Refraction & Reflection

Demonstration

This demonstration presents viewers with an example of reflection and refraction and describes difference between the two.

Georgia State University

Number of Participants: 2-30

Audience: Elementary (ages 5-10) and up

Duration: 5-10 min

Difficulty: Level 1

Materials Required:

- Clear glass of water
- Mirror
- Laser pointer
- Pencil or pen
- Optional: A fish tank with water

Setup:

1. Fill a clear glass with water and place a pencil or pen inside.

Presenter Brief:

Be familiar with Snell's law and introductory optics. Expect to answer questions on the difference between reflection and refraction, and why light behaves in this way. See Additional References.

Vocabulary:

- Reflection – An abrupt change in the direction of a wave that occurs at a change in media, but remains in the original propagation media; occurs because of a change in the refractive index.

- Refraction – The bending of a wave when a wave enters a new medium; occurs because of a change in the refractive index.
- Index of Refraction – A characteristic of materials which describes how waves propagate through the medium in relation to space. In general, light moves slower through objects with higher indices of refraction.
- Medium – A material through which waves propagate.

Physics & Explanation:

Elementary (ages 5-10):

The image seen in a mirror is a reflection. Light starts from a source, such as lightbulbs in your bathroom. When you see yourself in the mirror, the light starts at the bulb, bounces (or reflects) off of you, reflects again off the mirror, then finally reaches your eyes. Most objects don't normally emit light, but sources such as the sun, lightbulbs, and lasers do.

> Shine a laser pointer at the mirror (be careful to not point it at your eye). The light will not appear on a (clean) mirror, but instead will reflect onto a different object. Change the incident angle of the laser and encourage the participants to imagine the path the laser beam is taking. If you place a mirror in a fish tank and fill the fish tank with water, the laser beam path can be easily seen indoors.

🔑 For reflections, light can bounce off surfaces, like a mirror.

Any object we see either reflects light or emits light (source). Everything around us reflects some light, but most objects only reflect a small amount of light striking it (when compared to a mirror, which reflects almost all light).

Refraction occurs when light passes into a medium from another medium. Refraction, or the bending of a wave when a wave enters a new medium, usually occurs because of a change in the refractive index. This can produce interesting optical effects, such as dessert or hot road mirages.

When you observe an object through a window, a glass of water, or other transparent object, the light is refracted.

🔑 In refraction, light passes through a material.

> Point to the clear glass of water with the object (pen or pencil) inside it. From certain angles, the object looks segmented, or broken because light travels at different speeds through different materials. Air and water, for example, are different mediums, and light travels differently through air and water (~3.0×10^8 m/s versus 2.3×10^8 m/s, or about ¾ as fast).

🔑 Since light travels through air and water differently, a continuous object will look segmented when viewed through the two.

Middle (ages 11-13) and general public:

After completing the previous section, explain that reflected light bounces off a surface at the same angle in a continuous medium. Snell's law describes how light is refracted:

$$n_i sin\theta_i = n_r sin\theta_r$$

Where n_i and n_r are the indices of refraction of the material through which the incident ray and refracted ray travel, respectively. Similarly, θ_i and θ_r are the angles of the incident and refract rays – see Figure 1.

🔑 Reflection and refraction describe how light responds to a change in medium.

Display or reproduce the ray diagram to show how light behaves at an index interface. Detail how reflected light moves back into the same medium, and refracted light changes path.

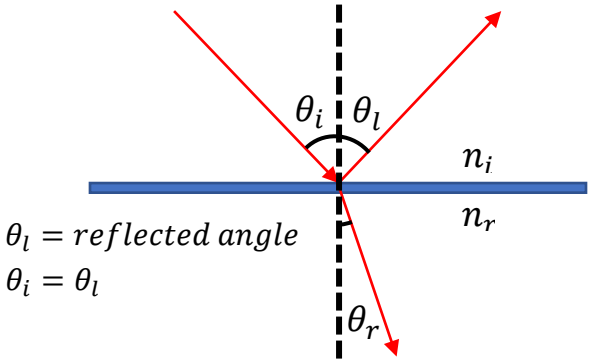

Figure 1

🔑 The angle the light strikes the barrier θ_i determines the reflection θ_i and refraction angle θ_r.

Explain that light splits at the interface: some light is transmitted (refracted) and some is redirected into the same medium (reflected).

🔑 When encountering a change of refractive index, some light is transmitted (refracted) and some is redirected into the same medium (reflected).

Highschool (14 +):

After completing the previous section, explain that the incident angle is measured from the "normal" – a virtual axis perpendicular to the surface.

Reflection and refraction can happen at the same point, and that the incident ray of light becomes componentized.

If light passes to a less-dense medium, the refracted ray of light will bend away from the normal ($\theta_i < \theta_r$). If light passes to a more-dense medium, the ray will bend toward the

normal ($\theta_i > \theta_r$). In the circumstance that the refracted ray of light is perpendicular to the normal, the incident angle is referred to as the critical angle (θ_c).

$$\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right)$$

🔑 The critical angle (θ_c) describes the angle at which the refracted light is parallel to the plane of the index barrier

In addition, if there is no detectable barrier (the two materials that have the same index of refraction) light will not respond to the barrier because optically, such a barrier does not exist.

Additional Resources:

- Same-index refraction experiment https://www.youtube.com/watch?v=D9CvH388K3s
- Bill Nye refraction clip https://www.youtube.com/watch?v=fD1544bM_c4
- An in-depth analysis with lenses http://physics.bu.edu/~duffy/PY106/Reflection.html
- Specular and diffuse reflection (mirror vs. white-wall) http://www.physicsclassroom.com/class/refln/Lesson-1/Specular-vs-Diffuse-Reflection
- Hecht. *Optics*, 1998. 95-100.
- Pedrotti, Frank L. and Pedrotti, Leno S. *Introduction to Optics*, 1997. 37-40.

Useful Equations:

Snell's Law	$n_i sin\theta_i = n_r sin\theta_r$
Critical angle	$\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right)$

$n = Index\ of\ refraction\ for\ various\ media$

- $n_i = incident\ media$
- $n_r = refractive\ media$

$\theta = angle\ of\ incidence\ (\theta_i), refraction\ (\theta_r)$