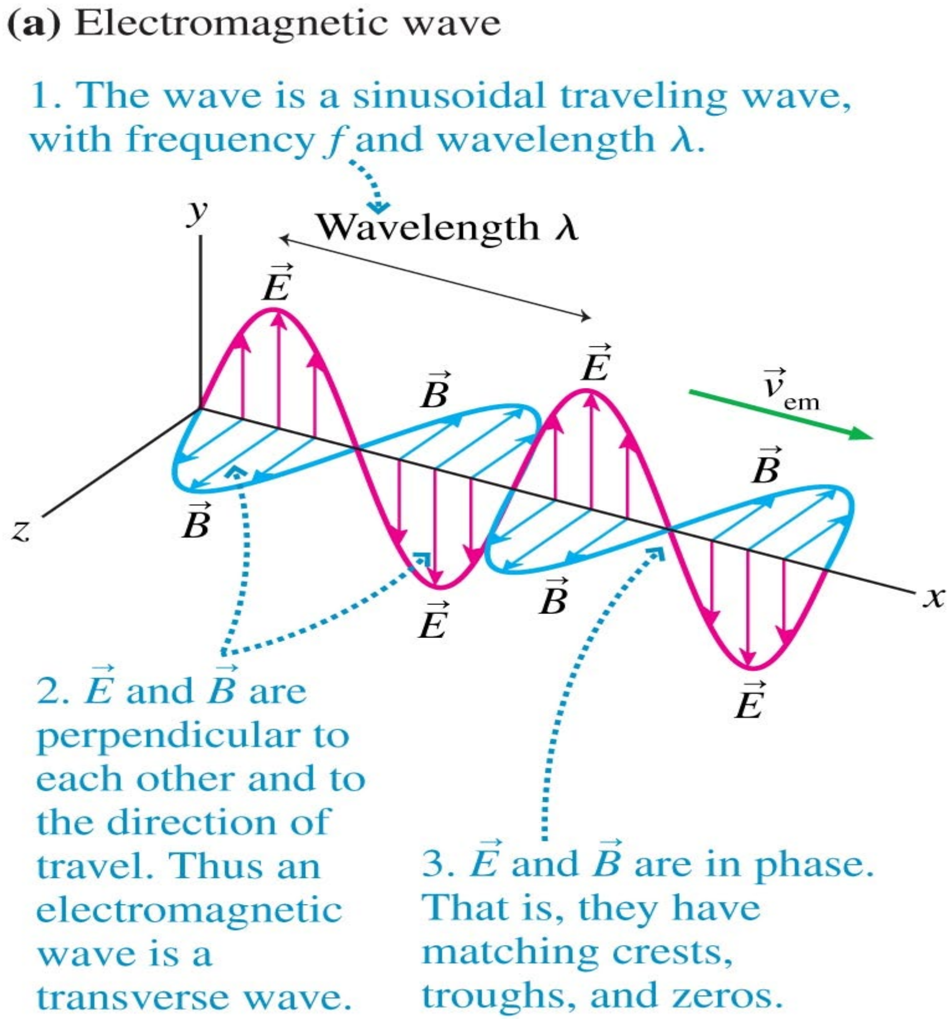
You'll learn **Snell's law** for refraction and how images can be formed by refraction.

Lenses and Mirrors

Rays refracting at the surfaces of this lens form a magnified **image** of the girl behind it.

You'll learn how to locate and characterize the images formed by lenses and mirrors.

Light Waves

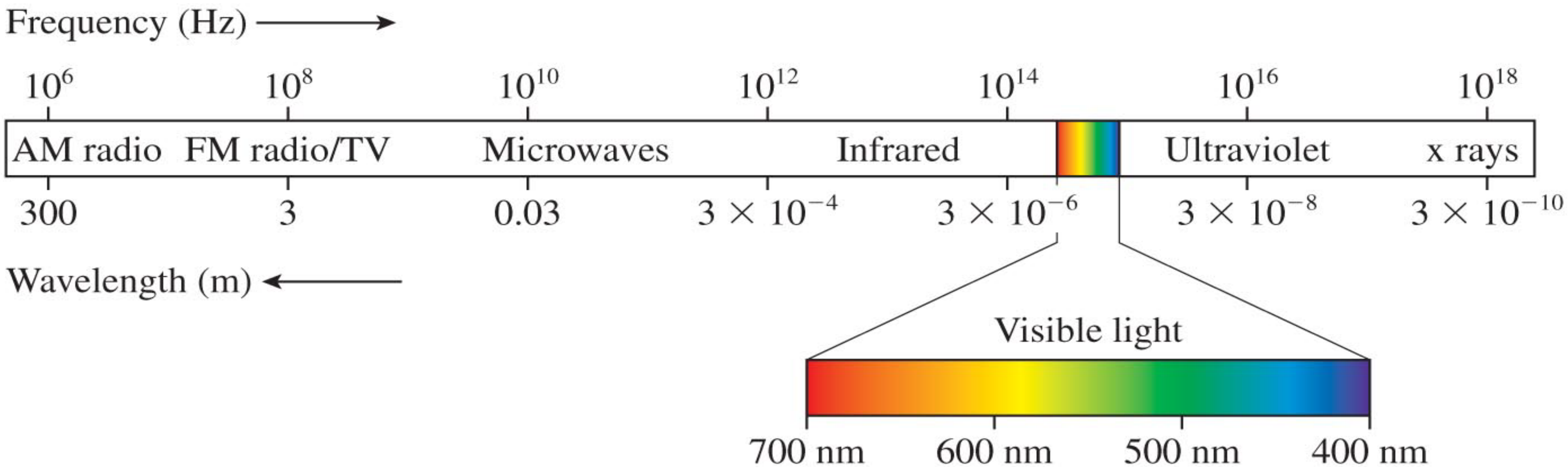


An electromagnetic (light) wave is an oscillating magnetic field travelling at right angles to an oscillating electric field. The 2 fields are in phase with each other.

Light and other electromagnetic waves in vacuum and in air move at the same speed, 3.00×10^8 m/s.

Light Waves

Light and other electromagnetic waves
in vacuum and in air
move at the same speed, 3.00 x 10^8 m/s.



(Knight, Jones, Field, section 15.4, p. 495)

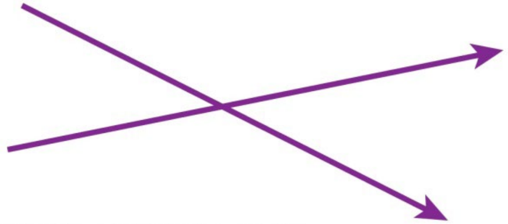
Study Question 1

- Revise wave equation question from from previous lecture eg.

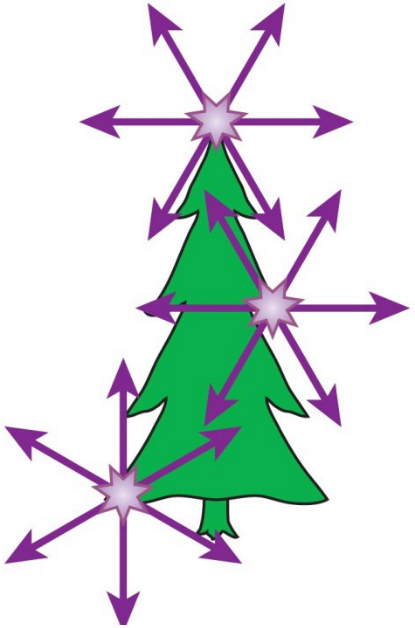
If a ray of light has frequency of 1000 Hz, what is its wavelength?

The Ray Model of Light

Light rays travel in straight lines.

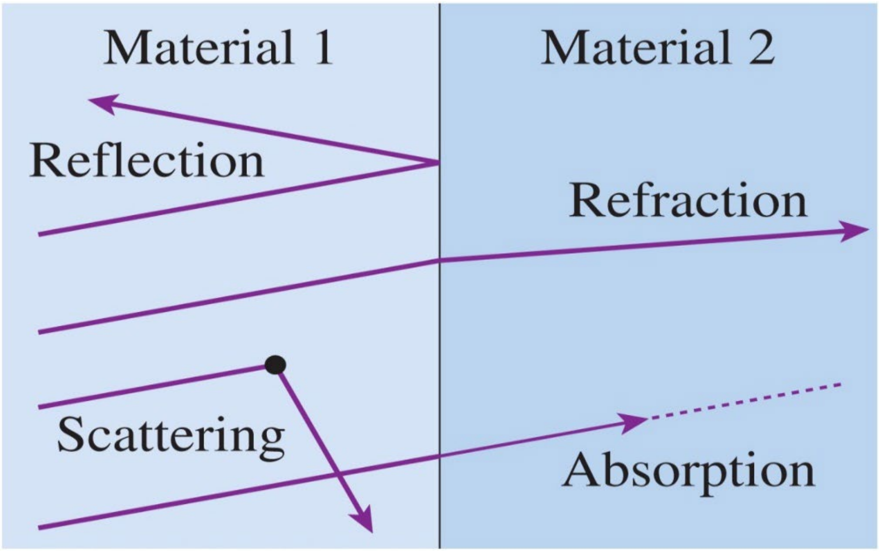


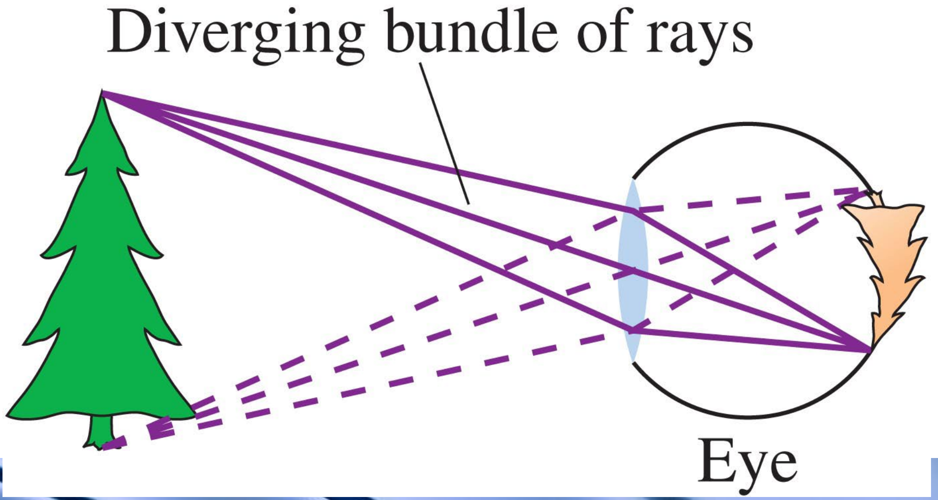
Light rays can cross.



An object is a source of light rays.

The eye sees by focusing a bundle of rays.





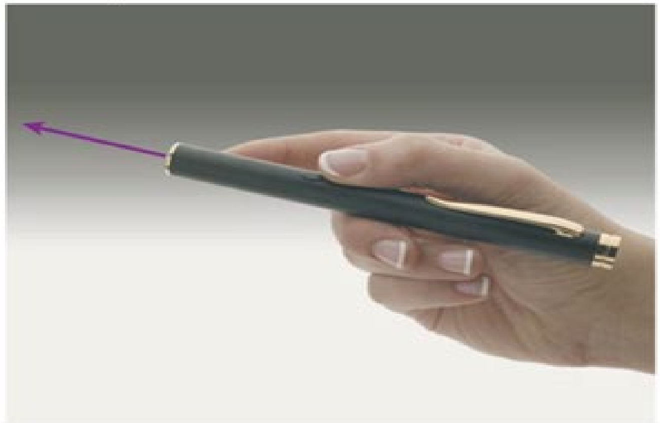
Sources of Light Rays

- **Self-luminous objects** (or *sources*) directly create light rays. Self-luminous objects include lightbulbs and the sun.

- **Reflective objects** are objects that reflect rays originating from self-luminous objects. These objects include a piece of paper or a tree.

Sources of Light ray – Self – Luminous Objects

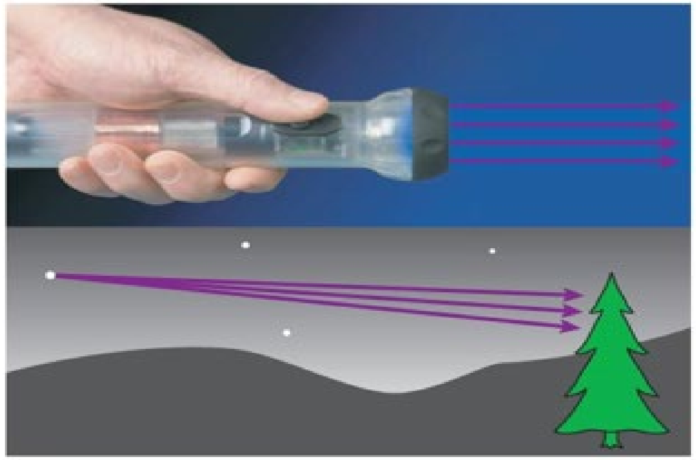
A ray source



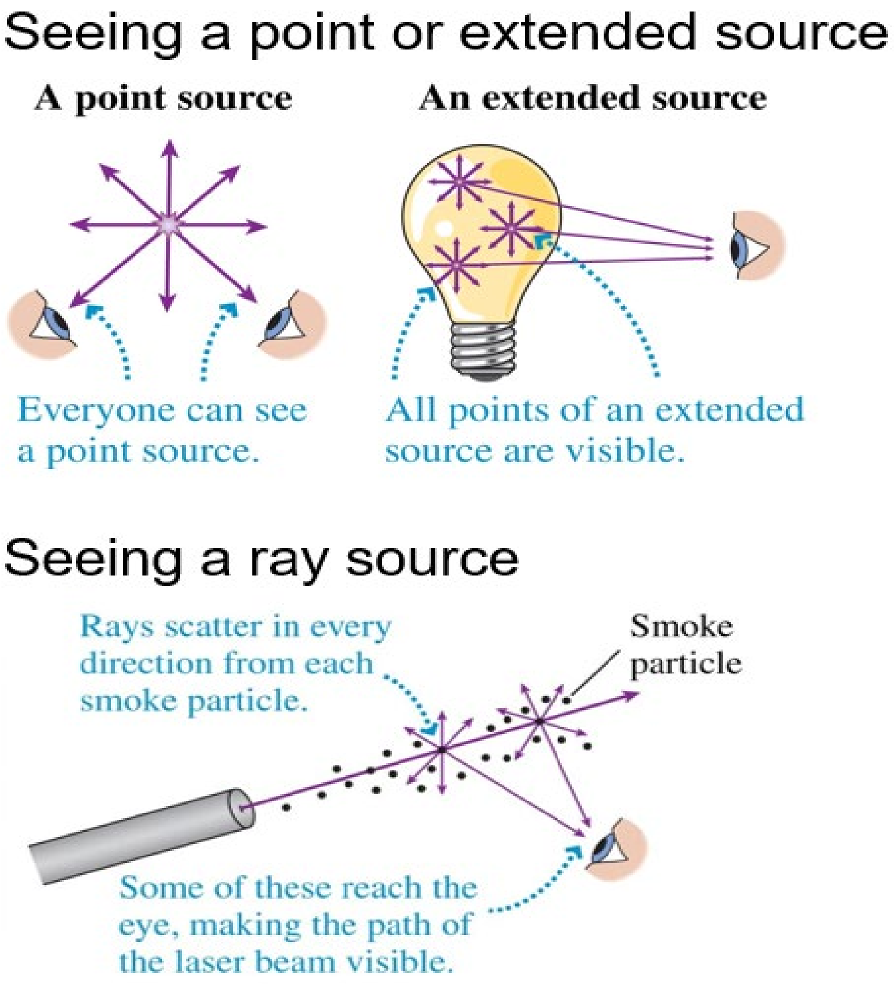
A point source

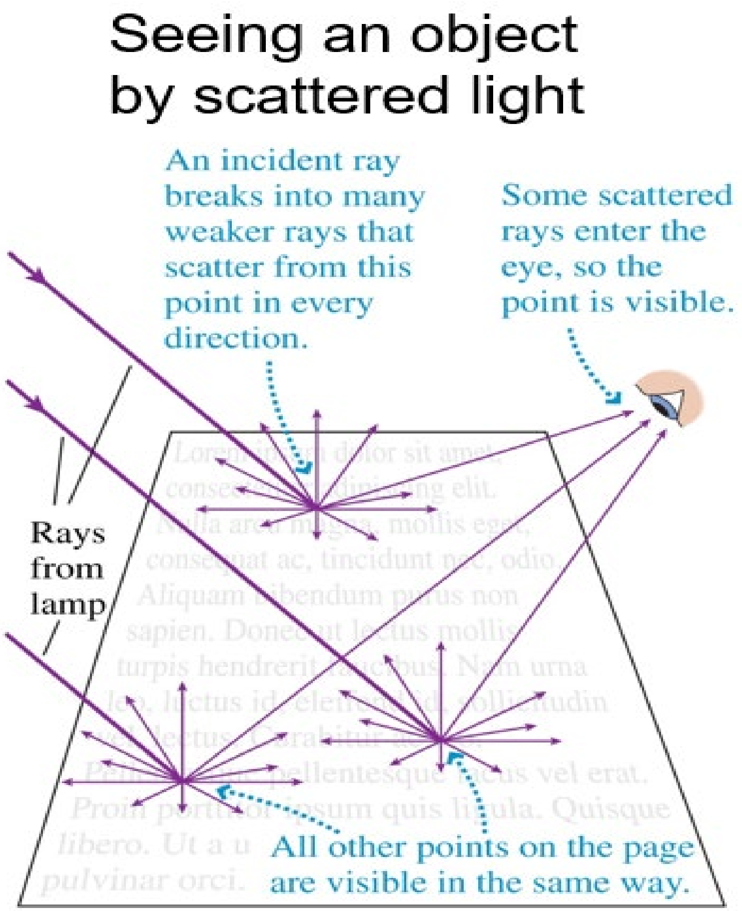
An extended source

A parallel-ray source

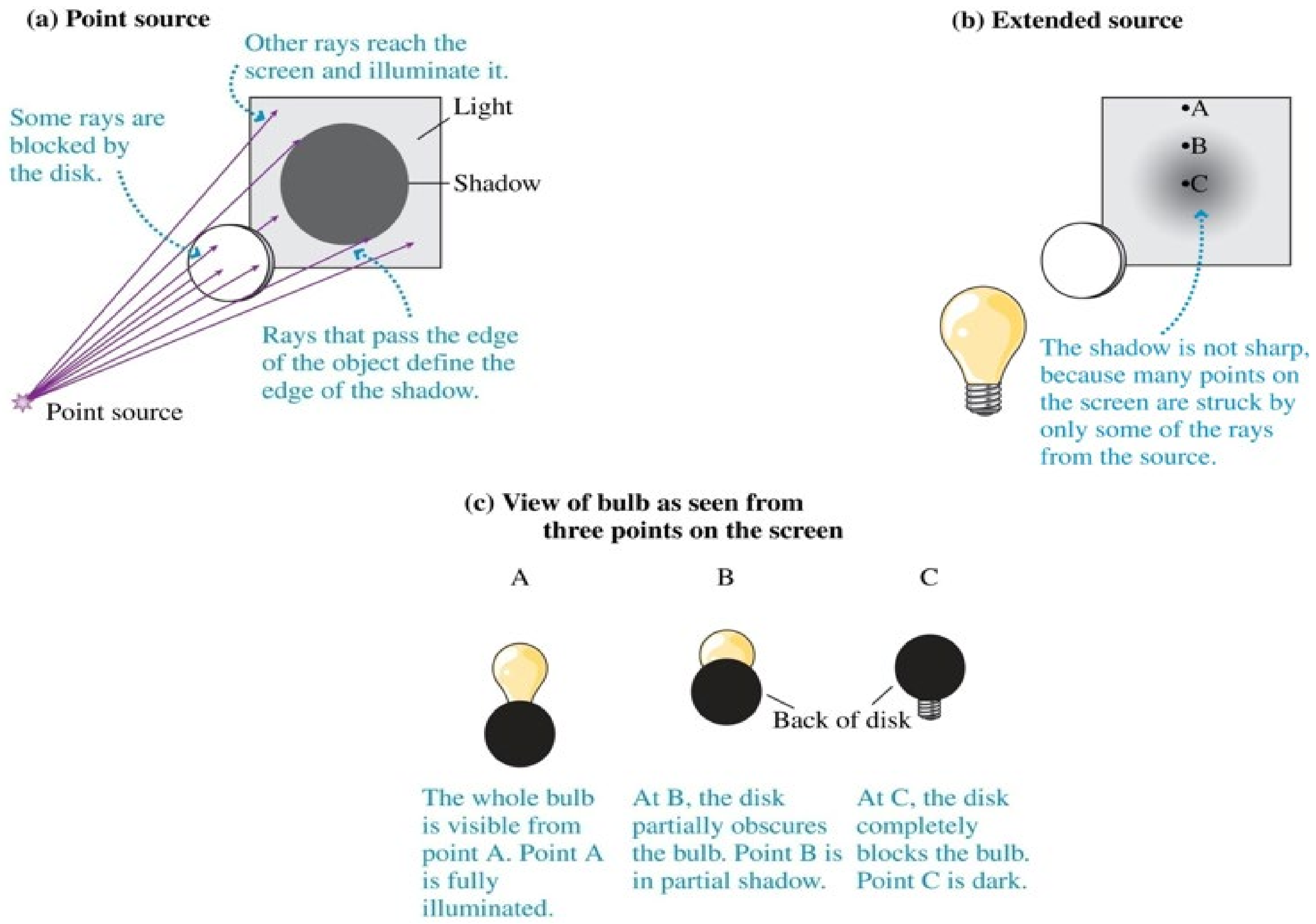


Seeing Objects





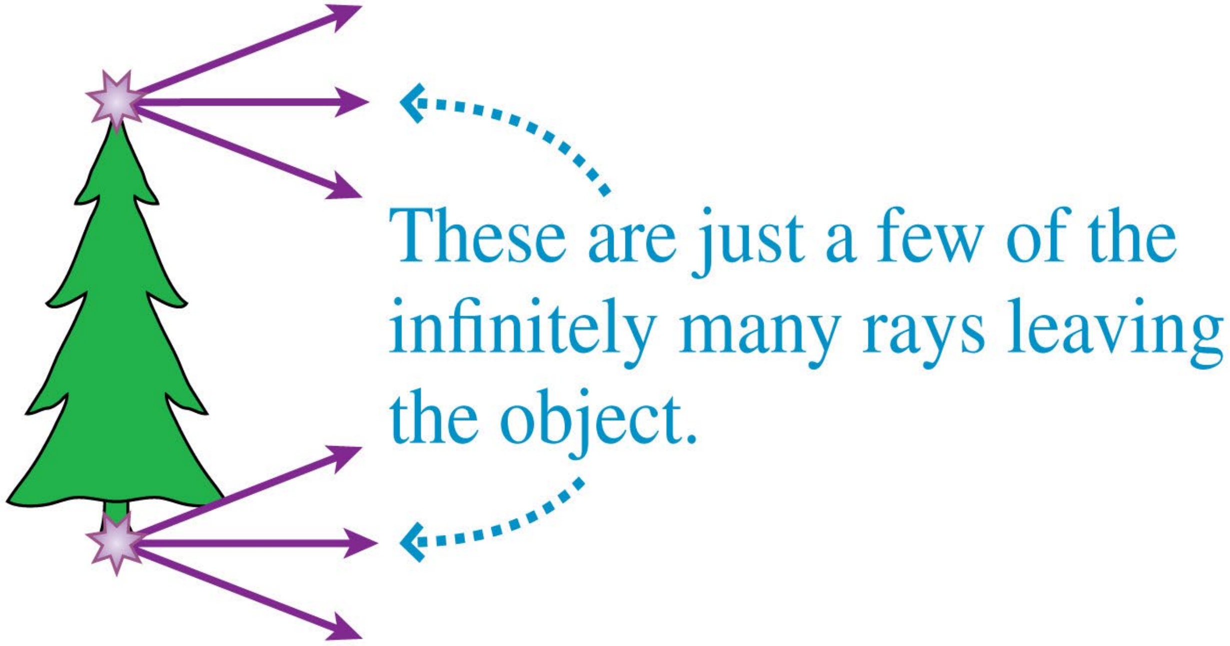
Shadows



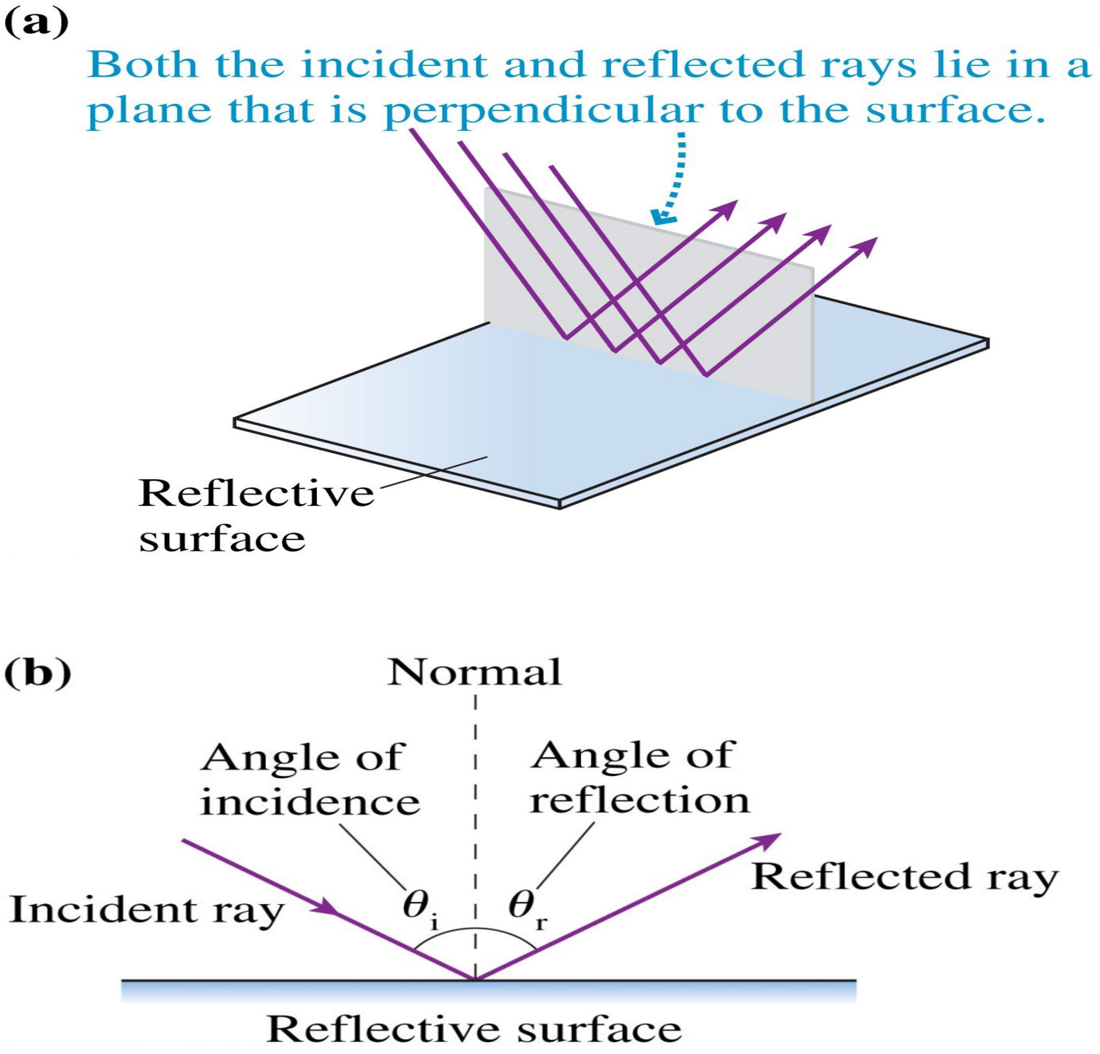
(a) Point source
Other rays reach the screen and illuminate it.
Some rays are blocked by the disk.
Light
Shadow
Rays that pass the edge of the object define the edge of the shadow.
Point source
(b) Extended source
•A
•B
•C
The shadow is not sharp, because many points on the screen are struck by only some of the rays from the source.
(c) View of bulb as seen from three points on the screen
A
B
C
Back of disk
The whole bulb is visible from point A. Point A is fully illuminated.
At B, the disk partially obscures the bulb. Point B is in partial shadow.
At C, the disk completely blocks the bulb. Point C is dark.

Ray Diagram

- A **ray diagram** is a diagram that shows a few light rays in order to simplify the situation.
- In reality, rays originate from *every* point on an object and travel in *all* directions.



The Law of Reflection

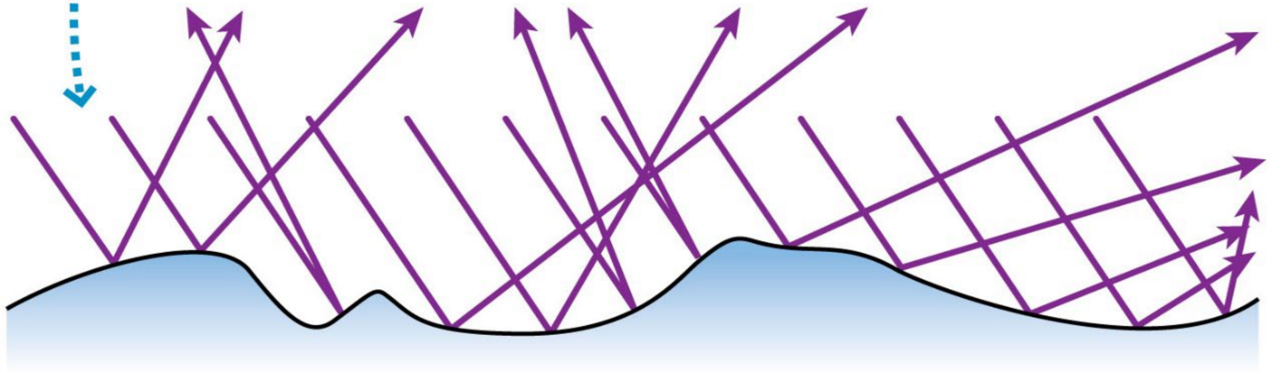


1. The incident ray and the reflected ray are in the same plane normal to the surface, and
2. The angle of reflection equals the angle of incidence: $\theta_r = \theta_i$.

Diffuse reflection

- On the microscopic scale, the surface of a diffuse reflector (paper or cloth) is rough.
- The law of reflection holds, but the irregularities of the surface cause the reflected rays to leave in all directions.

Each ray obeys the law of reflection at that point, but the irregular surface causes the reflected rays to leave in many random directions.



Magnified view of surface

Reflection

When you look at yourself in a mirror, you see an image of yourself and objects around you. Note that you do not see yourself as others see you. Left and right appear reversed in the image.

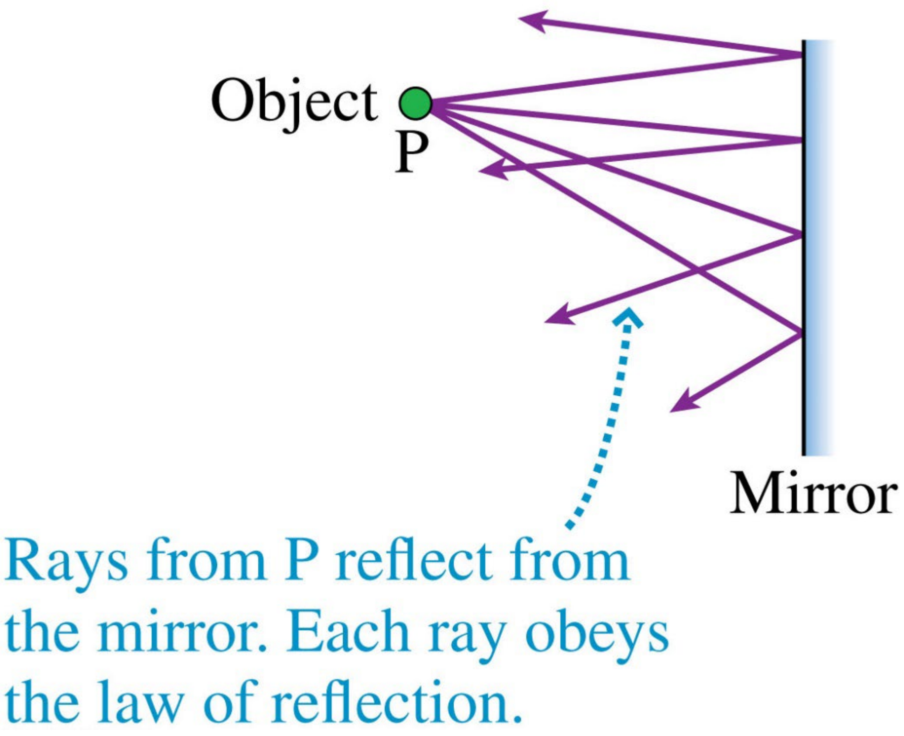
Mirrors and Lenses

John M. Dunay IV, Fundamental Photographs, NYC

Plane Mirror

A **plane mirror** is a flat mirror. Rays from point P will reflect according to the law of reflection.

(a)



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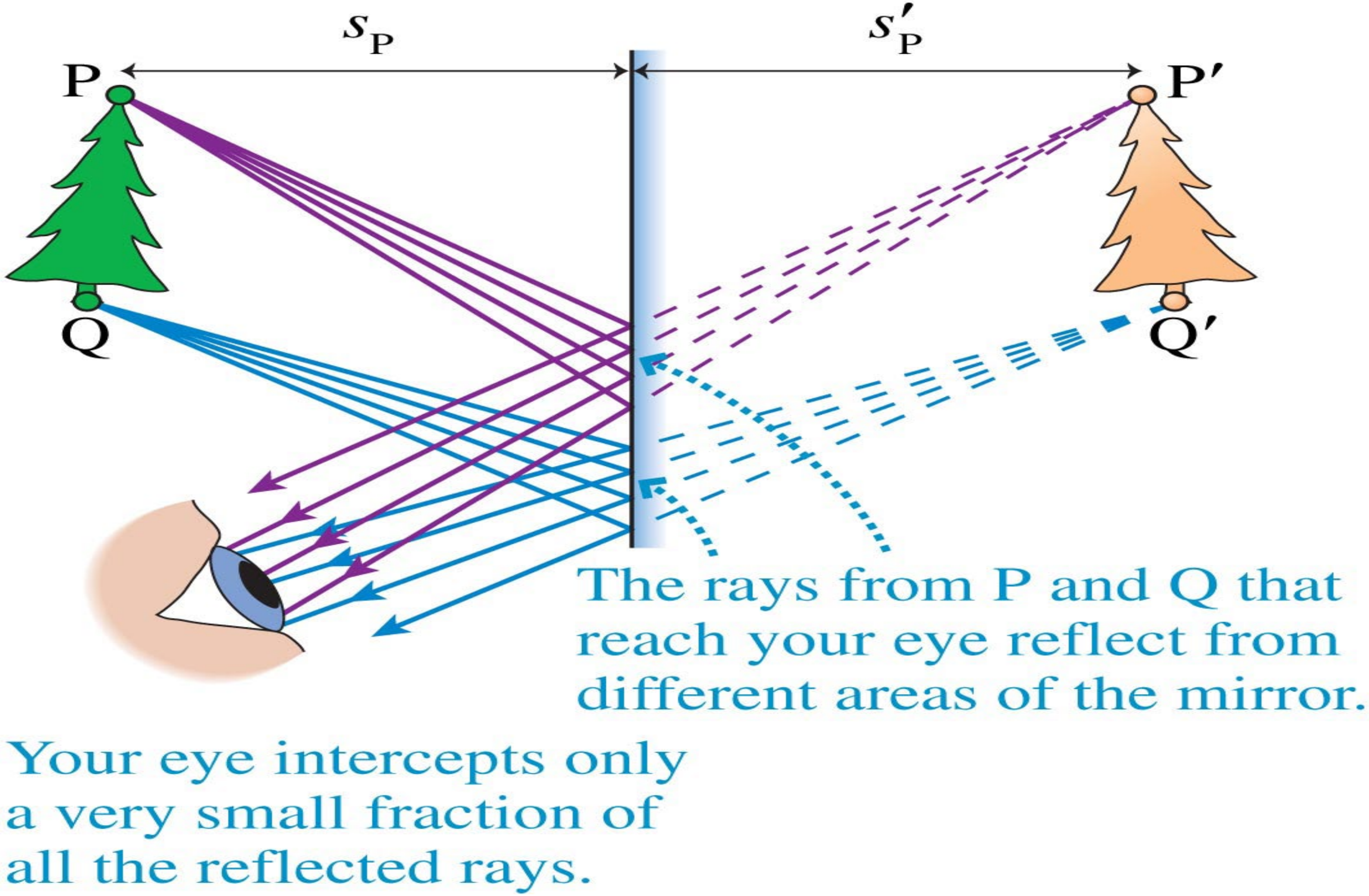
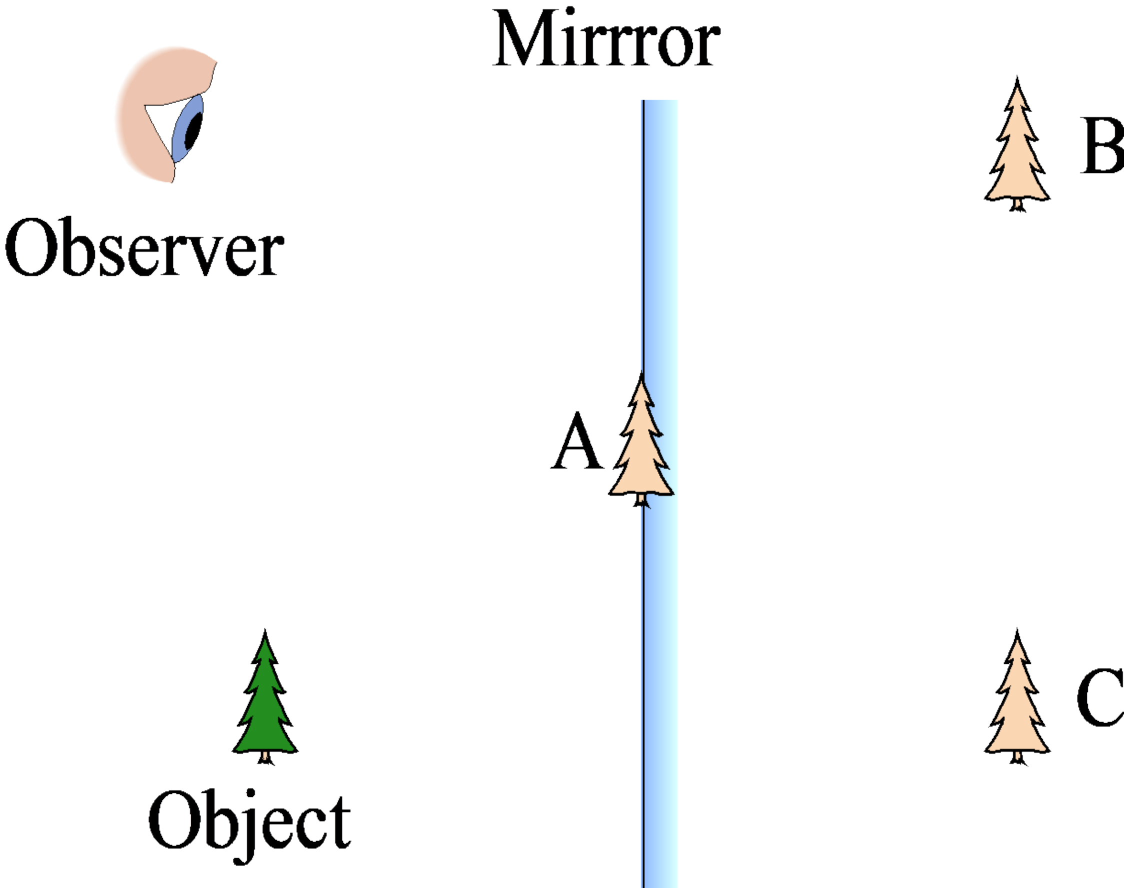
The Plane Mirror



Quick Check 1

- An object is placed in front of a mirror. The observer is positioned as shown. Which of the points shown best indicates where the observer would perceive the image to be located?



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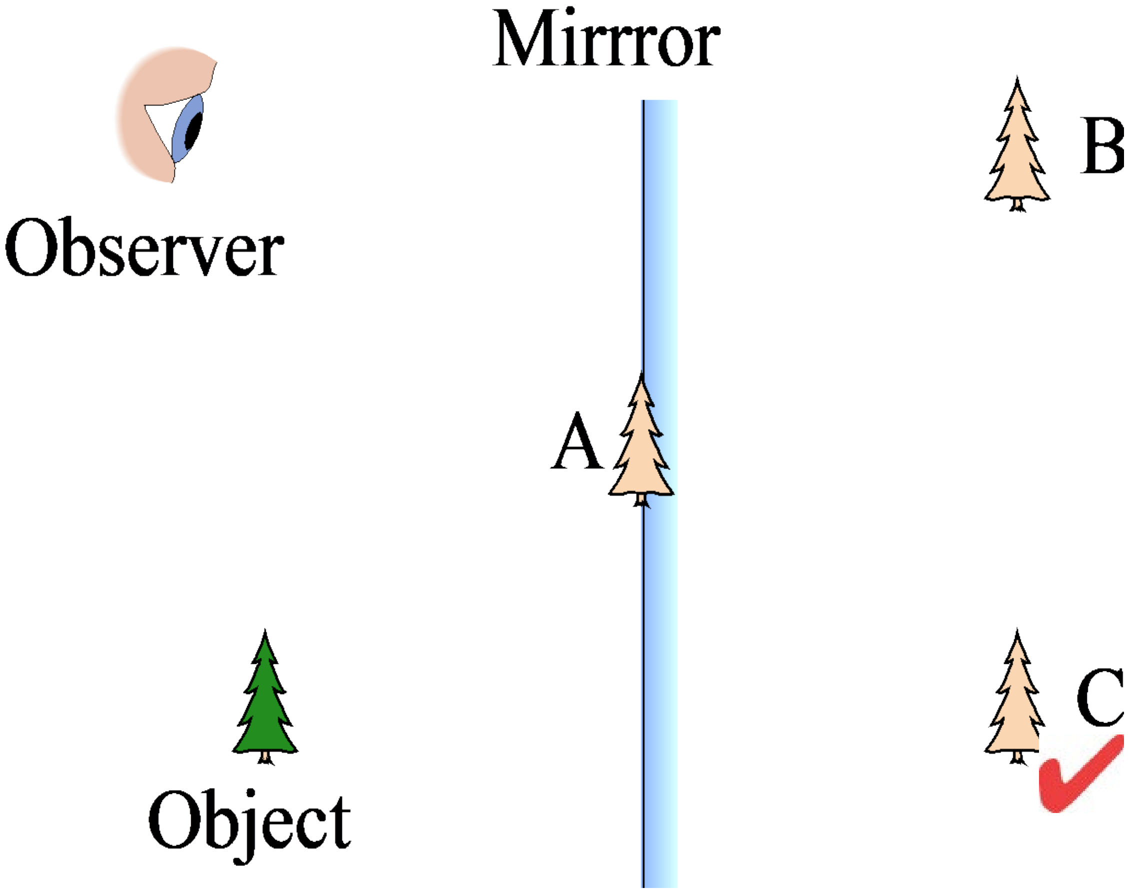
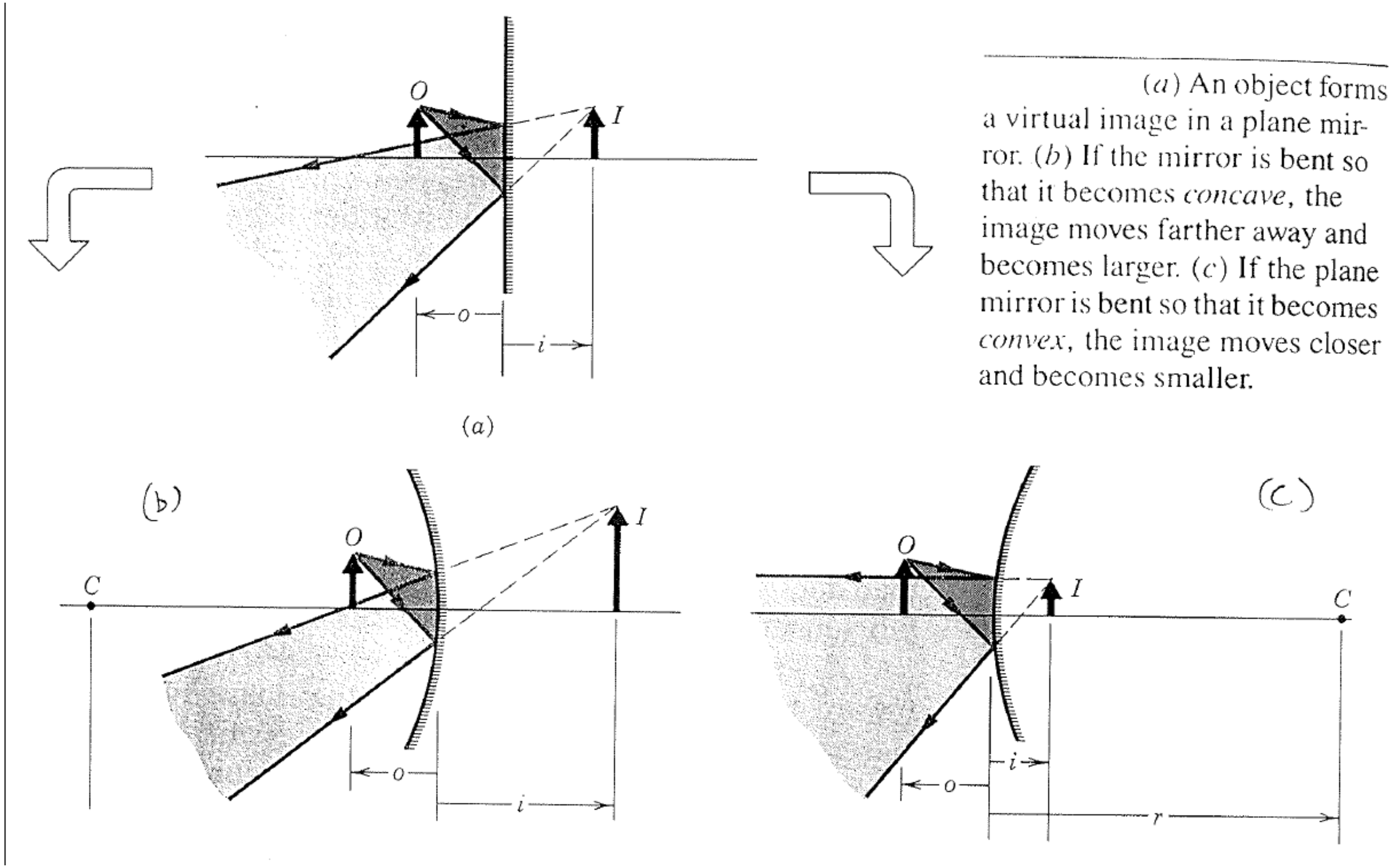


Plane and Curved Mirrors



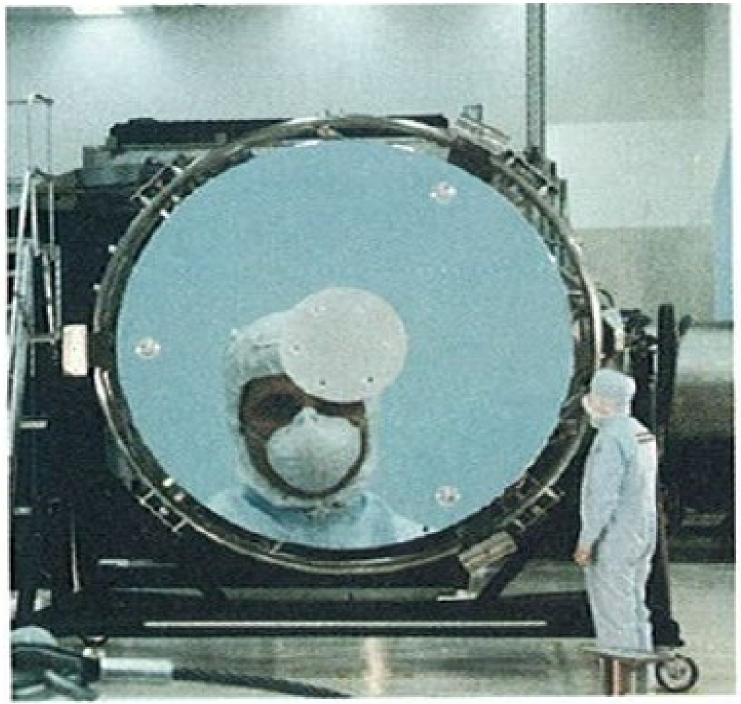
(*a*) An object forms a virtual image in a plane mirror. (*b*) If the mirror is bent so that it becomes *concave*, the image moves farther away and becomes larger. (*c*) If the plane mirror is bent so that it becomes *convex*, the image moves closer and becomes smaller.

Curved Mirrors

Concave make-up mirror

Convex security mirror

Curved Mirrors



Concave mirror for the Hubble telescope

Junebug Clark/Science Source

Convex rear-vision mirror

Quick Check 2

You see an upright, magnified image of your face when you look into magnifying "cosmetic mirror." The image is located

- In front of the mirror's surface.
- On the mirror's surface.
- Behind the mirror's surface.
- Only in your mind because it's a virtual image.

Quick Check 2

You see an upright, magnified image of your face when you look into magnifying "cosmetic mirror." The image is located

- In front of the mirror's surface.
- On the mirror's surface.
- ✔ Behind the mirror's surface.
- Only in your mind because it's a virtual image.

Refraction of Waves

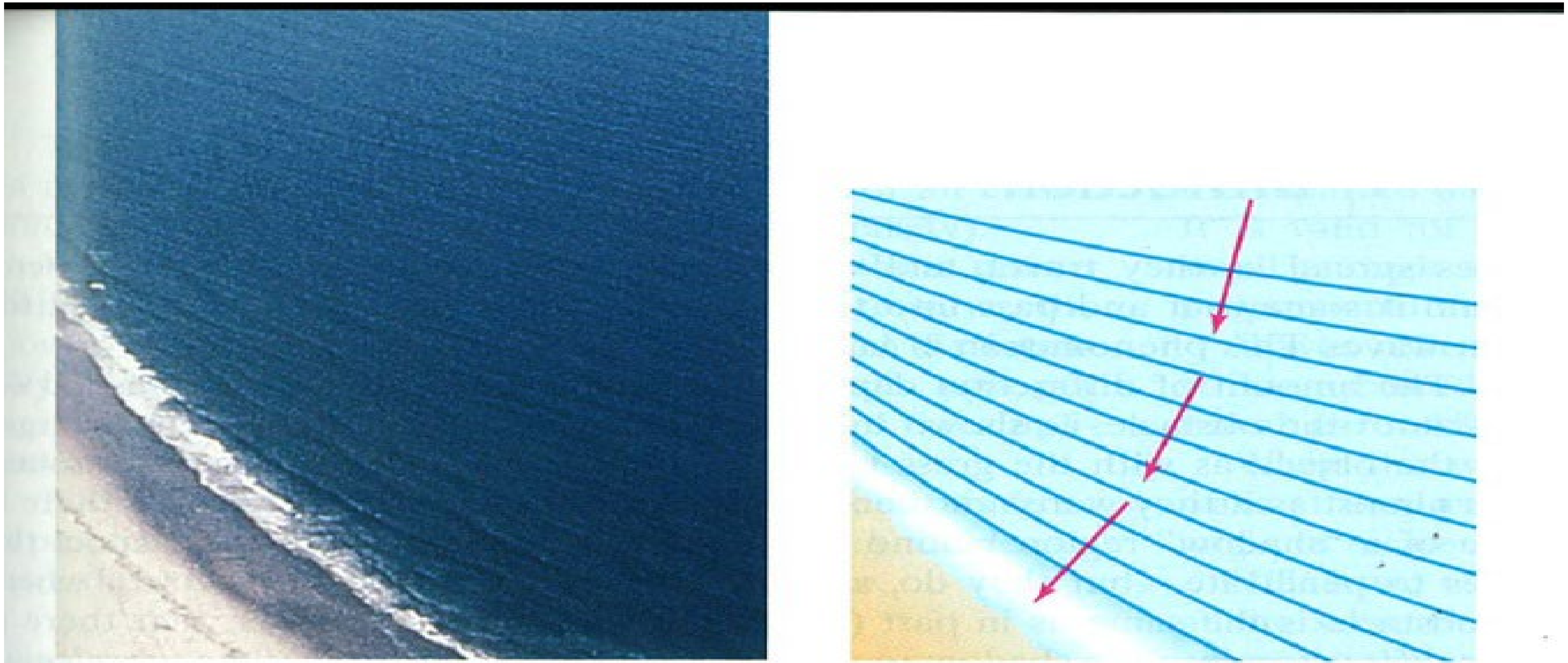


FIGURE 15–30 Water waves refracting as they approach the shore, where their velocity is less. There is no distinct boundary, as in Fig. 15–29, and the wave velocity changes gradually.

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The Law of Refraction

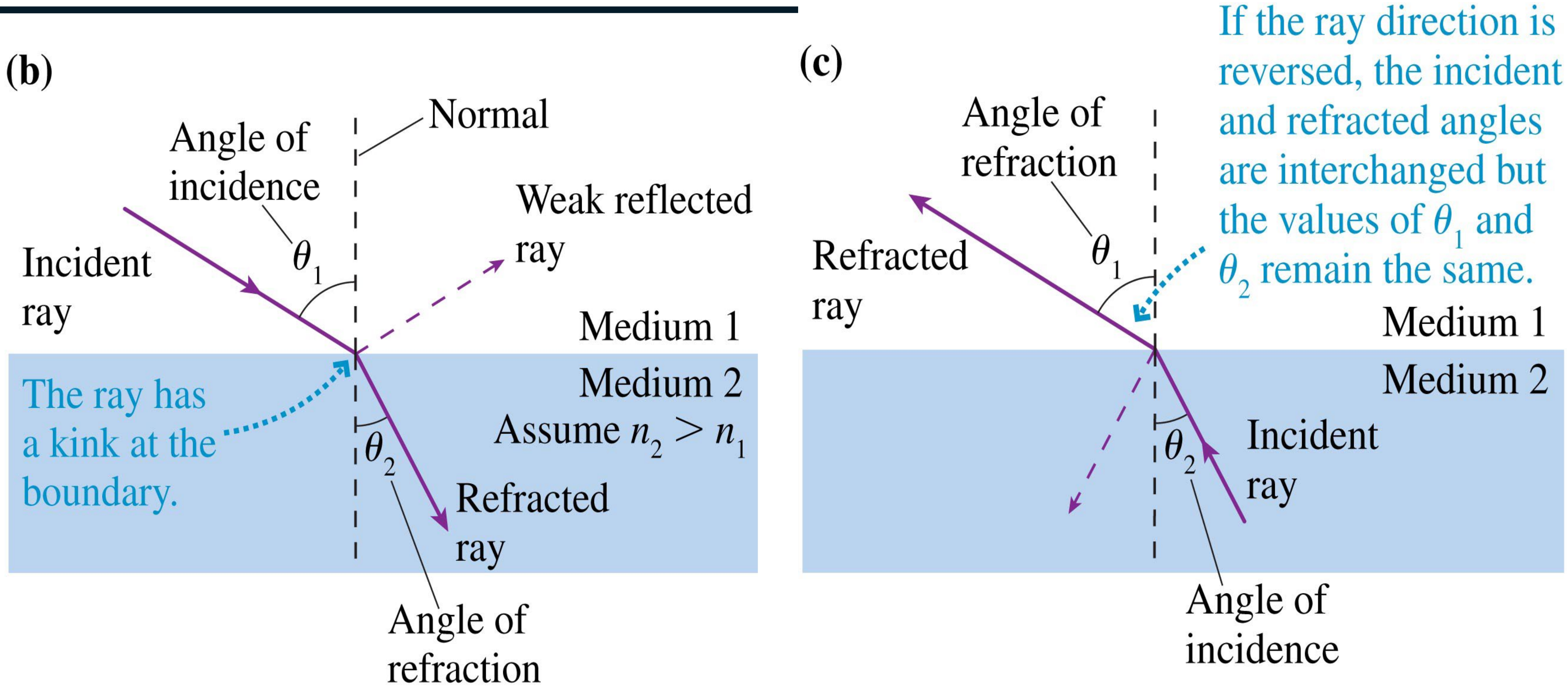
$$n \equiv \frac{\text{speed of light in vacuum}}{\text{speed of light in a medium}} = \frac{c}{v}$$

The Law of Refraction

Table 22.1 Indices of Refraction for Various Substances, Measured with Light of Vacuum Wavelength λ_0 = 589 mn

Substance	Index of Refraction	Substance	Index of Refraction
Solids at 20°C		**Liquids at 20°C**	
Diamond (C)	2.419	Benzene	1.501
Fluorite (CaF_2)	1.434	Carbon disulfide	1.628
Fused quartz (SiO_2)	1.458	Carbon tetrachloride	1.461
Glass, crown	1.52	Ethyl alcohol	1.361
Glass, flint	1.66	Glycerine	1.473
Ice (H_2O) (at 0°C)	1.309	Water	1.333
Polystyrene	1.49		
Sodium chloride (NaCl)	1.544	**Gases at 0°C, 1 atm**	
Zircon	1.923	Air	1.000 293
		Carbon dioxide	1.000 45

Law of Refraction



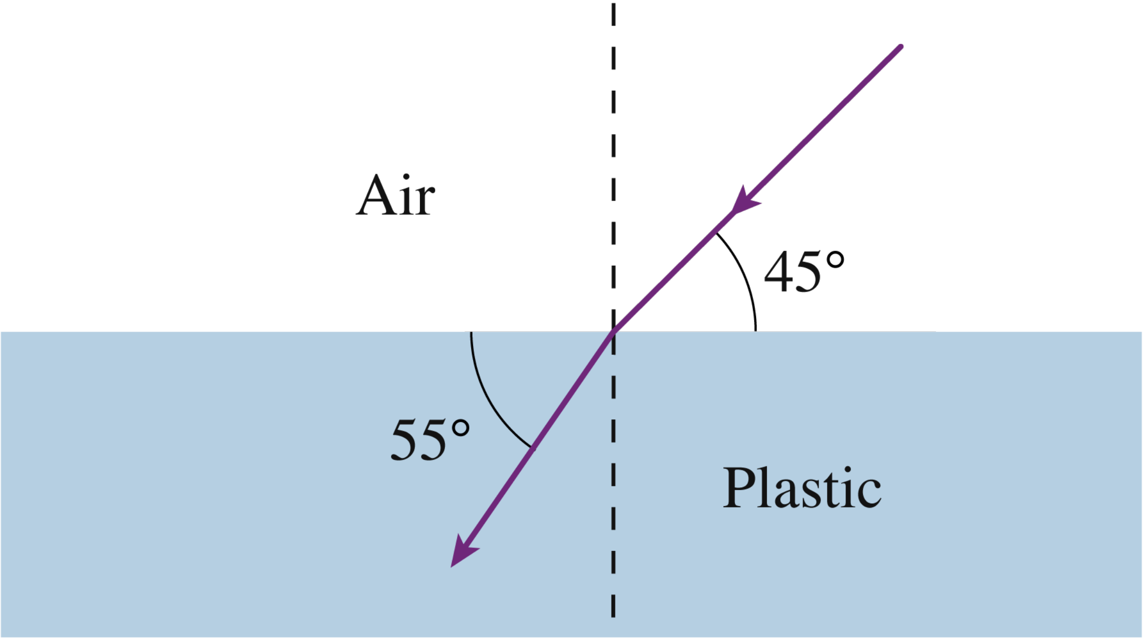
Snell's Law of Refraction

- When a ray is transmitted into a material with a higher index of refraction, it bends to make a smaller angle with the normal.
- When a ray is transmitted into a material with a lower index of refraction, it bends away from the normal.

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Example

What is the index of refraction of the plastic if a ray is refracted as in the figure?



Example

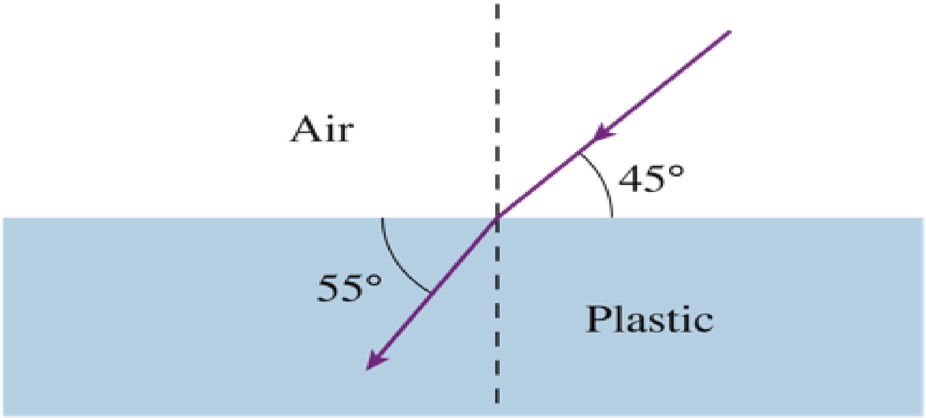
What is the index of refraction of the plastic if a ray is refracted as in the figure?

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$n_1 = 1.00$ $\theta_1 = 45^\circ$

$n_2 = ?$ $\theta_2 = 90^\circ - 55^\circ = 35^\circ$

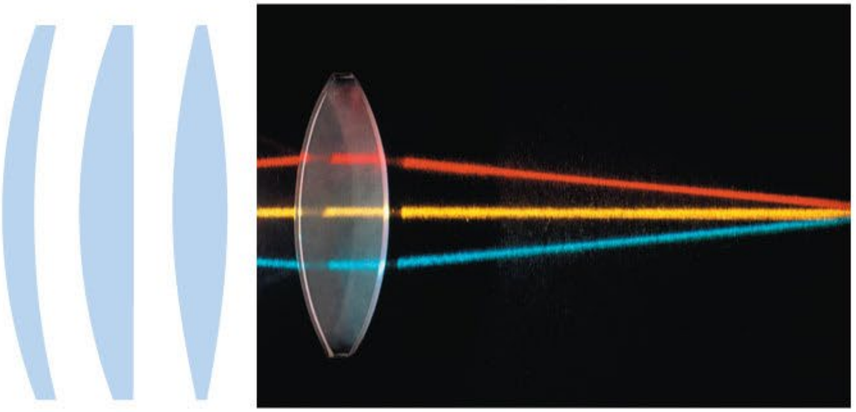
$$n_2 = \frac{n_1 \sin\theta_1}{\sin\theta_2} = \frac{\sin 45^\circ}{\sin 35^\circ} = 1.23$$



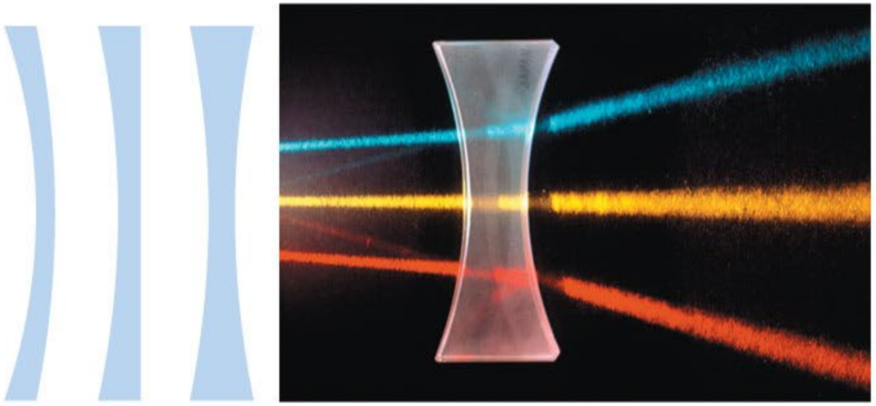
Thin Lenses : Ray Tracing

- A **converging lens** causes the rays to refract *toward* the optical axis.
- A **diverging lens** causes the rays to refract *away* from the axis.

(a) Converging lenses, which are thicker in the center than at the edges, refract parallel rays toward the optical axis.

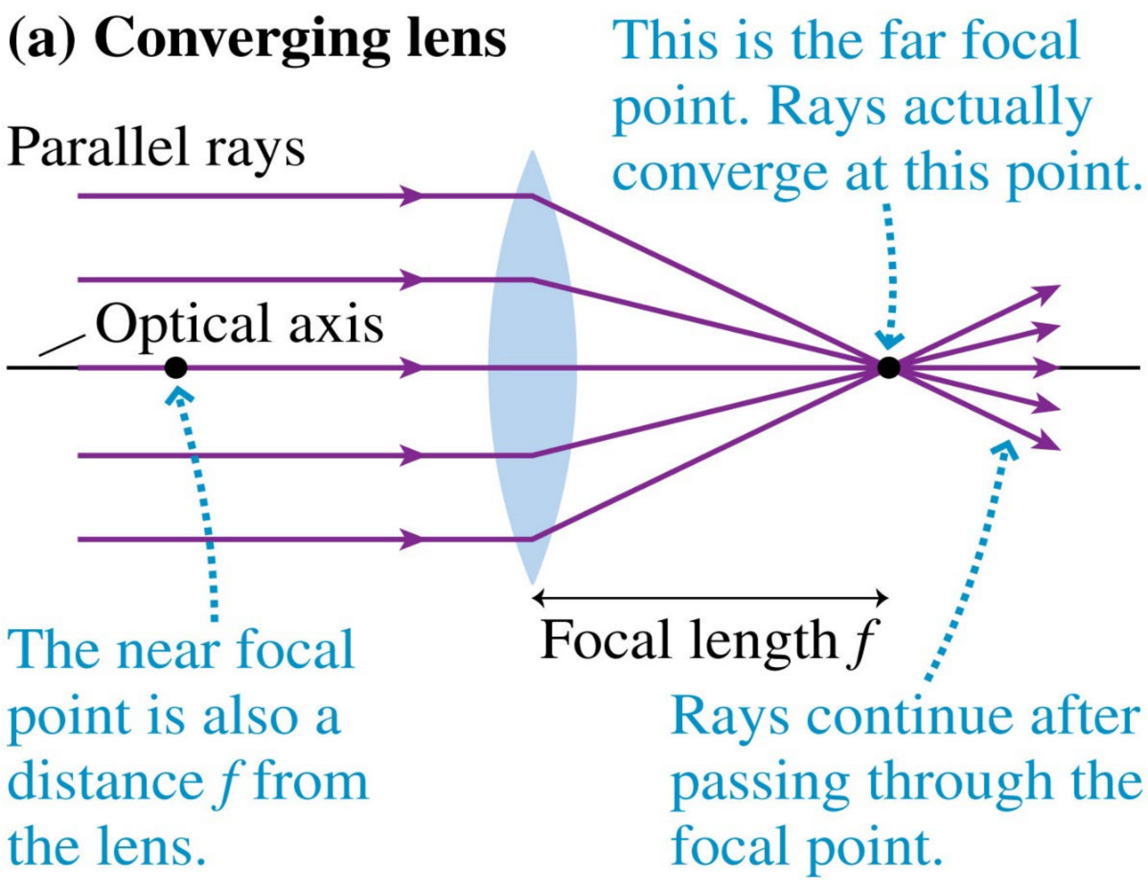


(b) Diverging lenses, which are thinner in the center than at the edges, refract parallel rays away from the optical axis.



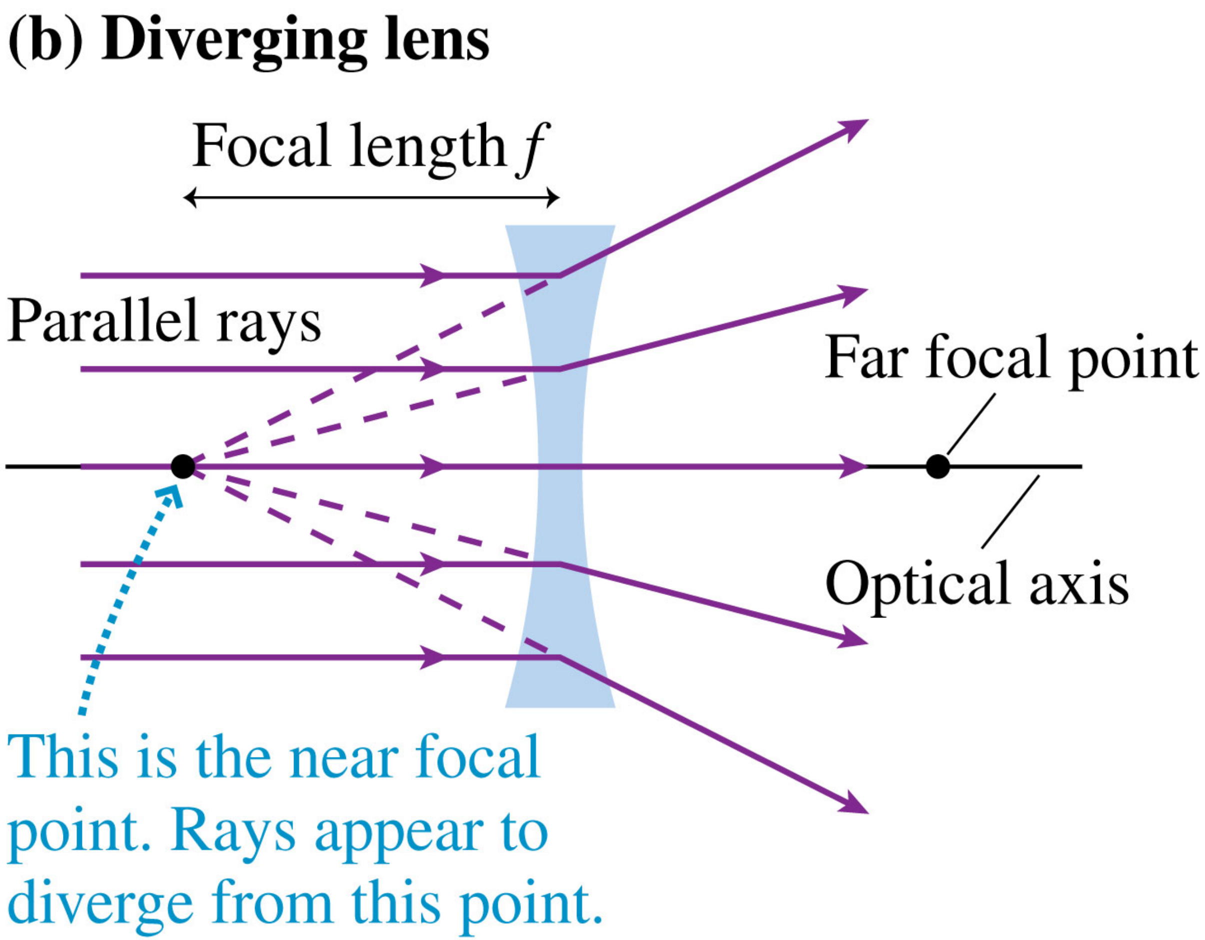
Thin Lenses : Ray Tracing

- The incoming rays initially parallel to the optical axis converge at the *same* point, the **focal point** of the lens.
- The distance of the focal point from the lens is called the **focal length** *f* of the lens.



Thin Lenses : Ray Tracing

- For a diverging lens, the **focal length is the distance from the lens to the point at which rays parallel to the optical axis converge or from which they appear to diverge.**



Thin Lenses : Ray Tracing

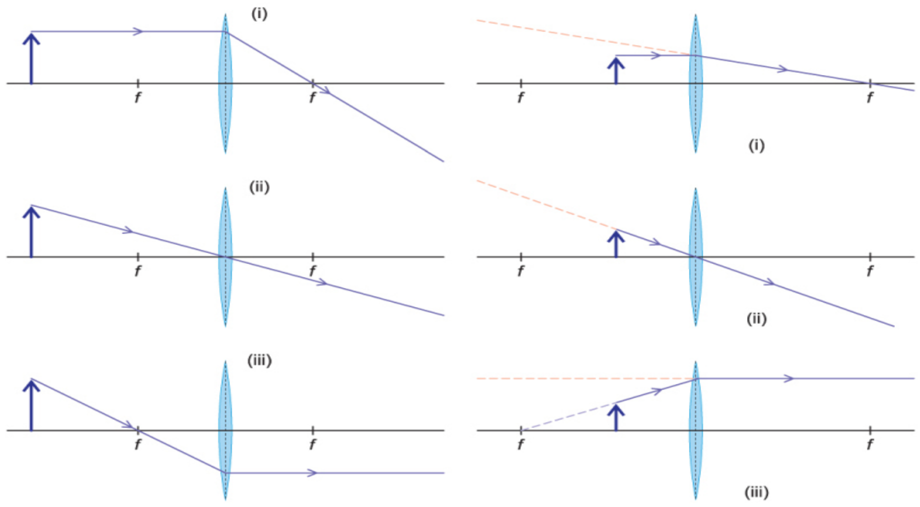


Figure 30.16

Three principal rays used to construct ray diagrams for a converging lens. The object is placed outside the focal plane of the lens in the example on the left and inside it in the example on the right. The rules are the same in each case, however.

Introduction to Biological Physics for the Health and Life Sciences Franklin, Muir, Scott, Wilcocks and Yates

Ray Tracing

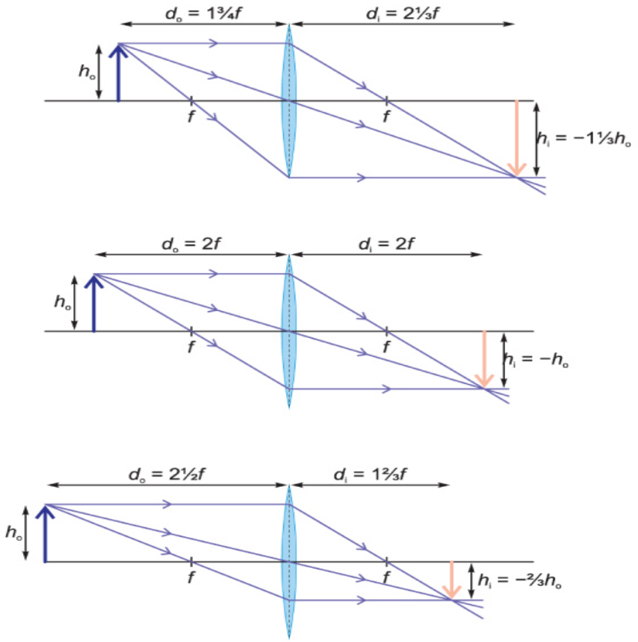


Figure 30.20

The same object is placed at three different positions with respect to a converging lens. When $2f > d_o > f$ the object is enlarged ($|M| > 1$) whereas when $d_o > 2f$ the object is reduced ($|M| < 1$). A special case exists when $d_o = 2f$. In this case $M = -1$.

Introduction to Biological Physics for the Health and Life Sciences Franklin, Muir, Scott, Wilcocks and Yates

Ray Tracing

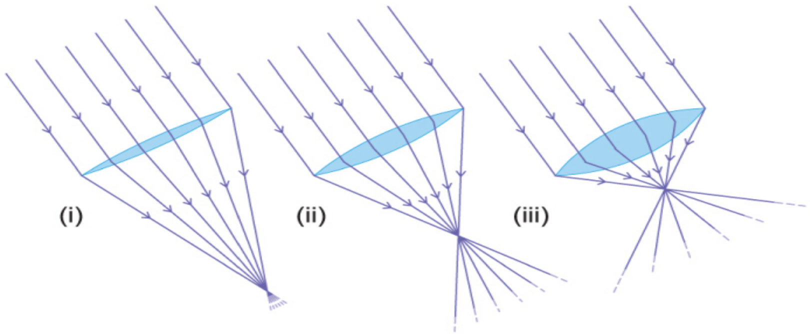


Figure 30.21

Three lenses of different optical power are shown. The most powerful lens (iii) bends the light to a greater degree than the weakest lens (i).

Introduction to Biological Physics for the Health and Life Sciences Franklin, Muir, Scott, Wilcocks and Yates

Ray Tracing

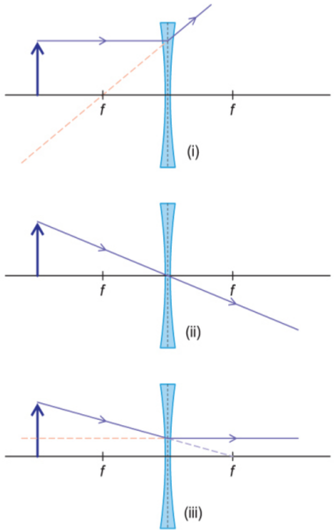


Figure 30.19

The principal rays used when constructing a ray diagram for a diverging lens.

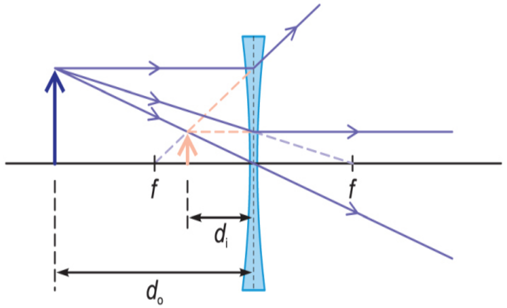


Figure 30.17

The image formed by a diverging lens. A diverging lens always produces a virtual image when a 'real' object is used. Figure 30.19 shows the principal rays used to construct this ray diagram.

Quick Check 3

You can use the sun’s rays and a lens to start a fire. To do so, you should use

A. A converging lens.
B. A diverging lens.
C. Either a converging or a diverging lens will work if you use it correctly.

Quick Check 3

You can use the sun's rays and a lens to start a fire. To do so, you should use

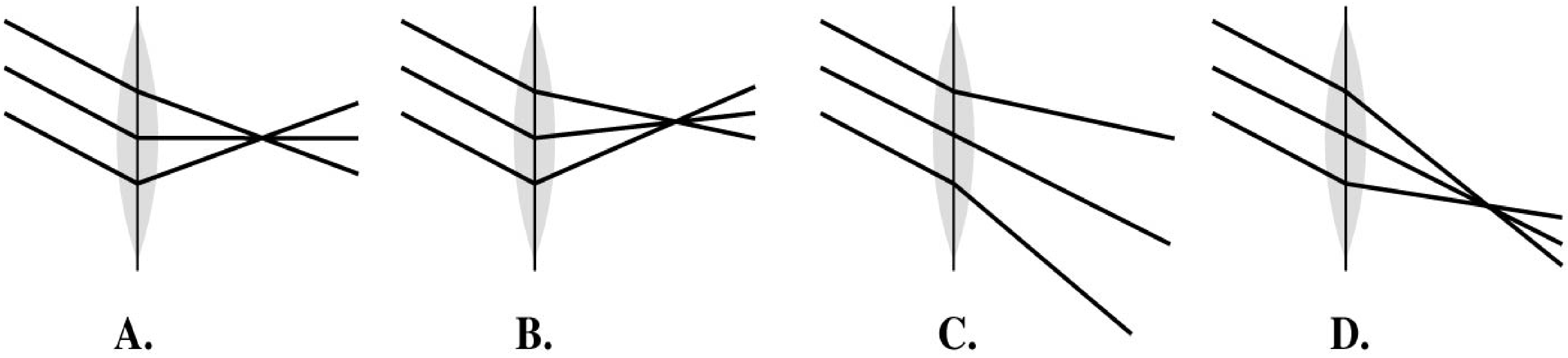
✔ A. A converging lens.

B. A diverging lens.

C. Either a converging or a diverging lens will work if you use it correctly.

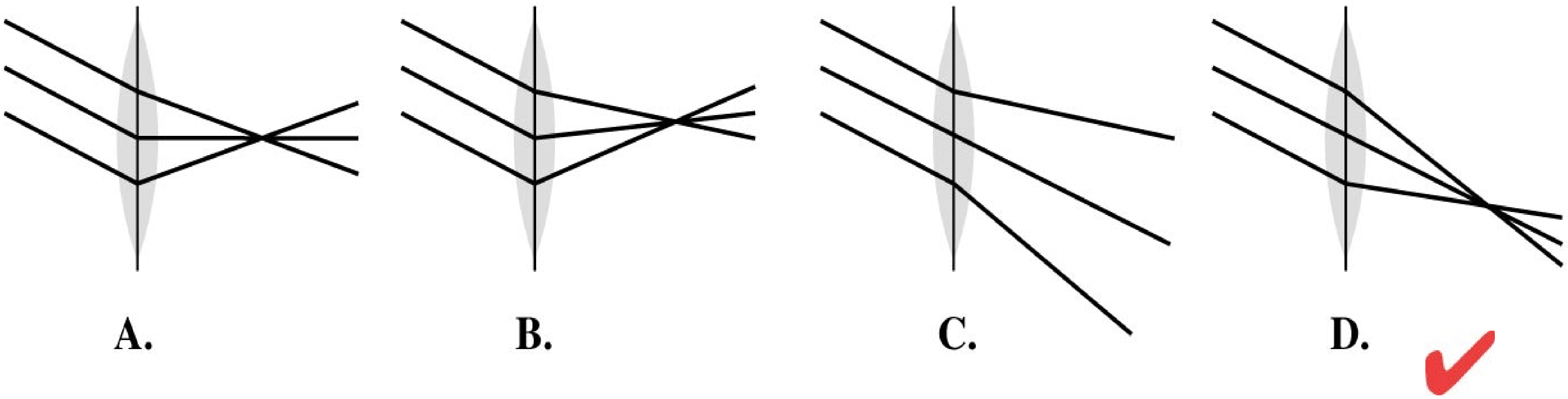
Quick Check 4

Which of these ray diagrams is possibly correct?



Quick Check 4

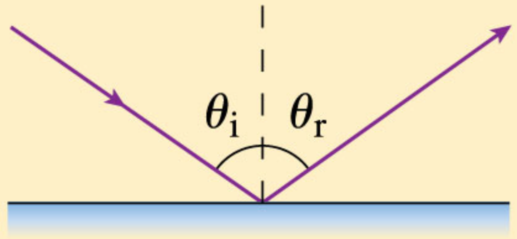
Which of these ray diagrams is possibly correct?



Summary

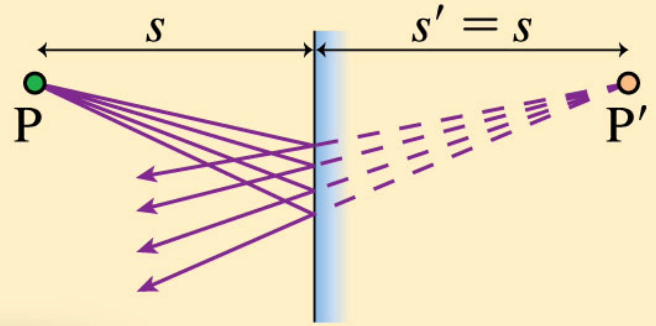
Reflection

Law of reflection: $\theta_r = \theta_i$



Reflection can be **specular** (mirror-like) or **diffuse** (from rough surfaces).

Plane mirrors: A virtual image is formed at P′ with $s' = s$, where s is the **object distance** and s' is the **image distance.**



Summary

Refraction

Snell's law of refraction:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Index of refraction is $n = c/v$. The ray is closer to the normal on the side with the larger index of refraction.