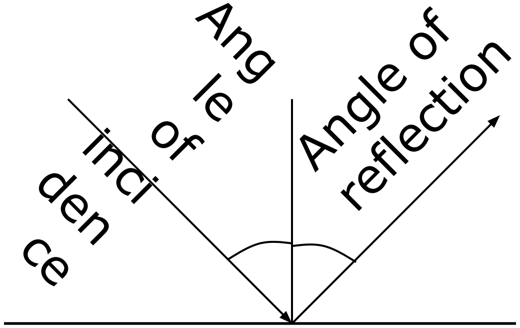
Reflection, Refraction, and Diffraction

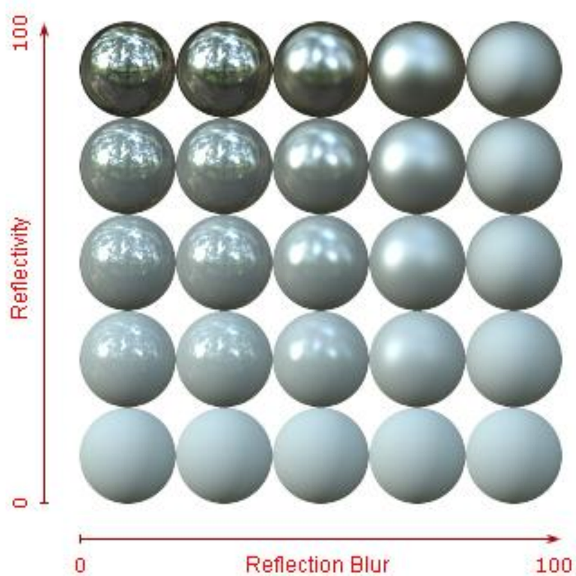
Reflection

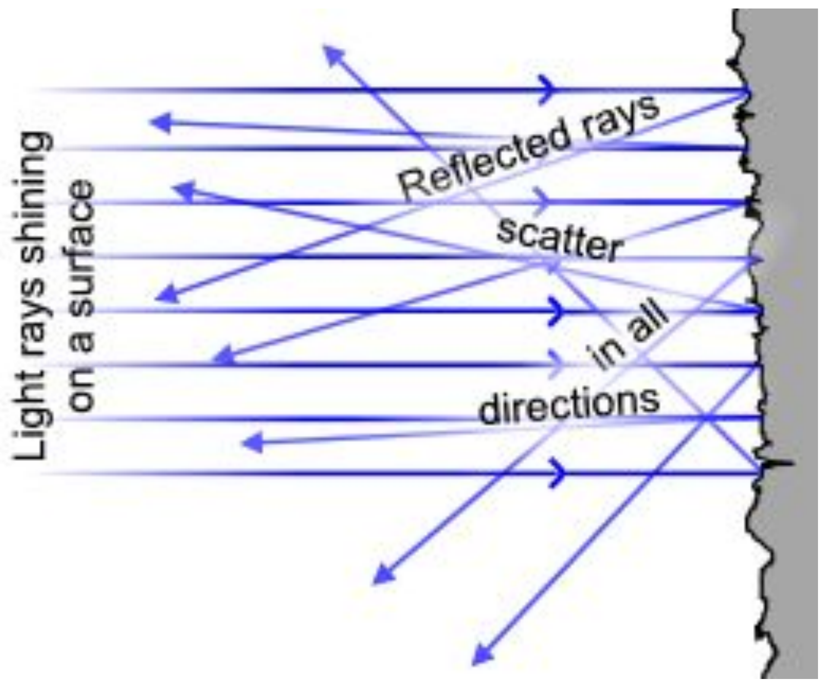
- **Reflection** – wave strikes a surface and is bounced back.
  - **Law of Reflection**: angle of incidence = angle of reflection
    - Assumes smooth surface.
    - Measured from normal.



Specular vs. Diffuse Reflection

- **Specular Reflection**
  - Mirror-like
  - Retains image
- **Diffuse Reflection**
  - Energy reflects but not image.





Refraction

- **Refraction** – change in wave’s direction as it passes from one medium to another.
  - Due to differences in speed of wave.
- **Index of refraction** (n) – measure of how much a wave’s speed is reduced in a particular medium.
  - Most frequently applied to light.

- $$n_{medium} = \frac{\text{speed of light in vacuum} = c_{vacuum}}{\text{speed of light in medium} = c_{medium}}$$
- Speed of light in vacuum = 300,000 km/s.

Refraction

Refraction

- The refractive index of glass is 1.50. What is the speed of light in glass?

- $n = c_{vacuum} / c_{medium}$

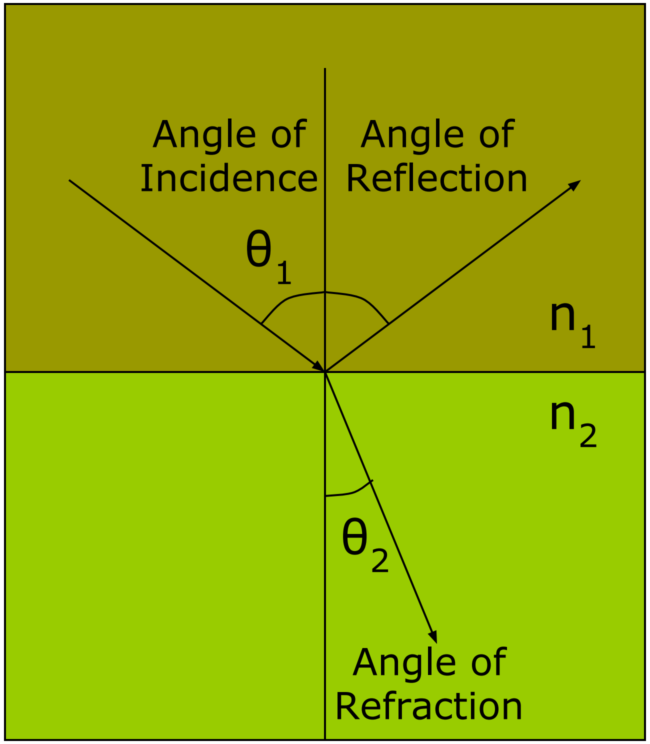
- $1.50 = (300{,}000 \text{ km/s}) / (c_{medium})$
- $c_{medium} = (300{,}000 \text{ km/s}) / 1.50$
- $c_{medium} = 200{,}000 \text{ km/s}$

Refraction

- The refractive indices of several materials are:
  - water = 1.33
  - air = 1.00
  - diamond = 2.42
  - glycerin = 1.47
- Through which material does light travel the fastest? The slowest?

Snell's Law

- As light waves pass from one medium to another, they also change direction.
- Snell's Law:
  - $n_1 \sin\theta_1 = n_2 \sin\theta_2$

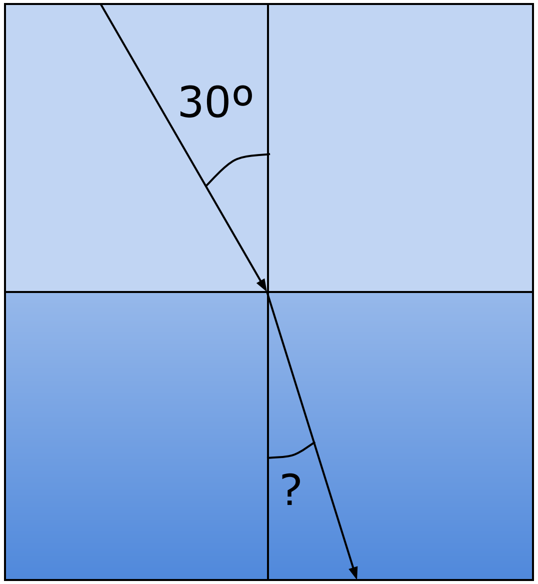


Snell's Law

- As a wave passes from low *n* to high *n*, it bends *toward* the normal.
- As a wave passes from high *n* to low *n*, it bends *away from* the normal.
- If *n* is the same for both media, the wave does not bend.

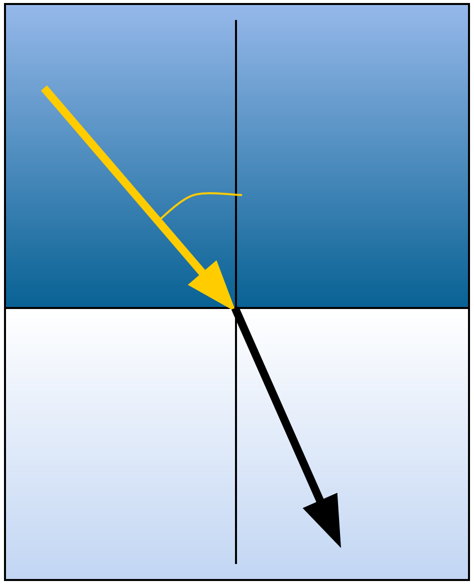
Snell's Law

- A light wave passes from air (n = 1) to water (n = 1.33). If the angle of incidence is 30º, what is the angle of refraction?
  - $n_1 \sin\theta_1 = n_2 \sin\theta_2$
  - $(1)(\sin 30^\circ) = (1.33)(\sin\theta_2)$
  - $0.5 = (1.33)(\sin\theta_2)$
  - $\sin\theta_2 = 0.376$
  - $\theta_2 = 22.1^\circ$



Snell's Law

- A light beam passes from water (n = 1.33) into diamond (n = 2.42). The beam is incident upon the interface at an angle 56º from the normal. What is the refracted angle of the light?
- $n_1 \sin\theta_1 = n_2 \sin\theta_2$
- $(1.33)(\sin 56^\circ) = (2.42)(\sin\theta_2)$
- $1.10 = (2.42)(\sin\theta_2)$
- $\sin\theta_2 = 0.455$
- $\theta_2 = 27.1^\circ$



Snell's Law

- A light beam exits a fiber optic cable (n = 1.42) at an incident angle of 22.5º. At what angle does the light beam enter the air (n = 1)?
- $n_1 \sin\theta_1 = n_2 \sin\theta_2$
- $(1.42)(\sin 22.5^\circ) = (1)(\sin\theta_2)$
- $0.543 = \sin\theta_2$
- $\theta_2 = 32.9^\circ$

Total Reflection

- When a wave passes from a low *n* to a high *n*, the angle increases.
  - At a certain incident angle, the refractive angle = 90º.
- **Critical angle** (θ_c)
  - For light passing from low *n* to high *n*, the incident angle above which there is no refraction.
  - Above θ_c all light is reflected back into the incident medium.

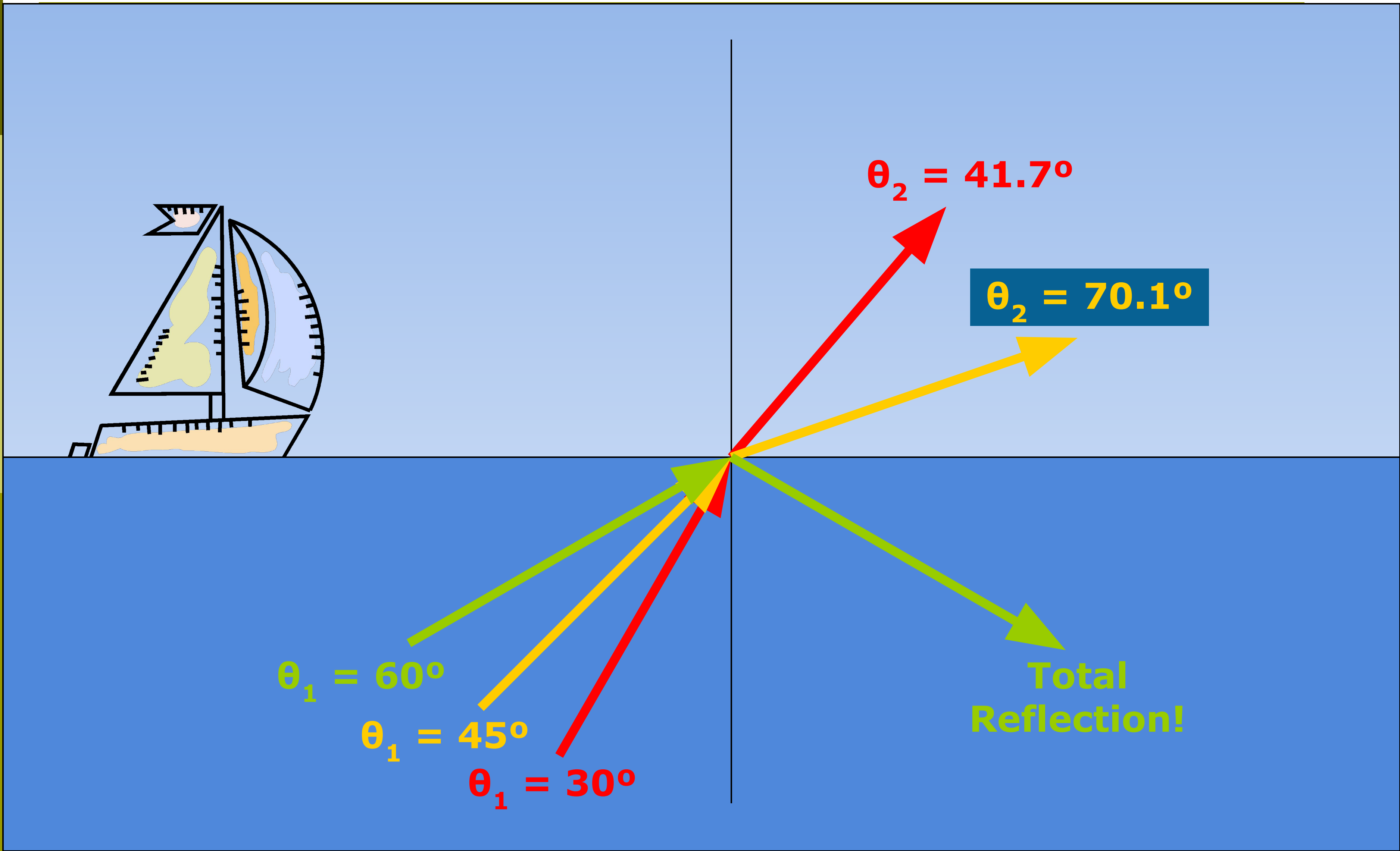
Critical Angle

- We can work out the formula for critical angle:
  - We know that the refracted angle is 90º, so:
  - $n_1 \sin\theta_c = n_2(\sin 90º)$
    - $\sin 90º = 1$
  - $n_1 \sin\theta_c = n_2$
  - $\sin\theta_c = \frac{n_2}{n_1}$
  - $\theta_c = \arcsin\left[\frac{n_2}{n_1}\right]$

Critical Angle

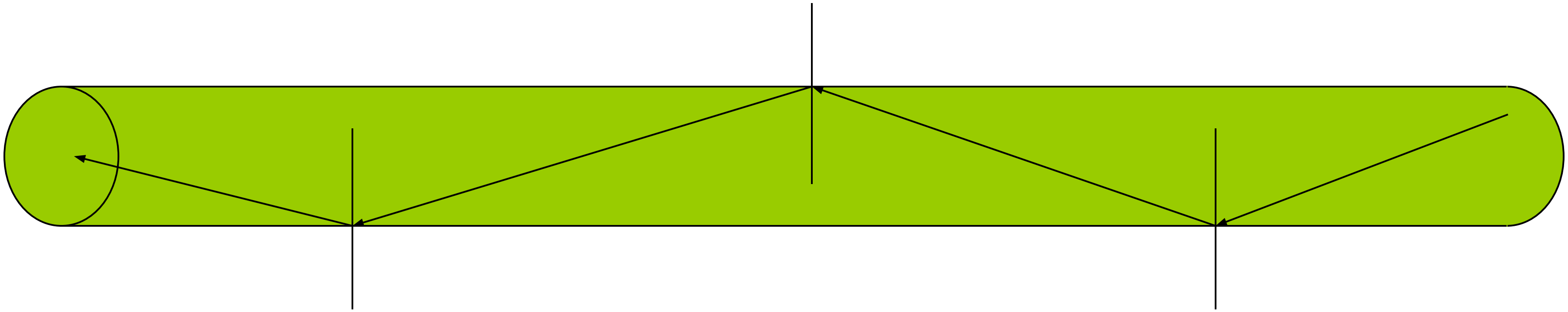
- What is the critical angle for the water-air boundary? (n_{water} = 1.33 and n_{air} = 1)
  - $\theta_c = \arcsin(n_2 / n_1)$
  - $\theta_c = \arcsin(1 / 1.33)$
  - $\theta_c = \arcsin(0.752)$
  - $\theta_c = 48.8^o$

Critical Angle



Fiber Optics

- Fiber optics cables make use of total reflection to keep a beam of light trapped inside the cable, even around bends.



Diffraction

- **Diffraction** – The bending of waves around an obstacle.
  - Can let you hear sounds the originate behind an obstacle.
  - Explains how waves can shape coastlines.
  - Explains the diffraction pattern produced in the double-slit experiment.