Fluids, Thermodynamics, Waves, & Optics
Optics
Lab 7
Reflection & Refraction

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Overview

- Purpose
- Laser safety
- Part 1: Reflection
- Part 2: Refraction
- Part 3: Total internal reflection

Purpose of the Lab

To explore basic ray optics including the reflection and refraction of beams of light.

You will use a laser beam on an optical bench and a device for measuring angles to investigate different ray optics situations.

You will

1. measure incidence and reflection angles to confirm the law of reflection.
2. measure a transparent block's thickness, incidence angles and beam displacement distances to find the block's index of refraction.
3. use the idea of total internal reflection to find the index of refraction of a transparent triangular prism.

Equipment

Laser Safety!

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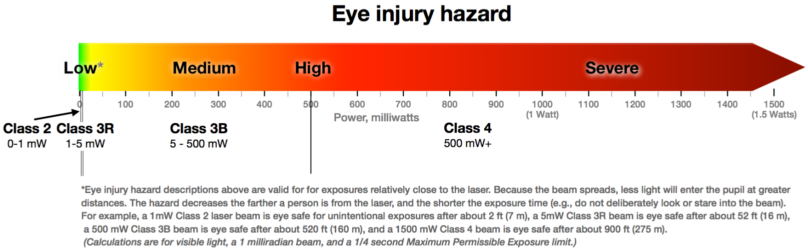

Do not stare into a laser beam.

[1] Figure from http://www.lasersafetyfacts. com/laserclasses.html

Laser Safety!

It is easy to use a laser to damage your eyes.

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Simple rule: never move your head through the plane of the optical bench with the laser beam on and the shutter open.

For example, you drop your pen. Just close the shutter all the way (labelled "attenuator") before you bend over to pick it up.

Since the lab has many groups, also close your eyes as you move your head through the plane of the benches. As much as possible try to keep your head above bench level.

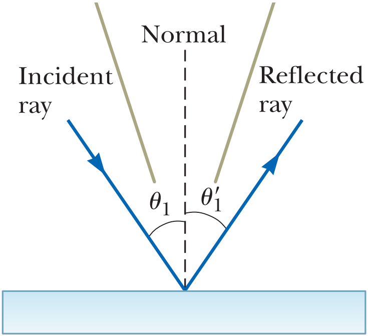
Theory: Reflection

Specular (mirror-like) reflection:

Courtesy of Henry Leap and Jim Lehman

Law of Reflection

$$\theta_i = \theta_r$$

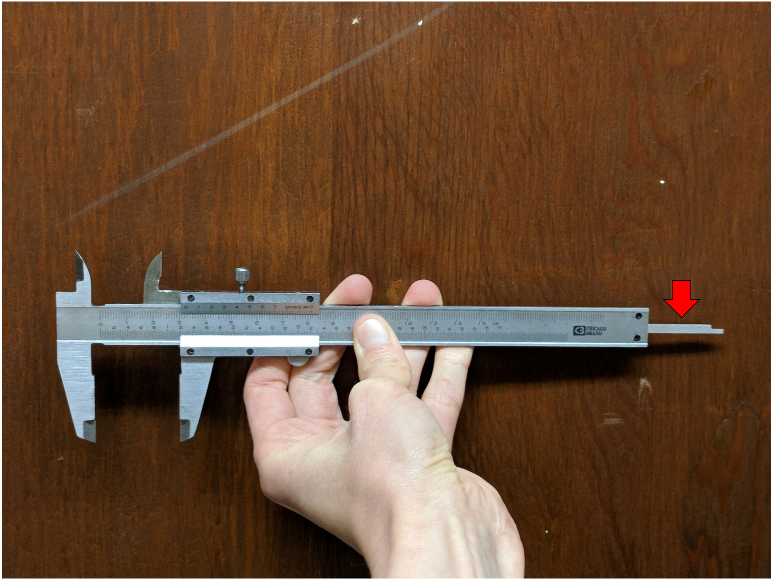


Equipment: Reflection Setup

Lab Activity - Part 1: Reflection

1. Use Vernier calipers to measure the depth of the mirror inside the plastic case.
2. Use this value to carefully set the surface of the mirror in the crosshairs of the angular translator.
3. Align the “zero” of the angular translator so that the beam from the laser hits the mirror and goes right back into the aperture.
4. Rotate the top the angular translator and mirror clockwise through some angle.
5. Measure the angle the reflected beam makes with the incident beam.
6. Repeat, rotating counterclockwise. Check that the angle the reflected beam makes with the incident beam is roughly the same as when rotating clockwise. If it is not, realign your mirror.

Measuring Depth of Mirror: Vernier Calipers



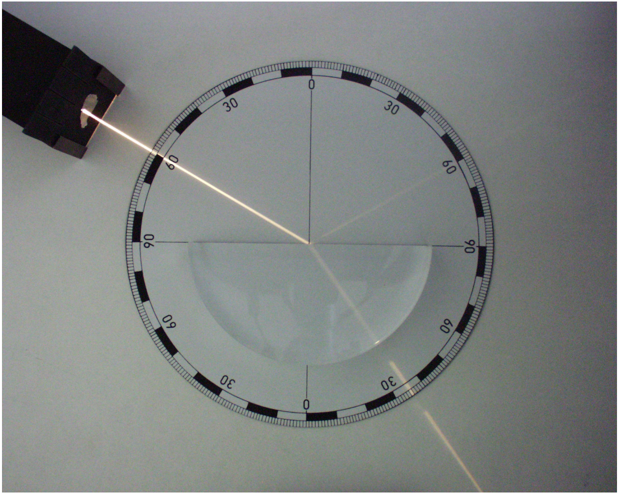
Measuring Depth of Mirror

Lab Activity - Part 1: Reflection

7. Take data for 3 angles going clockwise and three counterclockwise.
8. Find the ratio of the incidence angle to the angle between the incident and reflected ray for each incident angle.
9. Calculate the average and standard deviation.

Refraction

When light rays pass from one medium into another, they are often observed to bend.



[1]Image from Wikipedia, by Zátonyi Sándor.

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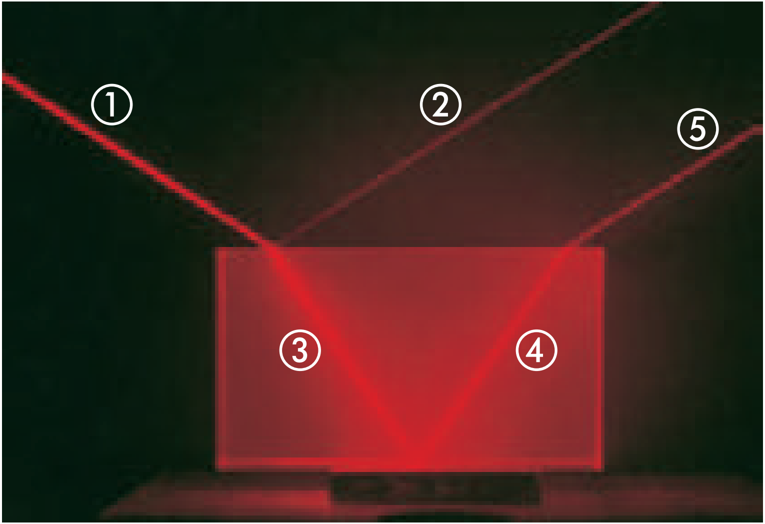
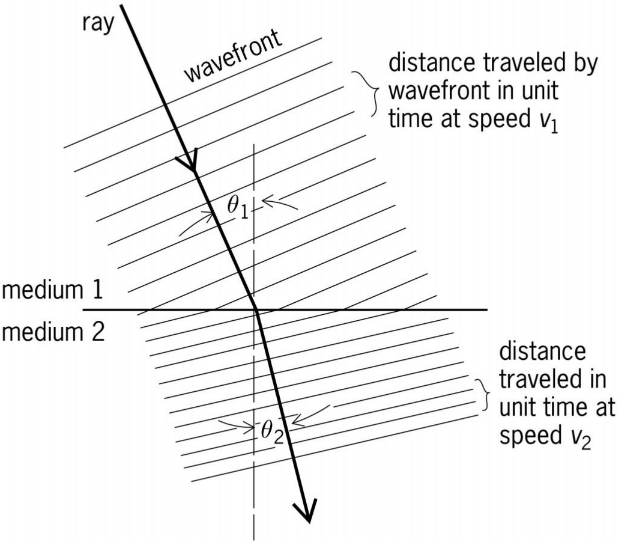


Courtesy of Henry Leap and Jim Lehman

Refraction



[1] McGraw-Hill Concise Encyclopedia of Physics. © 2002 by The McGraw-Hill Companies, Inc.

Refractive Index

Light *at a particular frequency* moves at different speeds in different media.

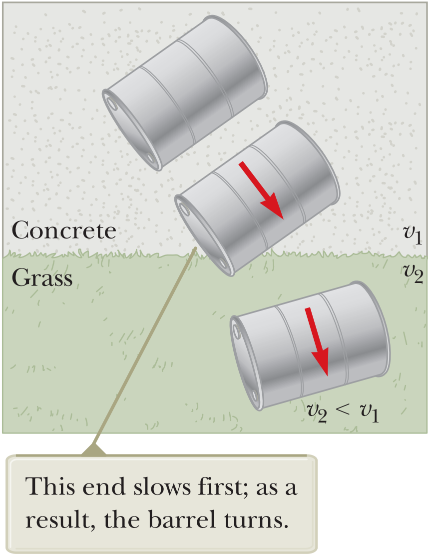
Refractive index of a medium, n

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

where $v = \frac{\omega}{k}$ is the phase velocity of light with angular frequency ω in that medium.

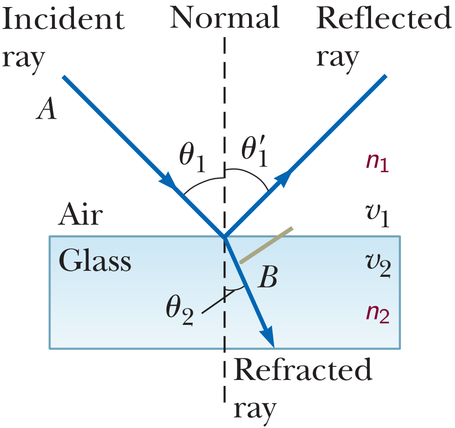
The larger the refractive index, n, the slower the speed in that medium.

Refraction



[1] Serway & Jewett, 9th ed, page 1066.

Refraction: Snell's Law



Snell's Law:

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

[1] Willebrord Snell discovered this law experimentally.

Equipment: Refraction Setup

Lab Activity - Part 2: Refraction

1. Measure the thickness of the block, T, with the Vernier calipers.
2. Align the “zero” of the angular translator so that the beam from the laser hits the surface of the block and goes right back into the aperture.
3. Rotate the block and find the two reflection dots on the screen.
4. Record the incidence angle and the dot separation, D, using the ruler markings on the screen.
5. Repeat for a total of 10 measurements, five rotated clockwise, and the same five angles counterclockwise.
6. Average the clockwise and counterclockwise values of D for each incidence angle.

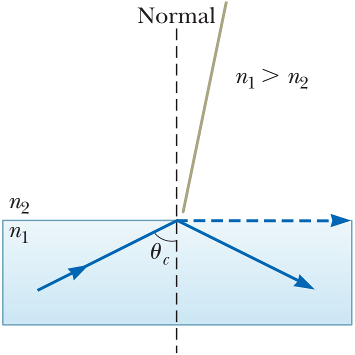
Lab Activity - Part 2: Refraction

7. Calculate n for each value of the incidence angle. (Gives five samples n_i.)

8. Find the average $\bar{n}$ and standard error on the sample mean.

Total Internal Reflection

The **critical angle**, θ_c, is the maximum angle of incidence such that there could be a refracted ray. The ray would just skim along the surface between the media.



In this case, the angle of refraction $\theta_2 = 90°$.

Equipment: Total Internal Reflection Setup

Lab Activity - Part 3: Total Internal Reflection

1. Align one of the short sides of the triangular prism on the crosshairs and zero the angular translator.
2. Align the screen so that its center lies along the line of the hypotenuse.
3. Rotate the prism and the screen together until a dot of light suddenly appears on the center of the screen.
4. Check the prism is at the critical angle by rotating it just slightly back and forth. The dot should disappear and reappear.
5. Record the incidence angle.
6. Use just this one measurement, some geometry, Snell's law, and the critical angle formula to calculate n for the prism.

Lab Activity

Does your result in part 1 confirm the law of reflection?

What index of refraction do you find for parts 2 and 3?