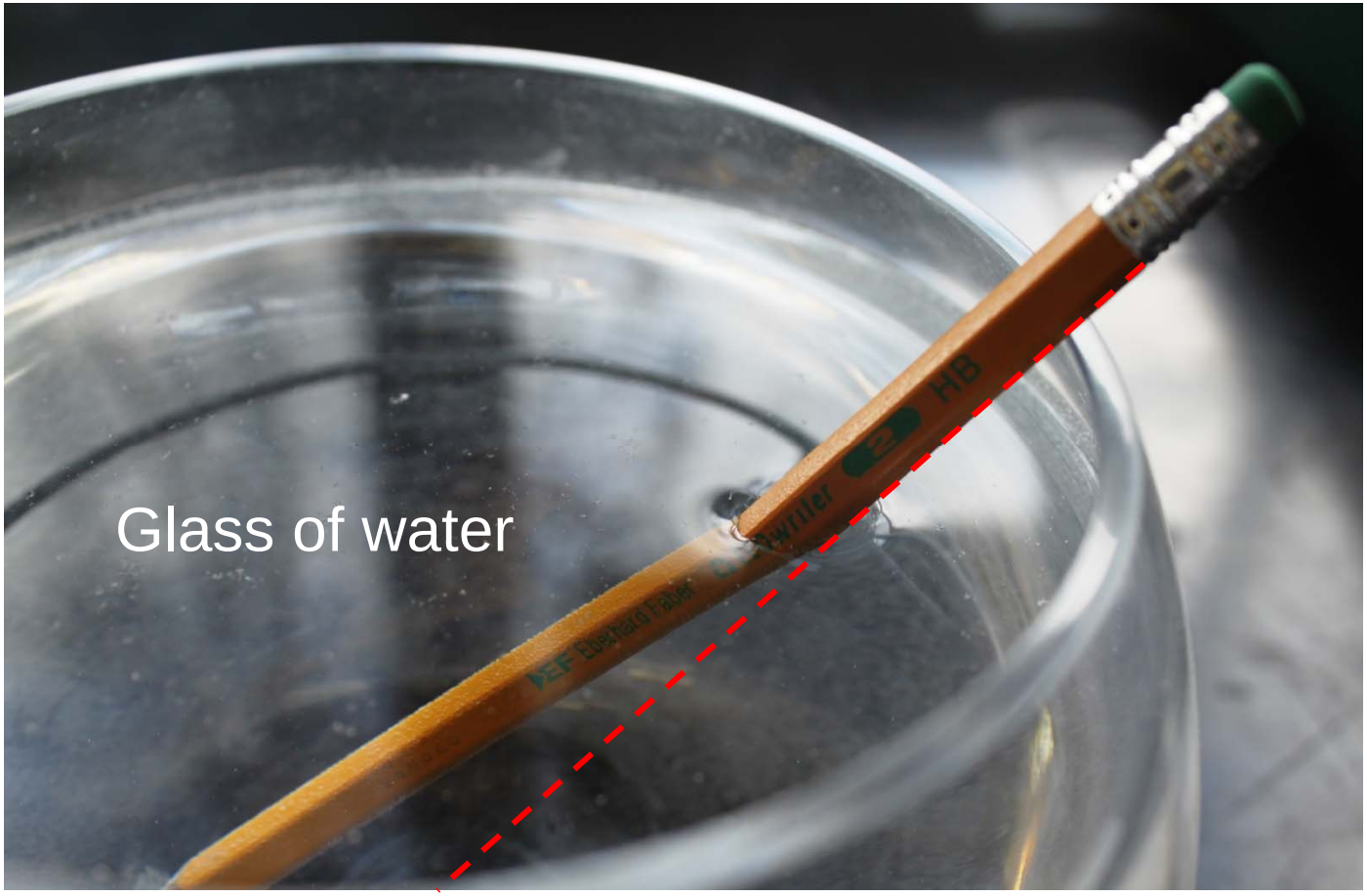
Refraction
Part 1

National Science Foundation
WHERE DISCOVERIES BEGIN

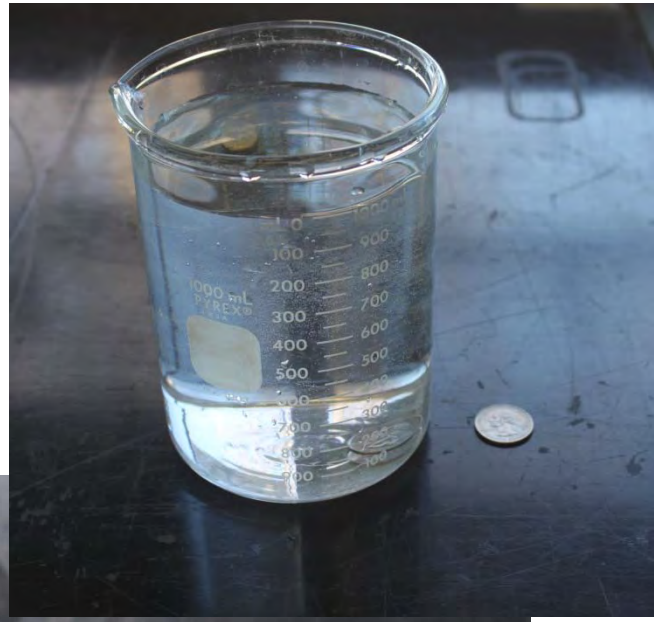
Refraction Distortions

Pencil appears to be bent
under the surface of the water.



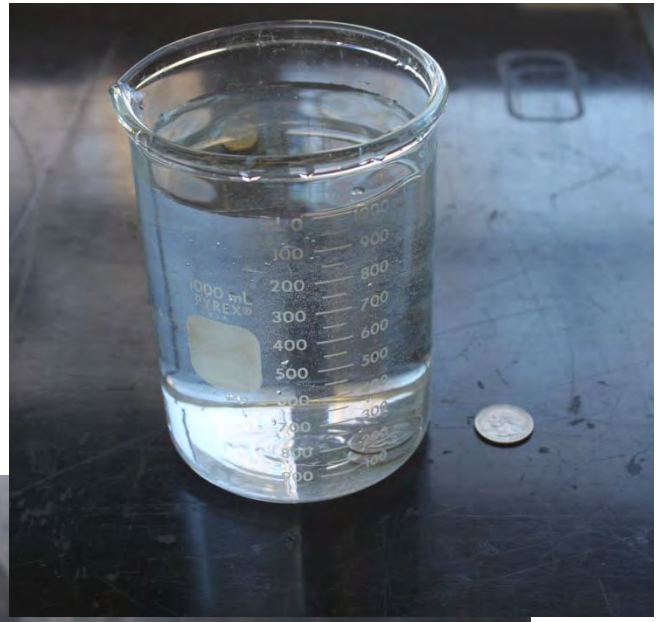
Refraction & Distance

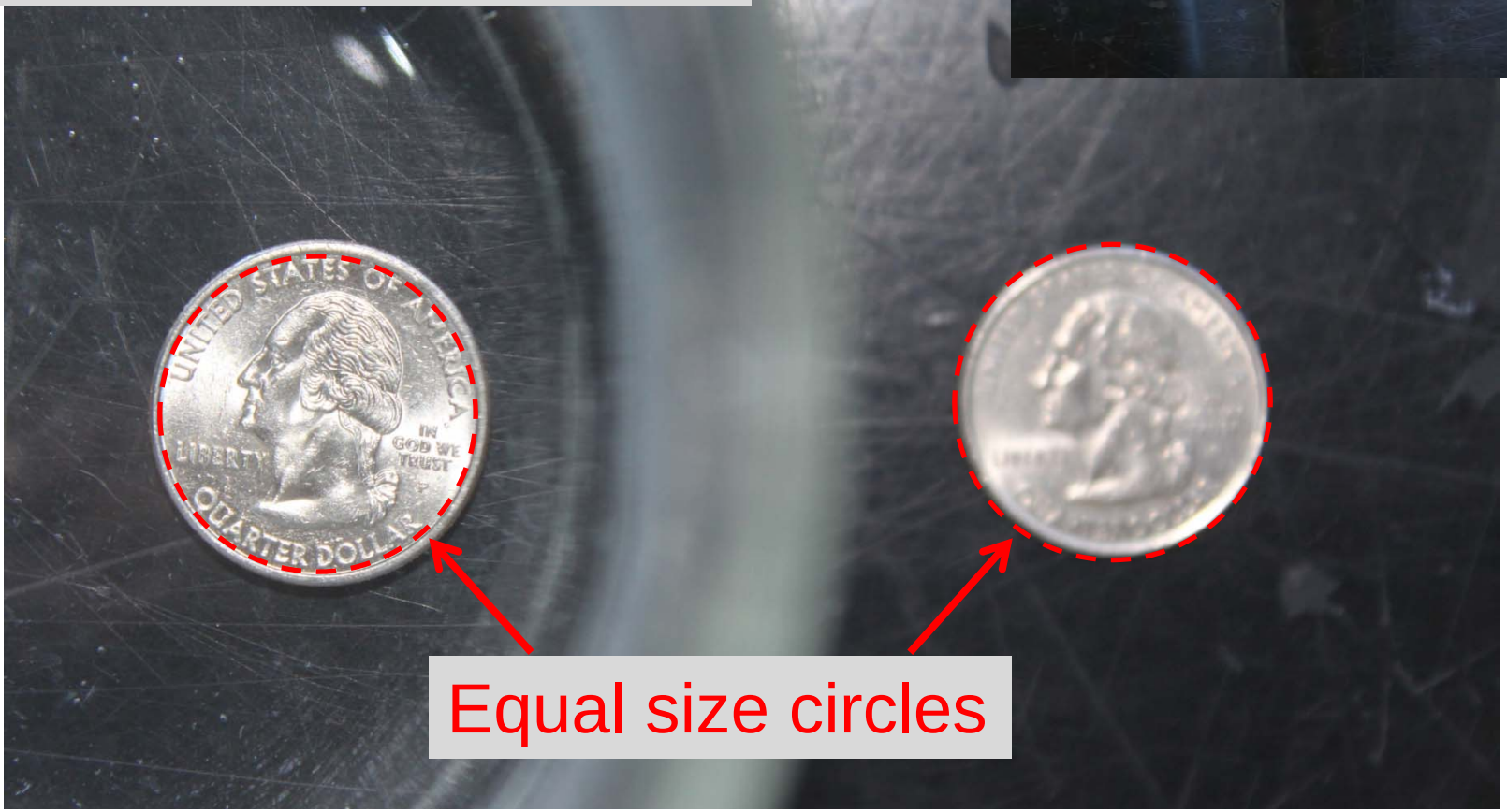
The coin underwater appears to be *closer*.



Refraction & Size

The coin underwater appears to be *larger*.

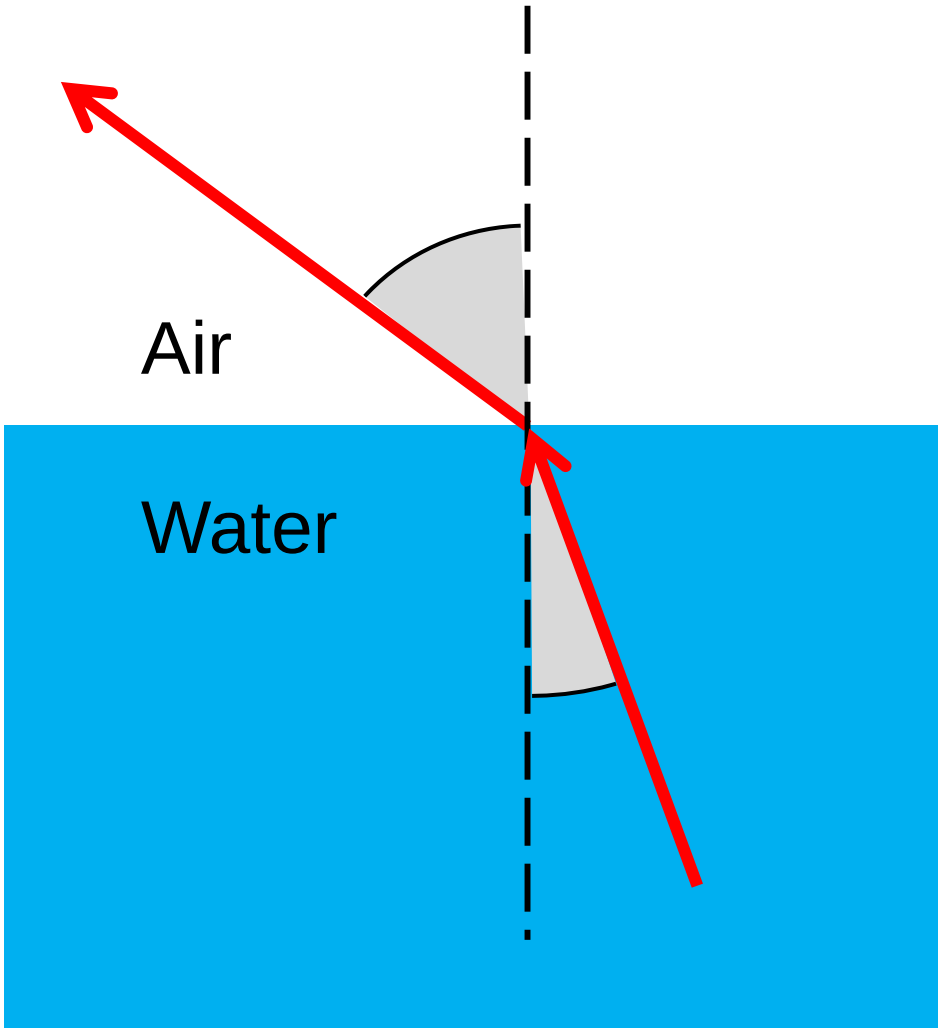




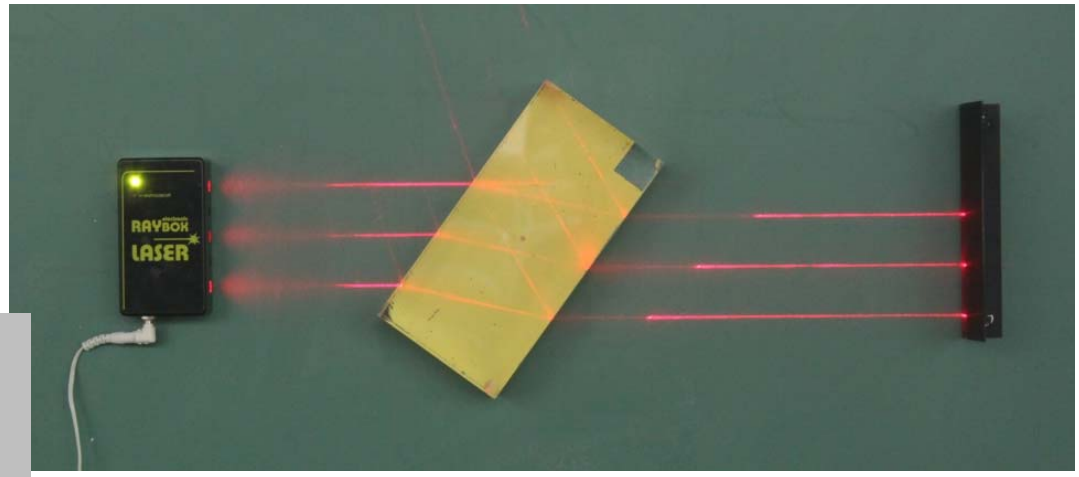
Refraction

Light rays passing from one material to another are deflected by an angle that depends on the optical properties of each material.

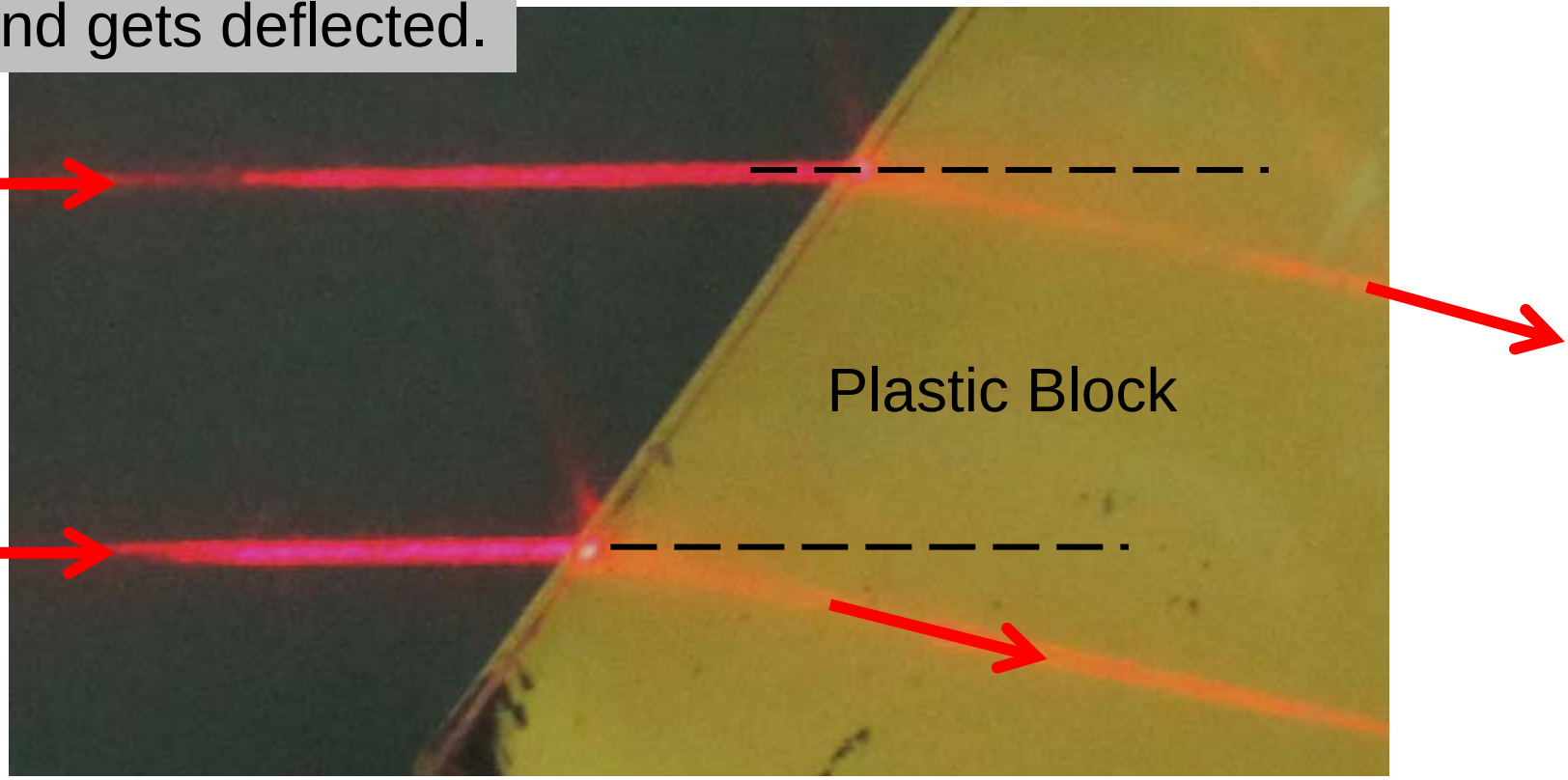
This effect is called *refraction*.



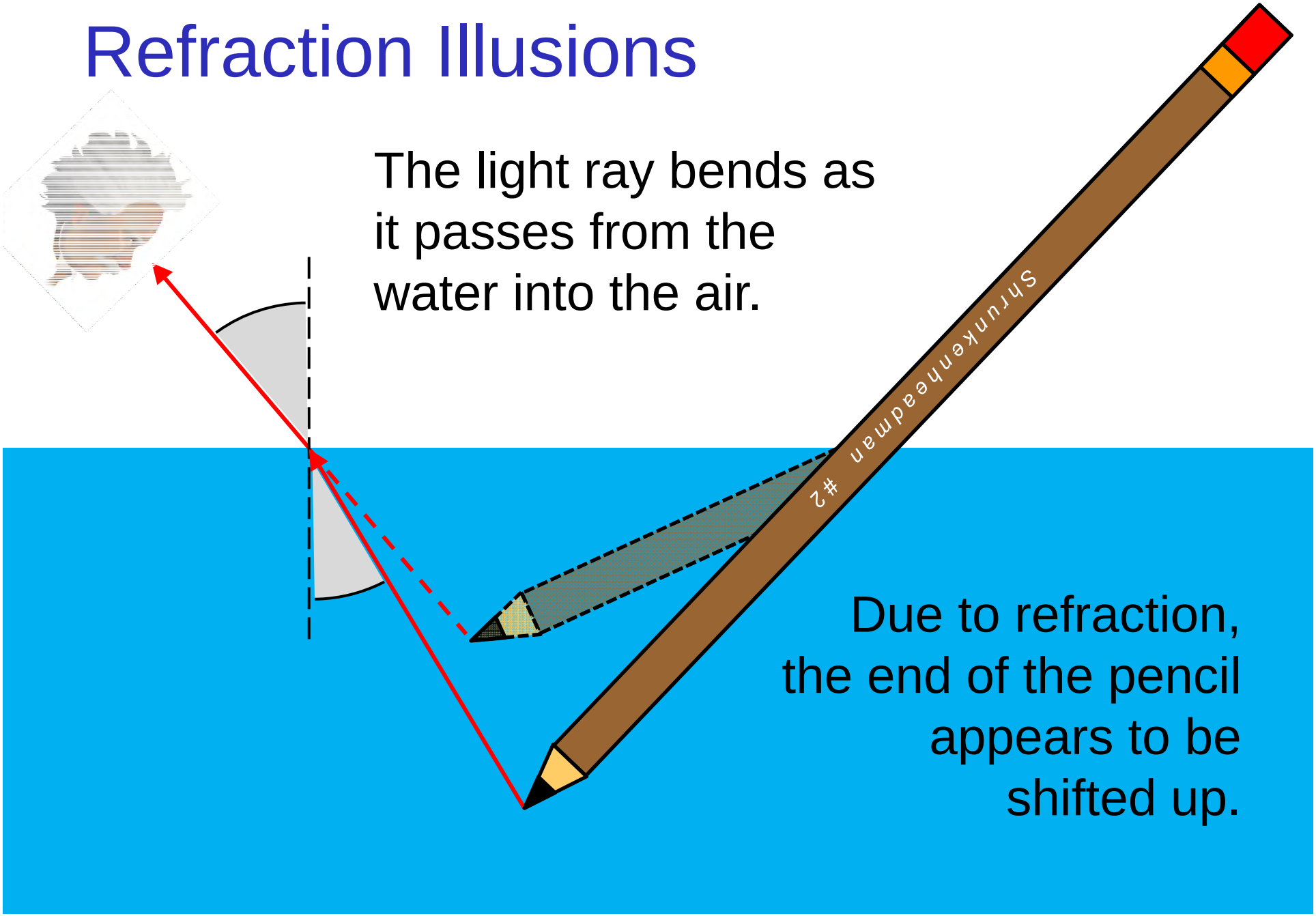
Refraction



Laser light enters the clear plastic block at an angle and gets deflected.

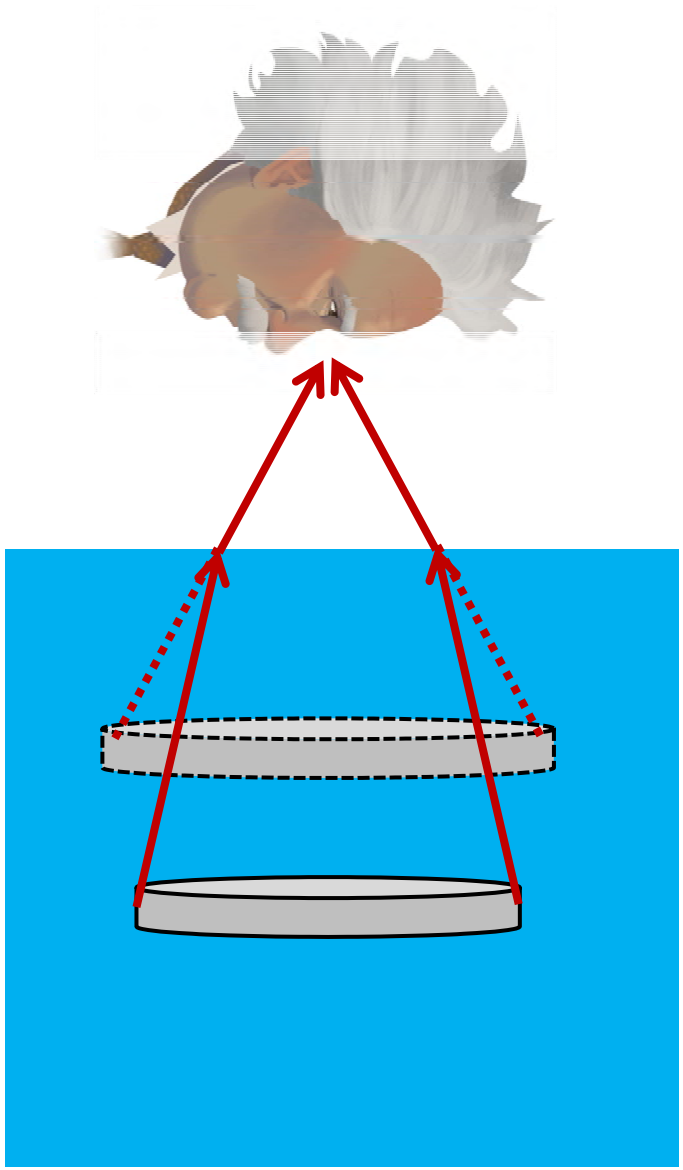


Refraction Illusions



Refraction Illusions

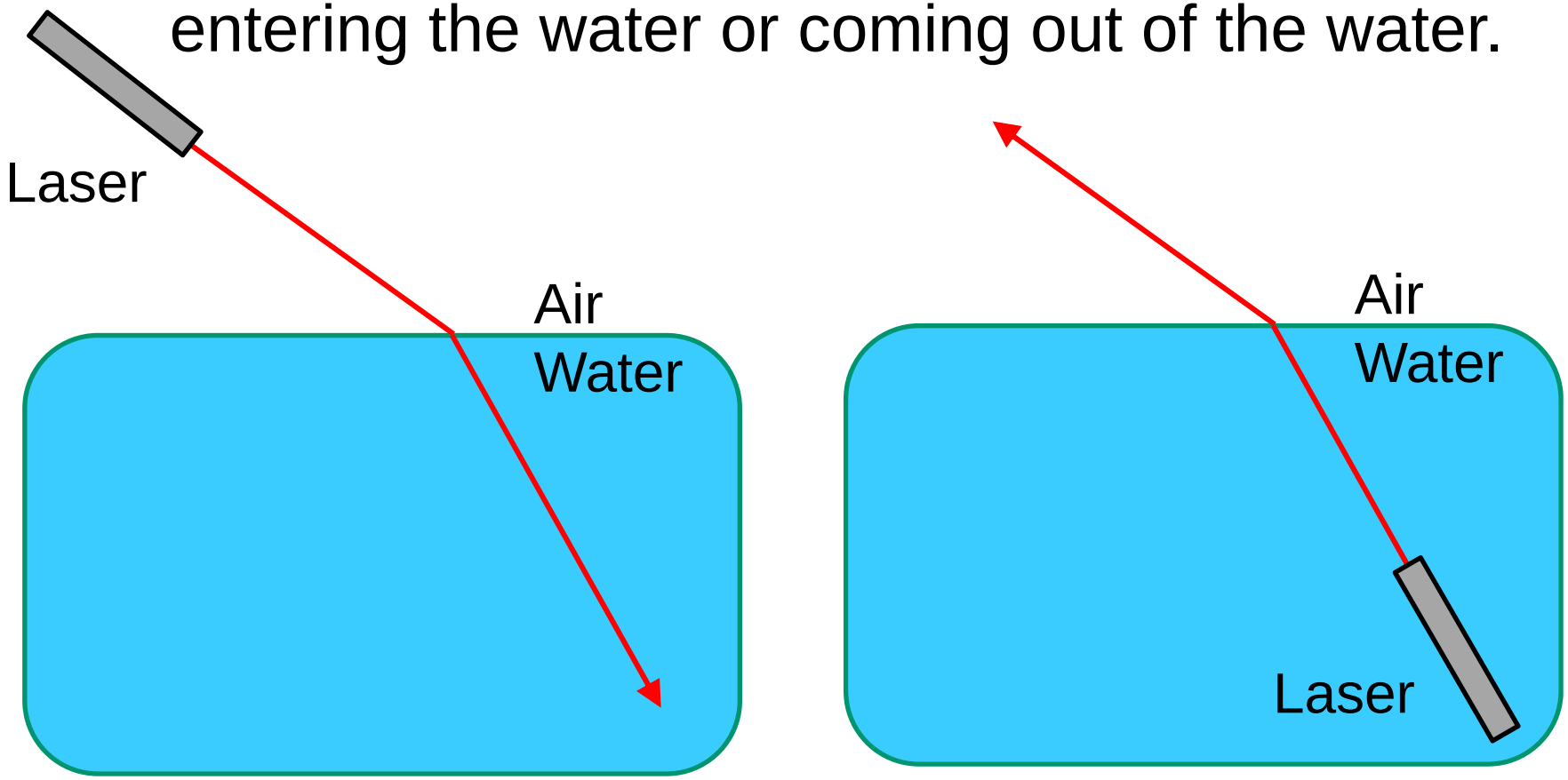
Refraction also explains why the coin underwater appears to be closer to the surface and larger.



The magnification is enhanced when viewed from the side the due to the curvature of the glass (lensing effect).

Reciprocity

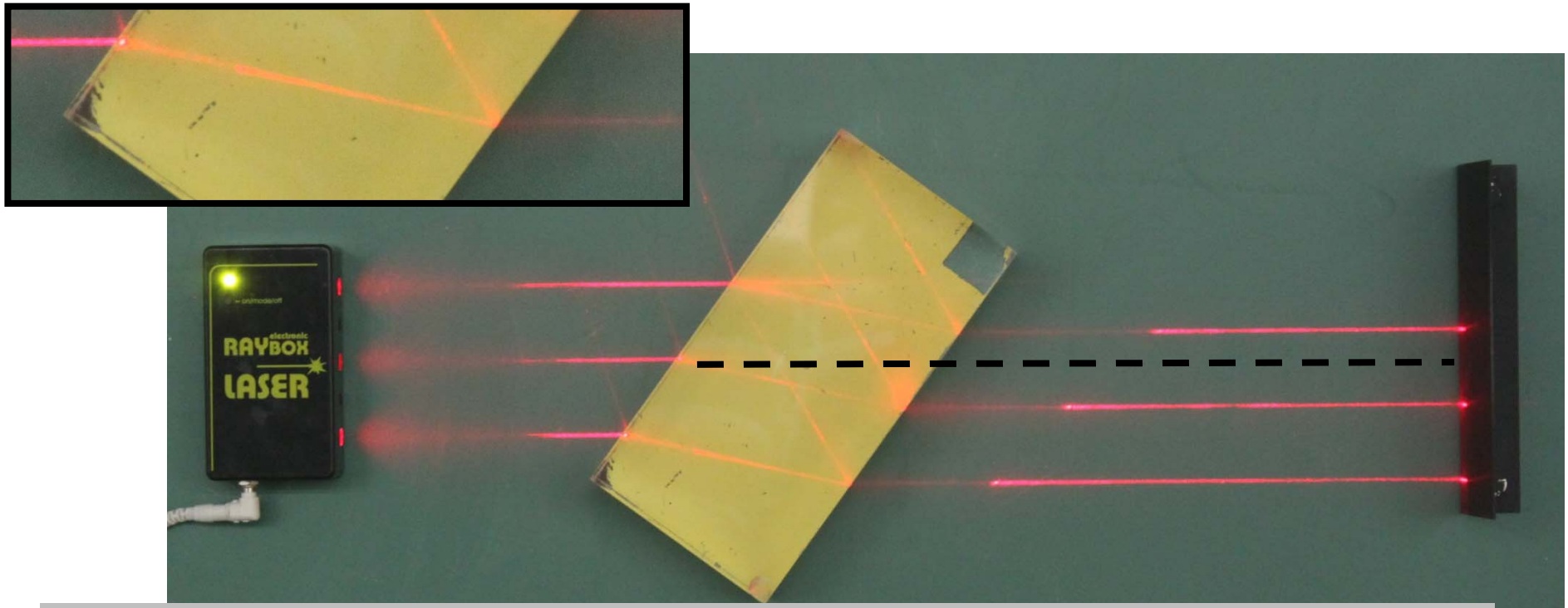
Light bends the same way whether it's entering the water or coming out of the water.



This symmetry for light rays is called *reciprocity*.

Refraction thru a Block

Light is refracted entering the block and refracted back on leaving the block.



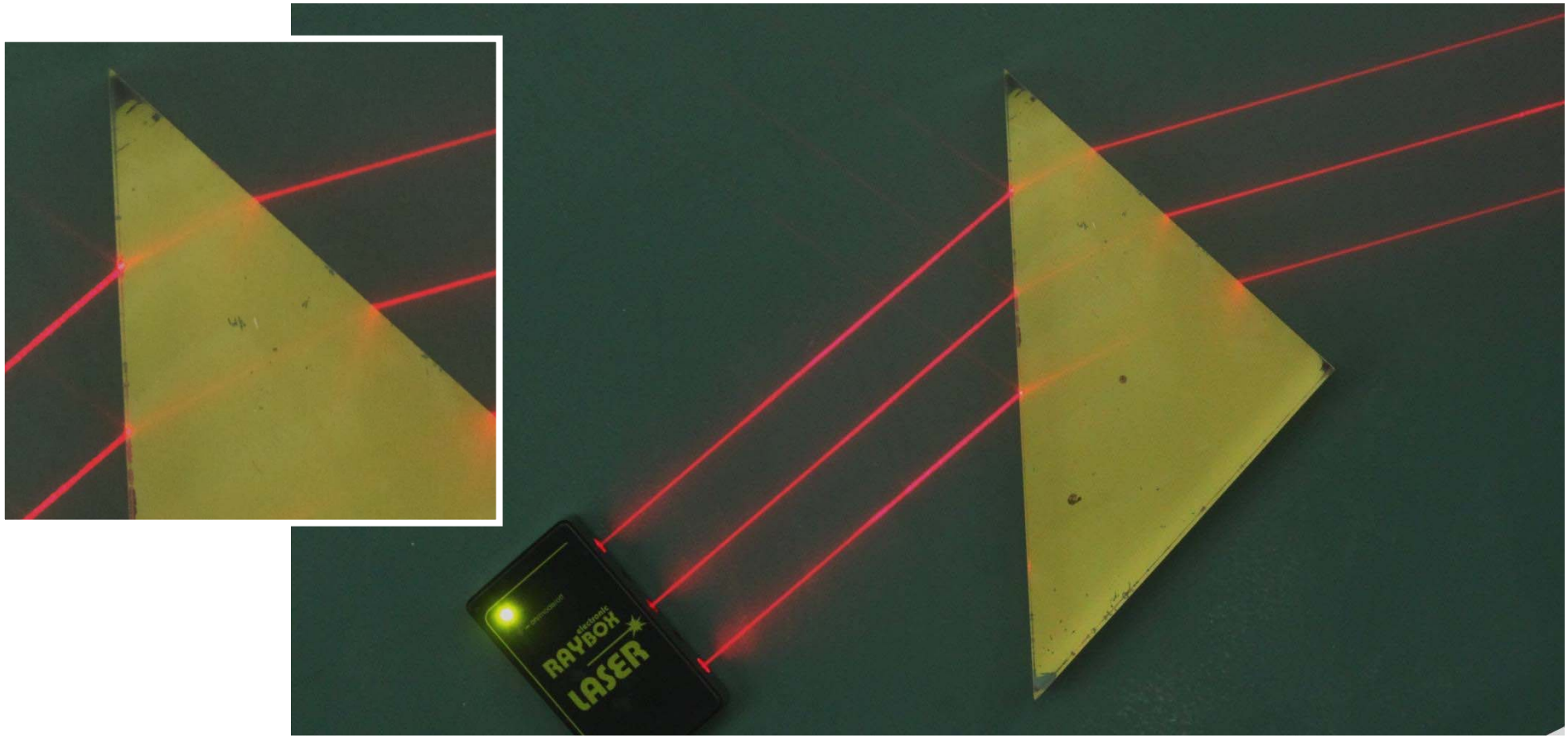
By reciprocity the light rays entering and exiting are parallel

Glass Windows

Refraction has little effect on the view when looking out of a glass window.

Refraction in a Wedge

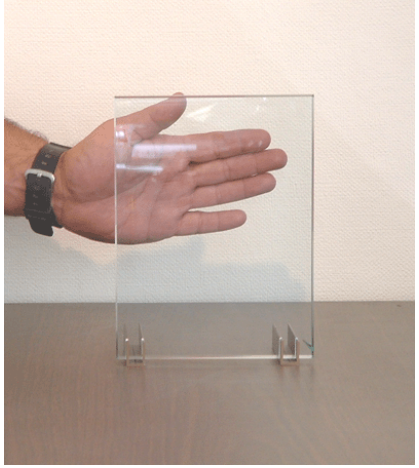
A wedge shape deflects the direction of the light rays passing through it.

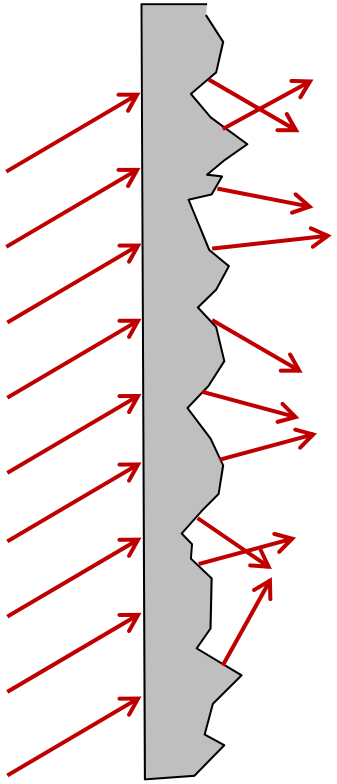


Frosted Glass

Frosted glass has an irregular surface that scrambles the direction of the light passing through it.

Smooth glass



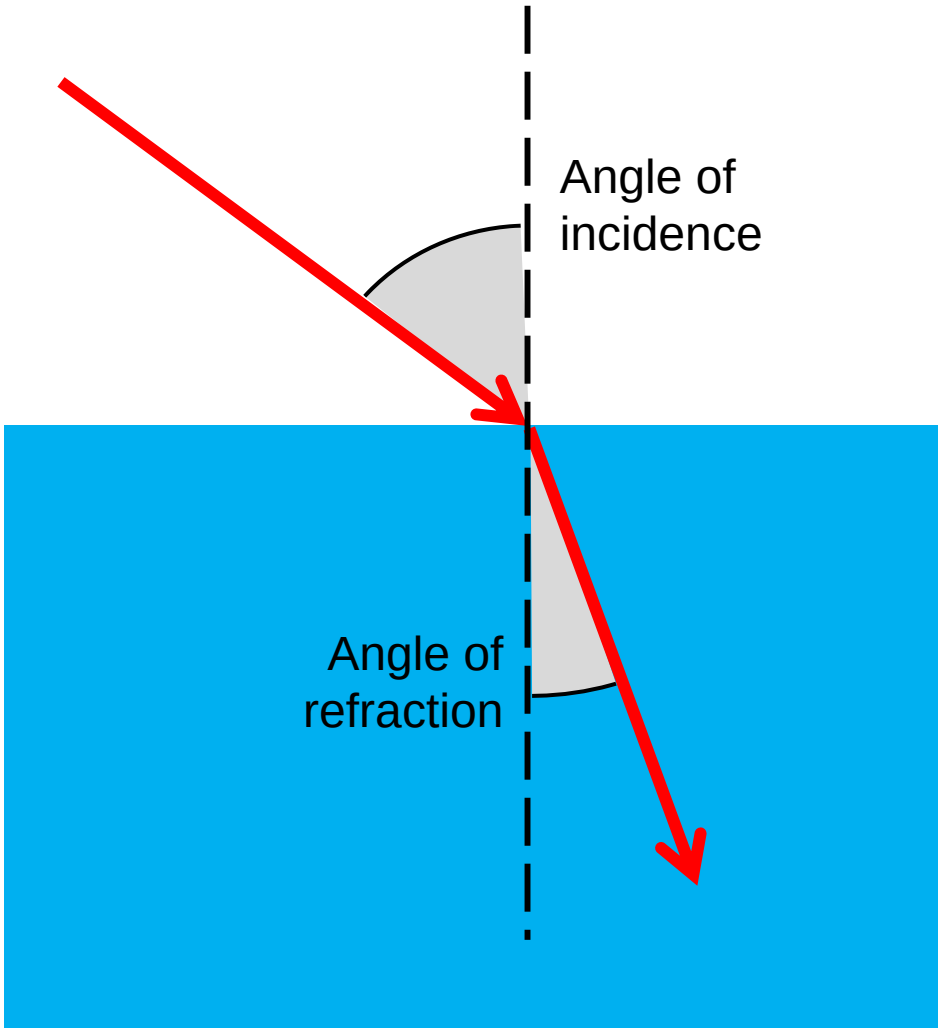


Angle of Refraction

The angle of refraction gives the deflection of the incident light ray.

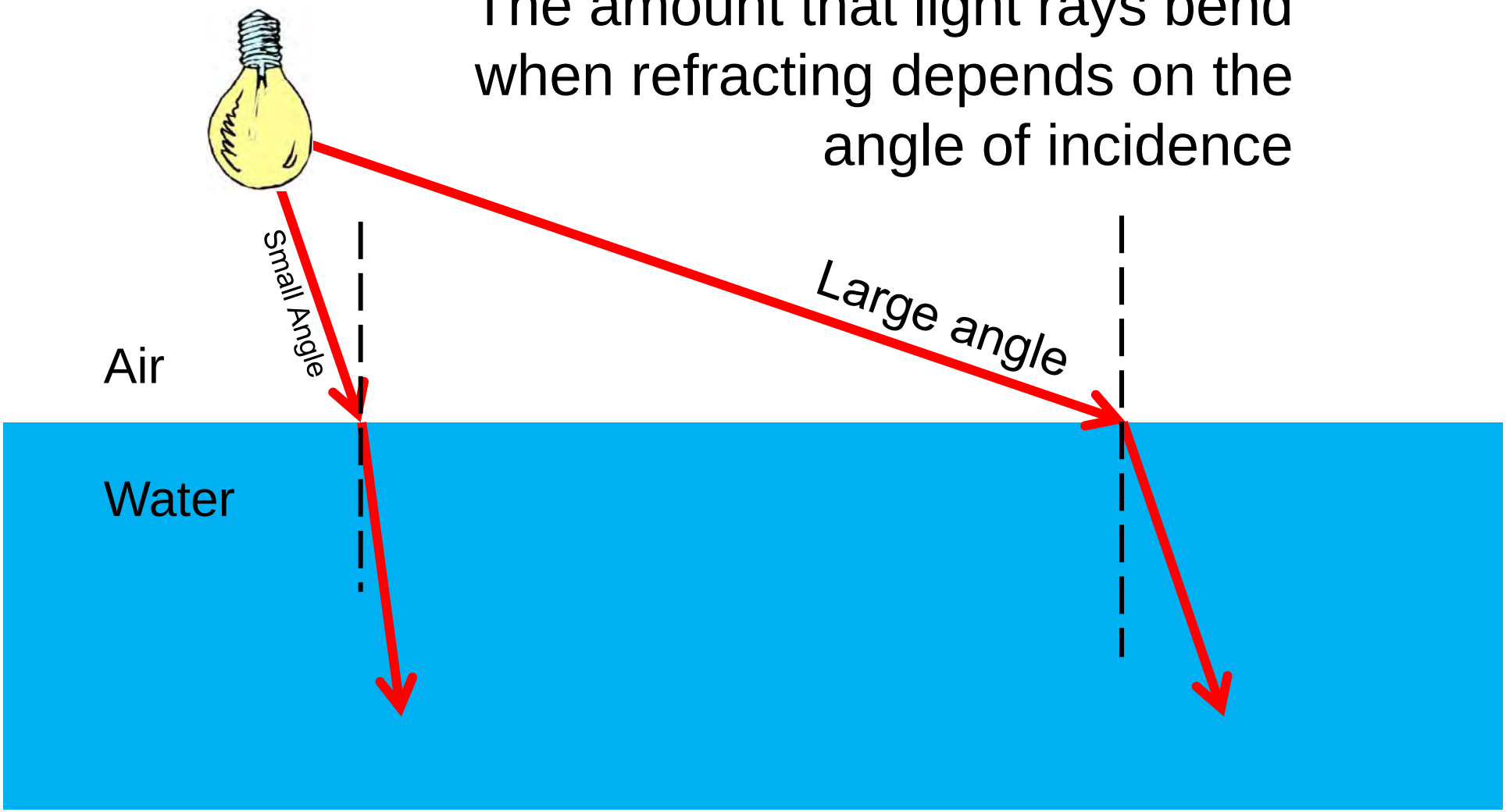
The larger the angle of incidence, the larger the deflection.

The formula is called *Snell's law*.



Refraction Angles

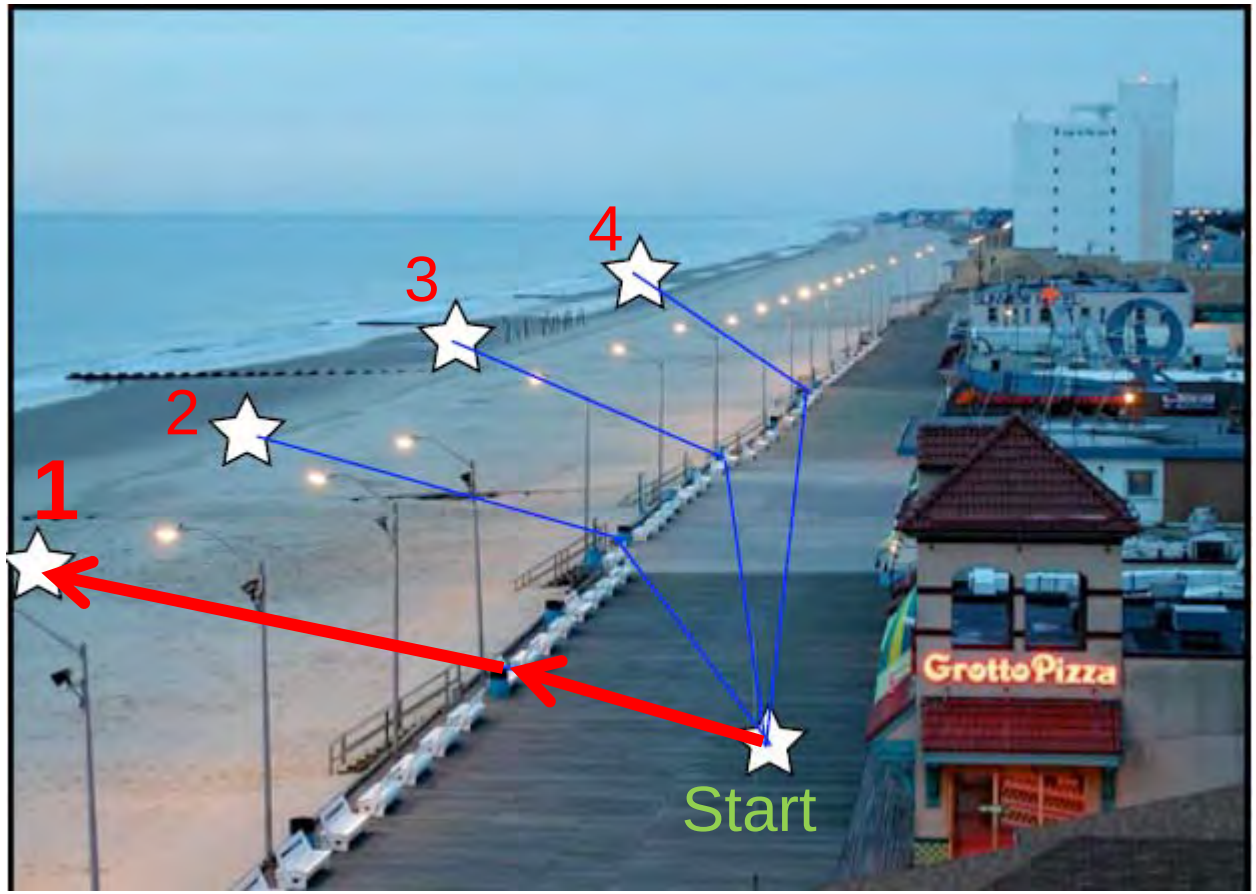
The amount that light rays bend when refracting depends on the angle of incidence



Fermat's Principle

Easy to walk on the boardwalk but you go slower walking on the sandy beach.

Walking to location #1 you would go fairly straight.



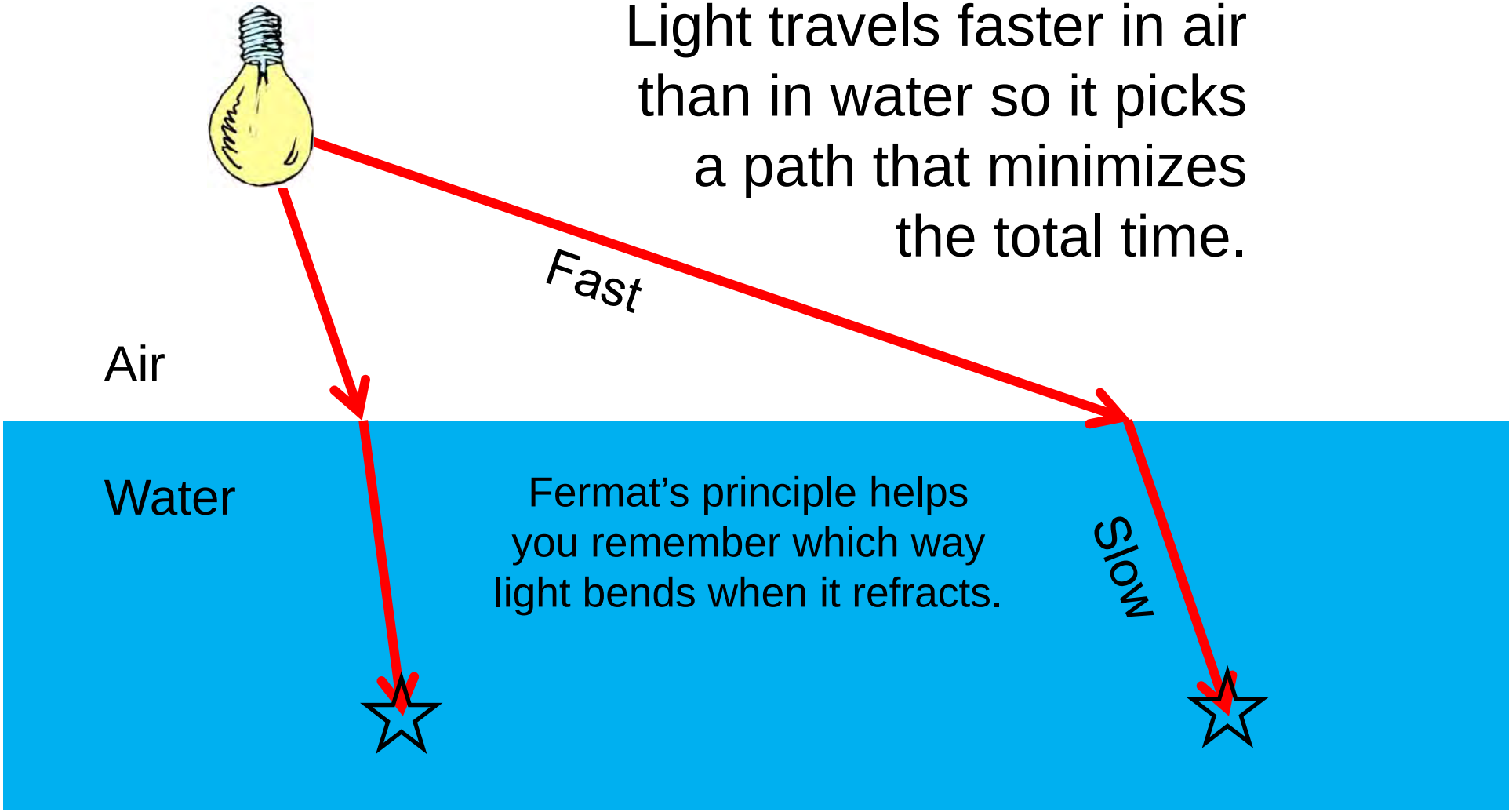
Fermat's Principle

Easy to walk on the boardwalk but you go slower walking on the sandy beach.

Walking to location #4 you go farther along the boardwalk then cut across

Fermat's Principle

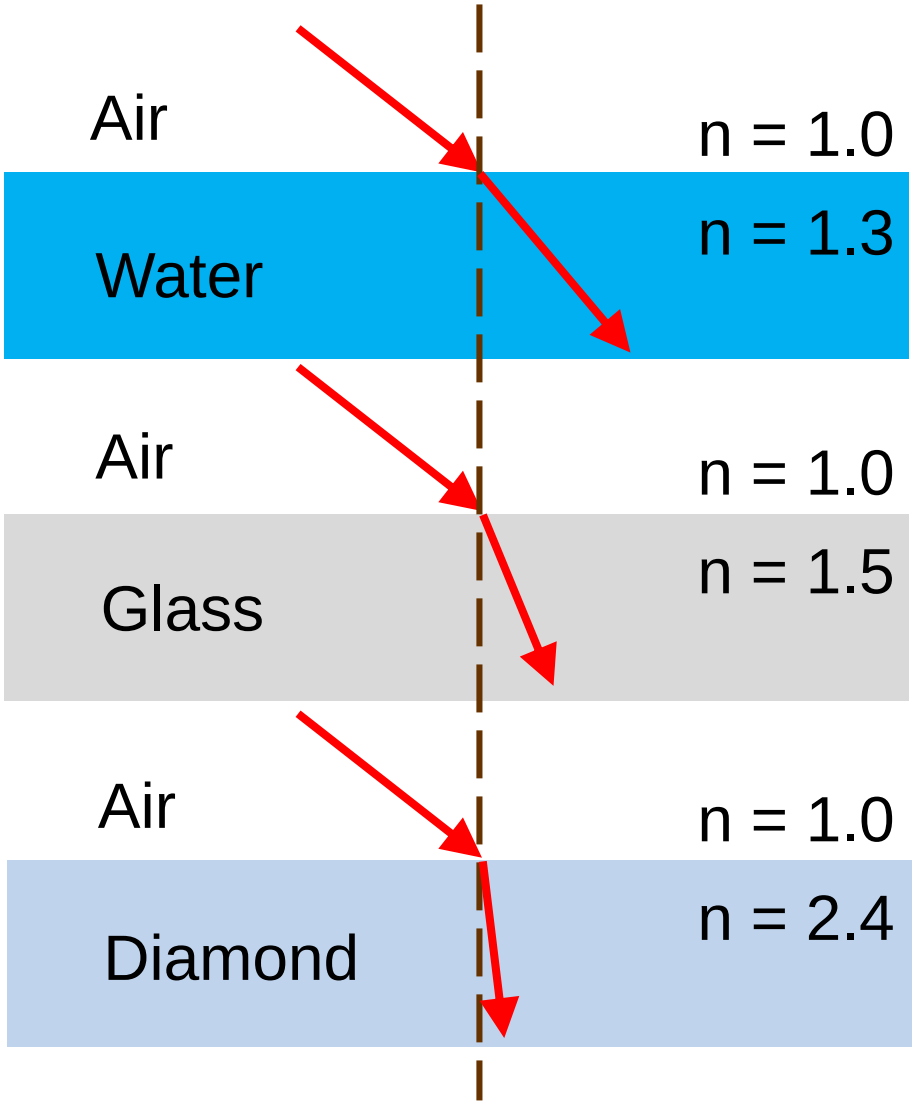
Light travels faster in air than in water so it picks a path that minimizes the total time.



Index of Refraction

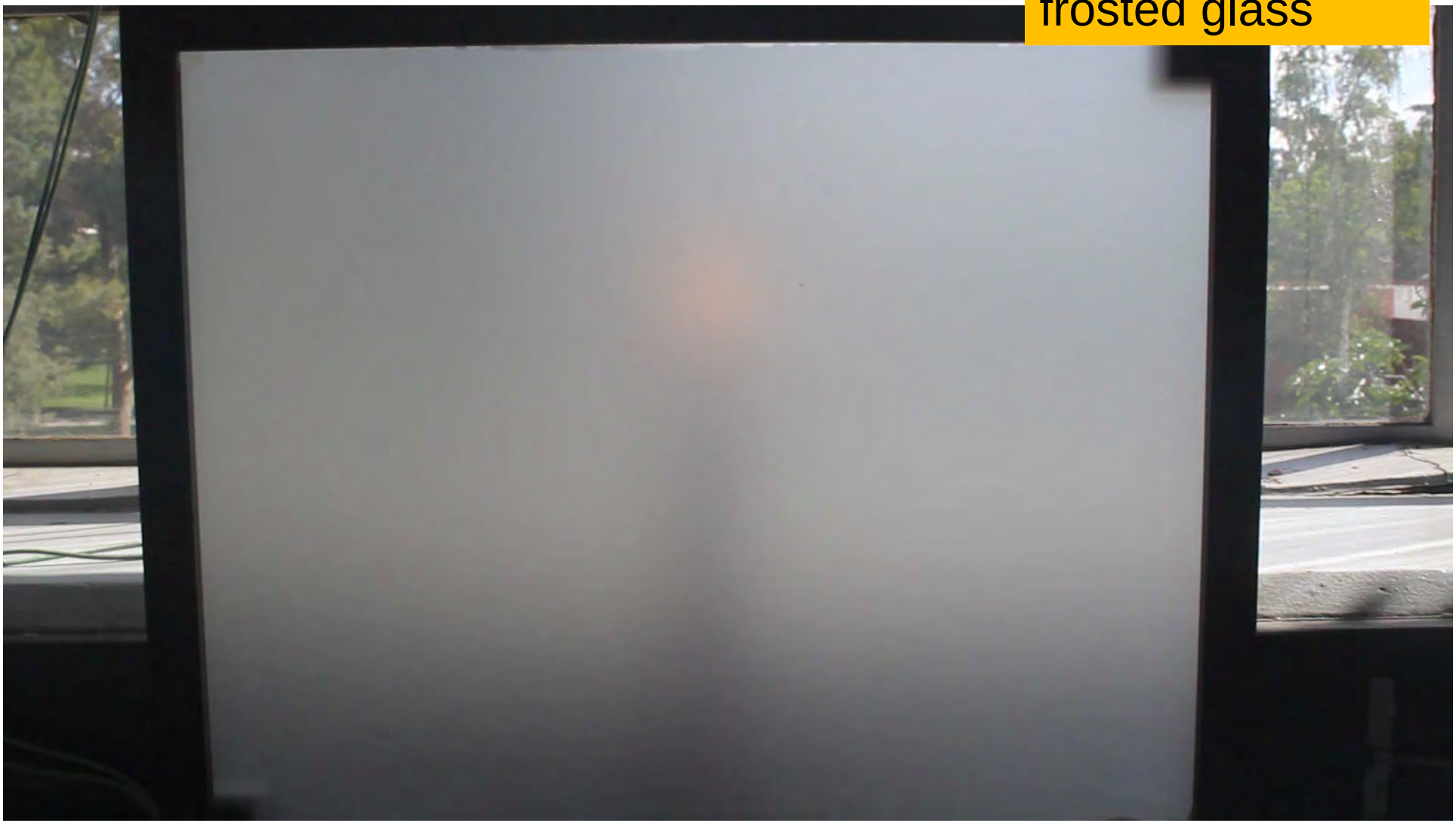
Index of refraction indicates the speed of light in a material.

Larger the difference between the indices at an interface, the larger the deflection.



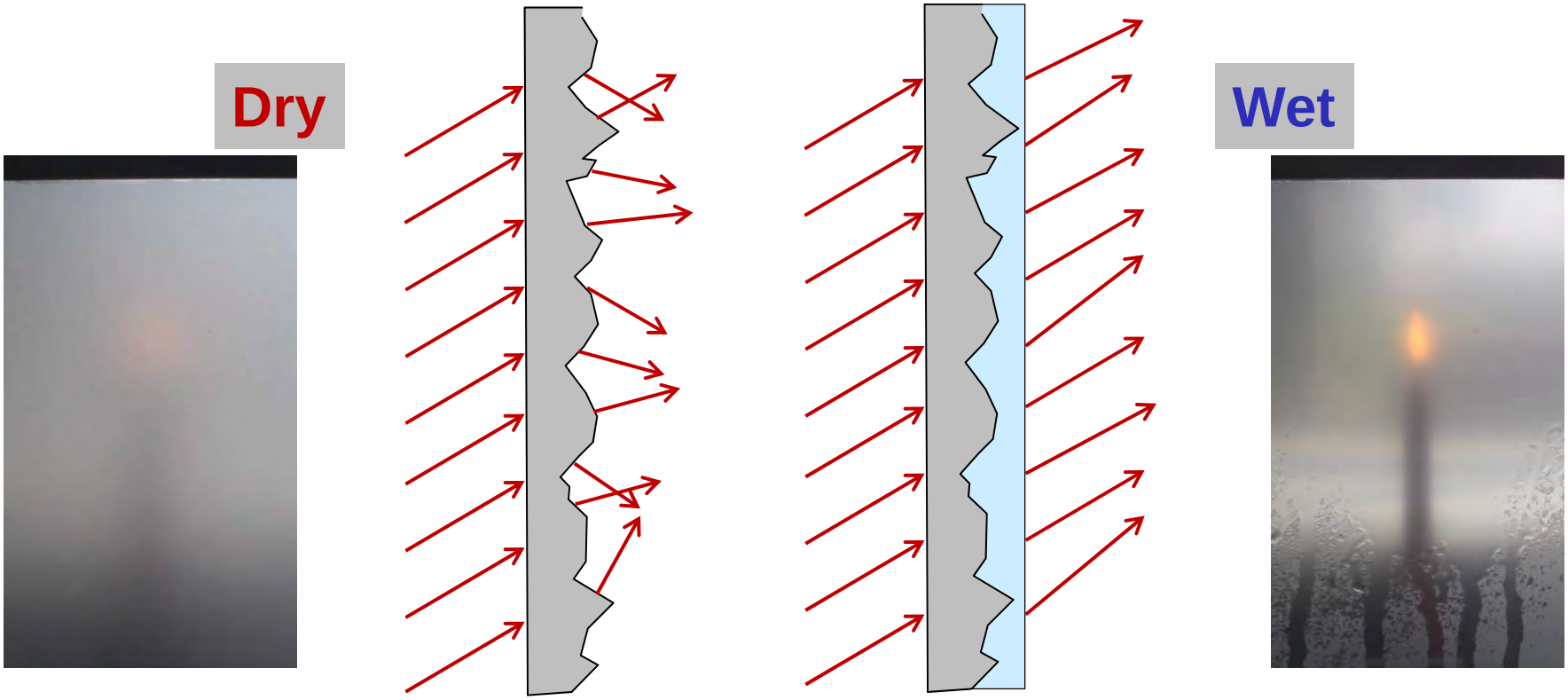
Water on Frosted Glass

Spray water on frosted glass

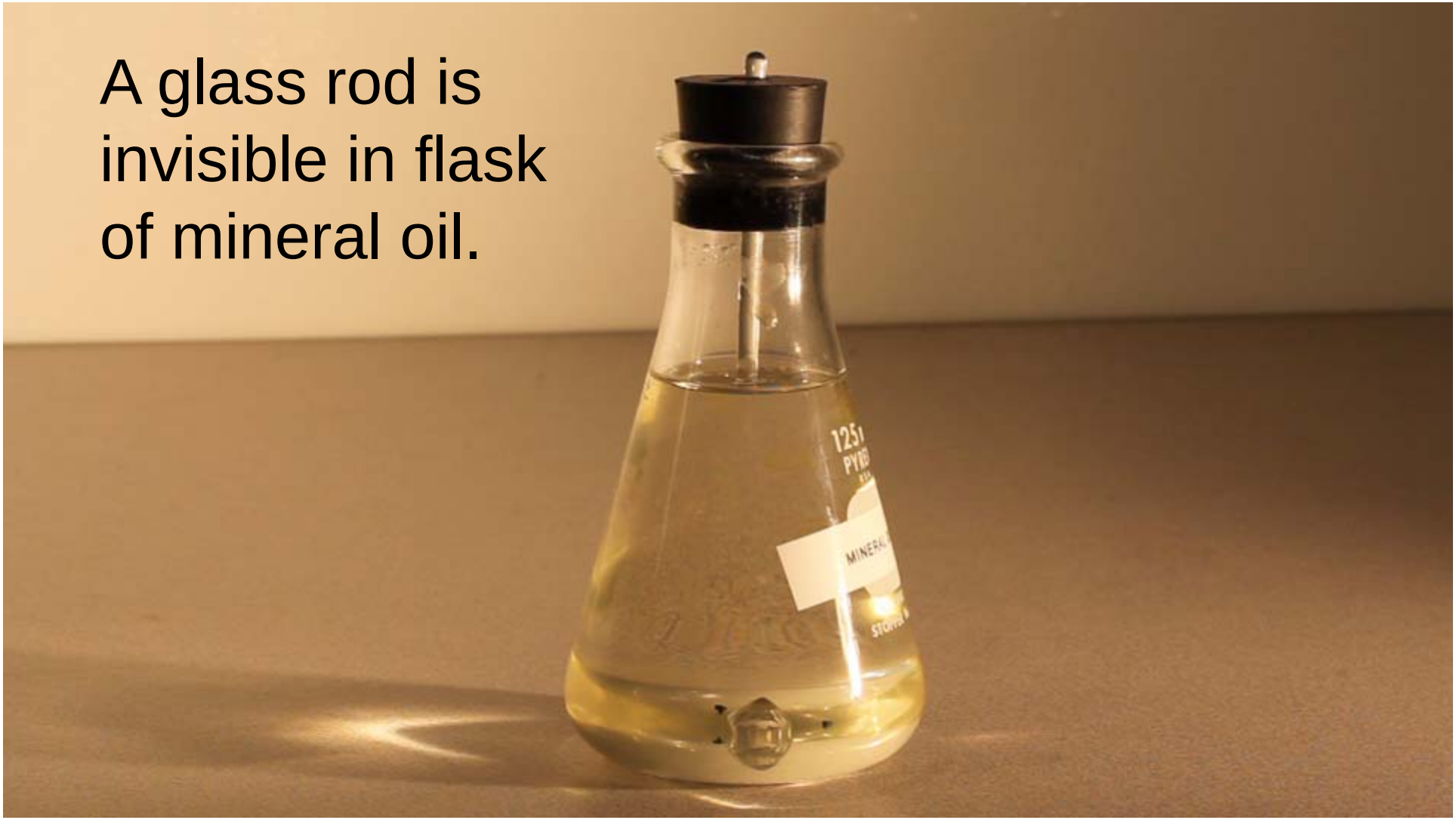


Frosted Glass, Dry vs. Wet

Put water on frosted glass plate
and it becomes nearly transparent.

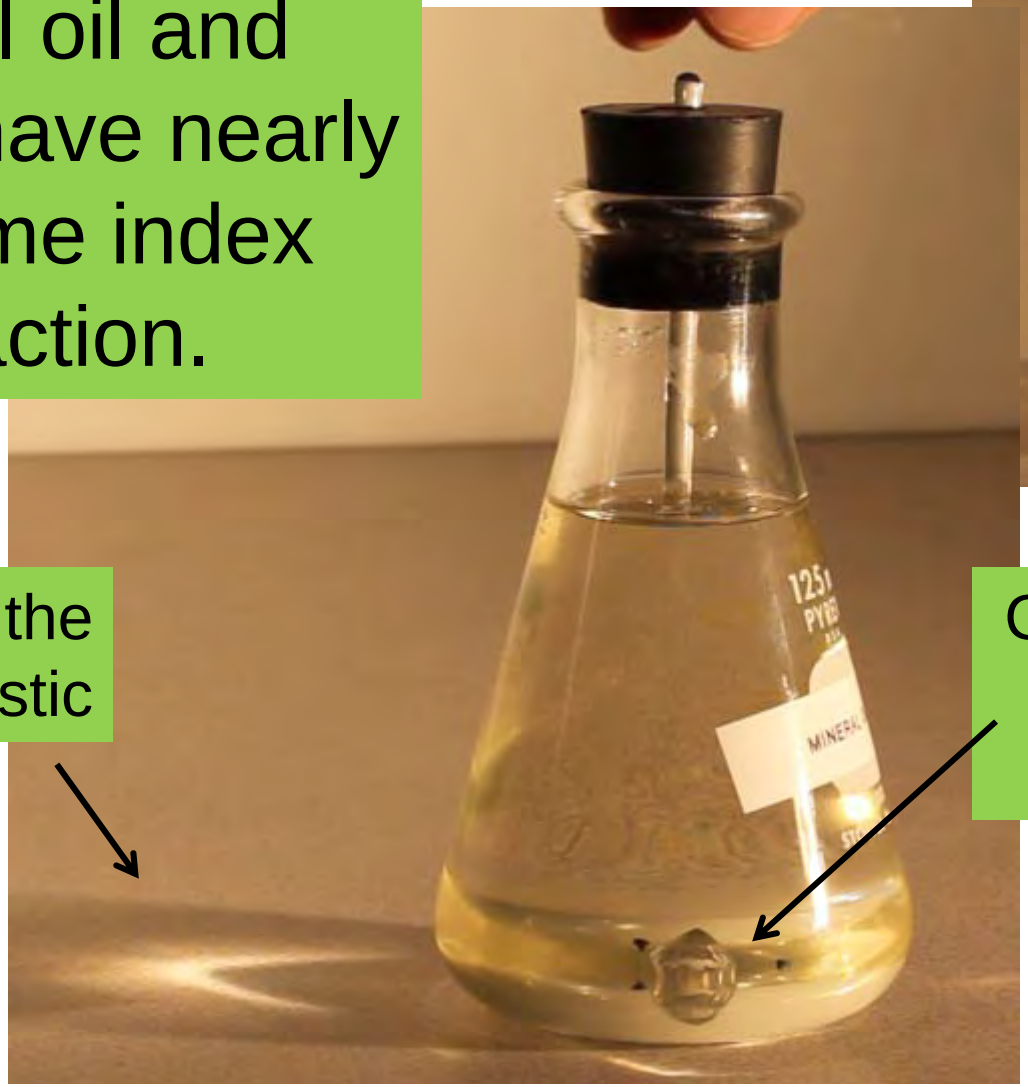


Invisibility



Invisibility

Mineral oil and glass have nearly the same index of refraction.



Notice the caustic

Cubic zirconium "diamond", is easily seen.

Summary

- Refraction is the bending of light rays passing from one material into another (e.g., water→air).
- The greater the angle of the incident light ray, the greater the deflection due to refraction.
- The angle of refraction also depends on the indices of refraction for each material.
- Index of refraction for a material indicates the speed of light in that material (higher↔slower).
- Materials with the same index of refraction (e.g., glass and mineral oil) are optically equivalent.