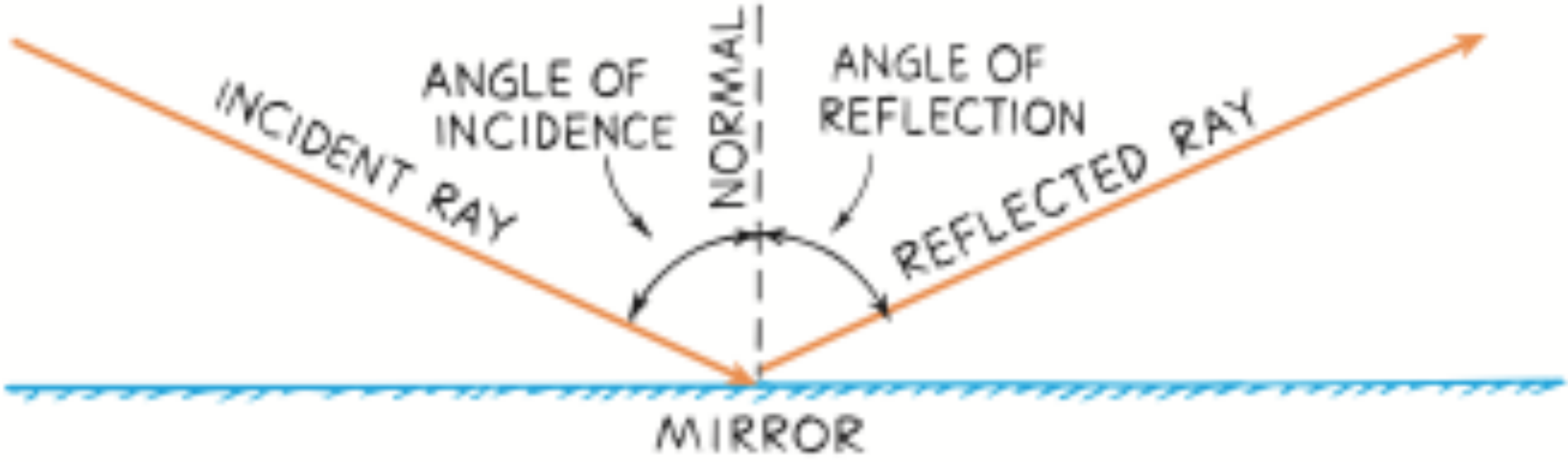
Reflection and Refraction

Reflection

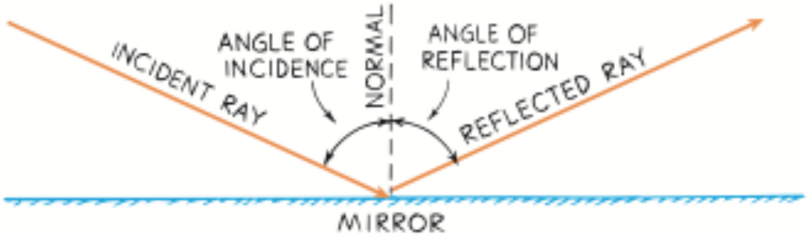
The Law of Reflection



$$\theta_i = \theta_r$$

Law of Reflection – the angle of incidence and the angle of reflection are equal.

The Law of Reflection



- Reflection - a wave bounces back into the first medium when hitting the boundary of a second medium.
- *Our brain thinks light travels in straight-lines.*
- **Angle of Incidence –** angle made by the incident ray and the normal
- **Angle of Reflection –** angle made by the reflected ray and the normal

Ex: Sitting in her parlor one night, Gerty sees the reflection of her cat, Whiskers, in the living room window. If the image of Whiskers makes an angle of 40° with the normal, at what angle does Gerty see him reflected?

Diffuse Reflection

- When light is incident on a rough surface, it is reflected in many directions.
- Diffuse Reflection – reflection of light from a rough surface.
- Each ray obeys the law of reflection, but the light rays come it at many different angles, so they leave at many different angles.

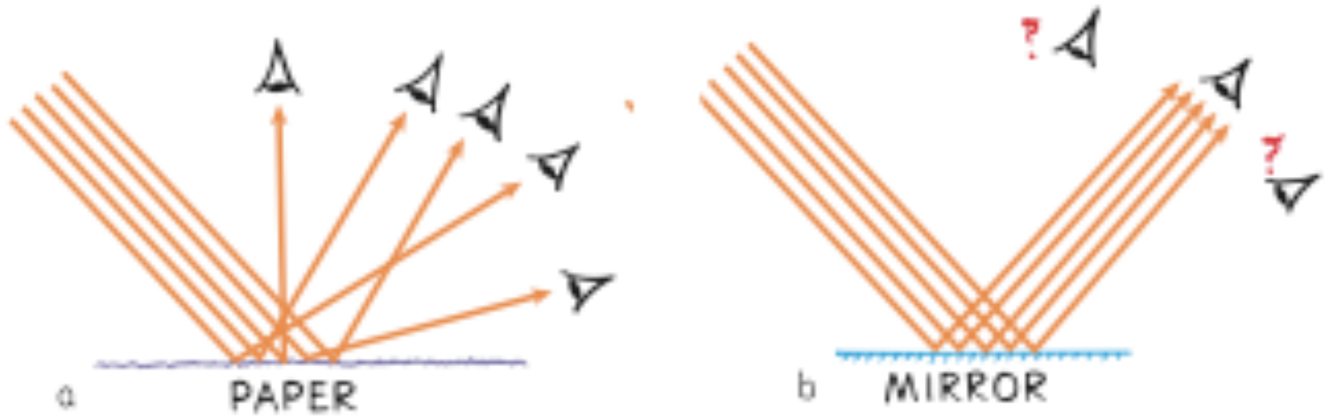


FIGURE 29.9
Diffuse reflection allows us to see most things around us. **a.** Light is diffusely reflected from paper in many directions. **b.** Light incident on a smooth mirror is only reflected in one direction.

Refraction

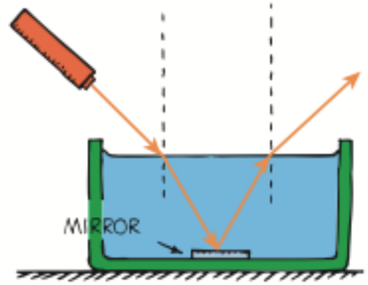


FIGURE 29.18 The laser beam bends toward the normal when it enters the water, and away from the normal when it leaves.

- **Refraction:** Bending of waves as they change
  - The imaginary line (perpendicular to surface) to which we measure the angles is called the *normal line.*
- This change in direction is caused by the fact that light travels at different speeds in different media.
  - **Optical Density** is the property of a medium that determines the speed of light in the medium.
- Speed of light is greatest in a vacuum, so it is convenient to compare to this value.
- This ratio is called the **index of refraction (n).**

$$n = \frac{c}{v}$$

n = index of refraction
$c = 3 \times 10^8$ m/s
v = speed of light in medium

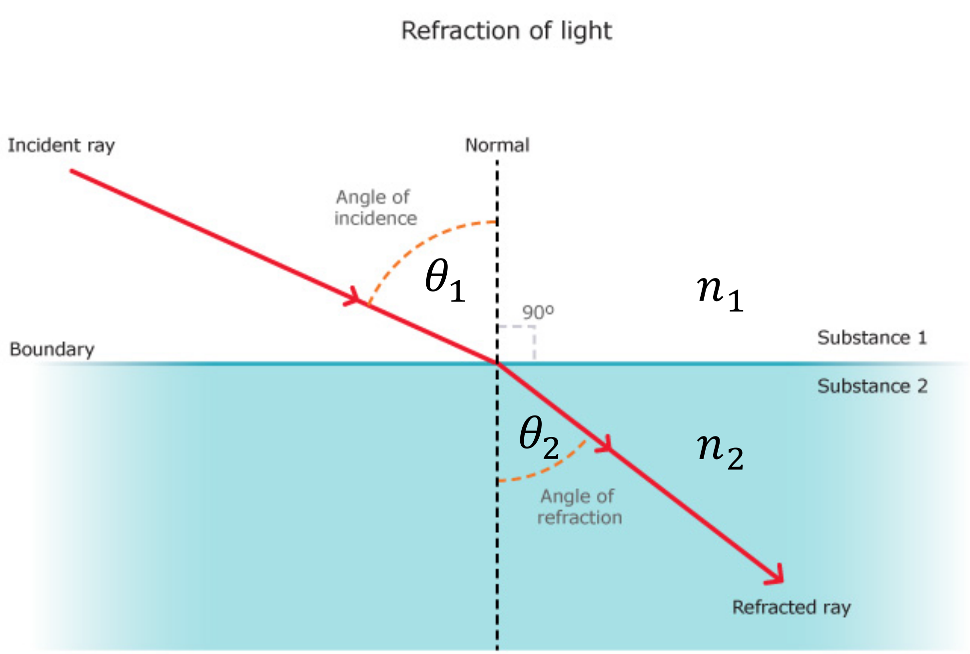
Substance	n
Glass	1.52
Water	1.33
Air	1.00
Ice	1.31
Diamond	2.42

Ex: Hickory, a watchmaker, is interested in an old timepiece that's been brought in for a cleaning. If light travels at 1.90×10^8 m/s in the crystal, what is the crystal's index of refraction?

Snell's Law

- Relationship between the angle of incidence (θ_1) and angle of refraction (θ_2) can be explained by **Snell's Law**.

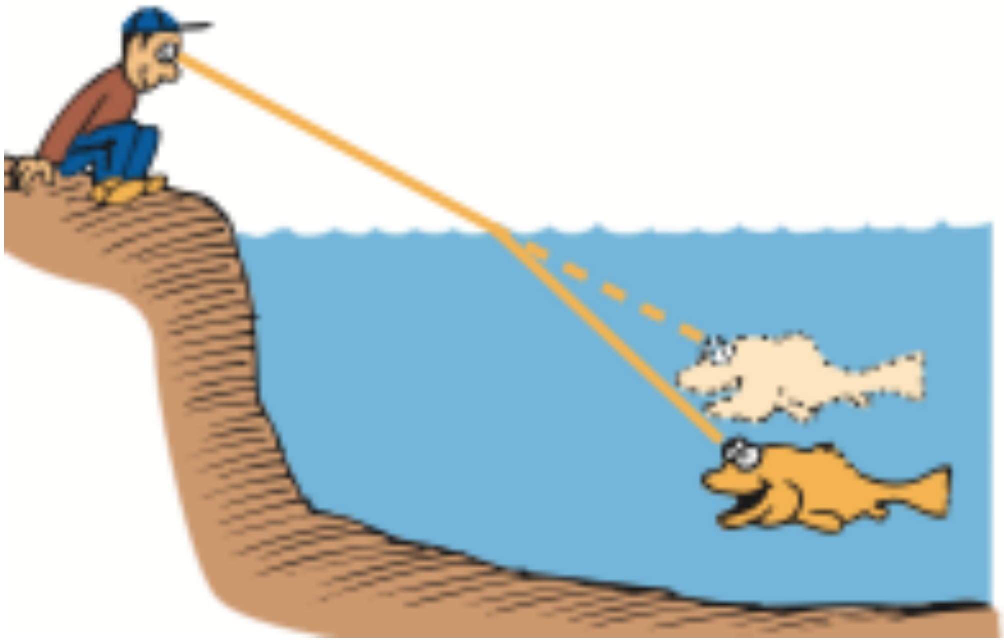
$$\frac{sin\theta_1}{sin\theta_2} = \frac{v_1}{v_2} \quad \text{or} \quad n_1 sin\theta_1 = n_2 sin\theta_2$$



- Light bends **TOWARDS** the normal when it moves from lower to higher optical density (slows down)
- Light bends **AWAY** from the normal when it moves from higher to lower optical density (speeds up).

Snell's Law and Refraction

- Crossing a boundary, the **frequency** of a wave does not change (to conserve energy). θ, v, and λ do change.
- Our brain thinks light travels in <u>straight lines</u>.
  - We see the fish shallow and far from the boat.

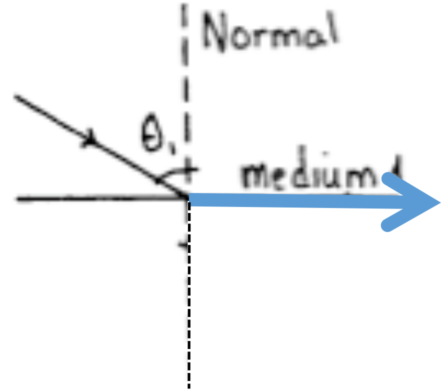


Ex: While fishing out on the lake one summer afternoon, Amy spots a large trout just below the surface of the water at an angle of 60.0° to the vertical, and she tries to scoop it out of the water with her net.

a) Draw the fish where Amy sees it.

b) At what angle should Amy aim for the fish? ($n_{water} = 1.33$).

Critical Angle
& Total Internal Reflection



- A special case of Snell's law is used when light travels ***from a more-dense medium to a less-dense medium*** and the refracted ray makes an angle of 90.0° with the normal.
- When this happens, the incident angle is called the <u>critical angle</u> (θ_C).

$$n_1 \sin\theta_c = n_2 \sin 90$$

- If the incident angle is bigger than the critical angle, there is no refraction. All the light is reflected back, and we get <u>total internal reflection</u>.