3.1 Reflection and Refraction

- Geometrical Optics
- Reflection
- Refraction

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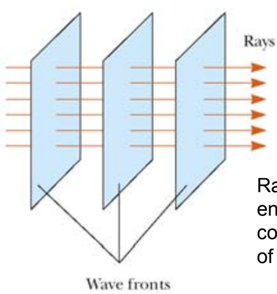
Geometrical optics

In geometrical optics light waves are considered to move in straight lines.

This is a good description as long as the waves do not pass through small openings (compared to λ)

Light waves

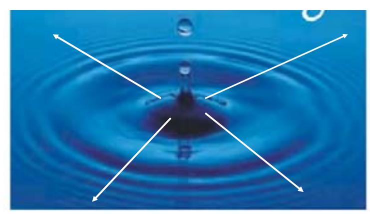


perpendicular to wave fronts

Rays are not physical entities but are a convenient representation of a light wave.

(surfaces with constant phase - e.g. maxima)

Rays are perpendicular to wave fronts



Reflection

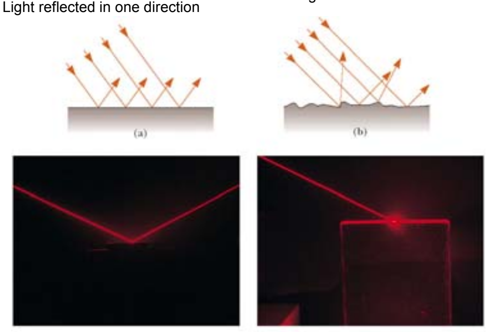
- Two general types of reflection
  - Specular reflection
  - Diffuse reflection
- Most of geometric optics deals with specular reflection.
- However, most of the time ambient lighting is due to diffuse reflection.

Specular reflection

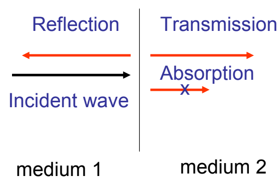
Flat surface
Light reflected in one direction

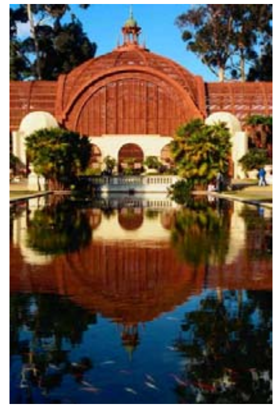
Diffuse reflection

Rough surface
Light reflected in all directions



Transmission and Reflection at an interface





What are some examples of these processes in this picture.

Specular Reflection

Diffuse reflection (scattering)

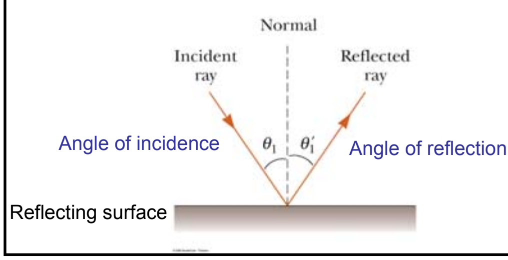
Transmission

Absorption

Law of Reflection

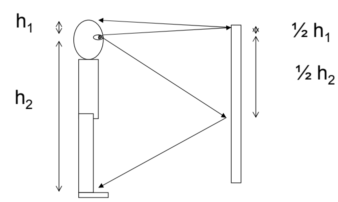
The angle of reflection equals the angle of incidence

$$\theta_1 = \theta_1'$$



Full length mirror

A 6 ft tall man wants to install a mirror tall enough to see his whole body. How tall a mirror is needed?

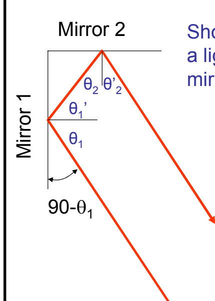


h_{mirror} = ½ (h_1 + h_2) = ½ (6) =3 ft

Multiple reflections

- For multiple reflections use the law of reflection for each reflecting surface.

2-Dimensional Corner reflector



Show that 2 perpendicular mirrors reflect a light beam in a plane perpendicular to both mirrors back along the opposite direction

we want to show that $\theta_2' = 90 - \theta_1$

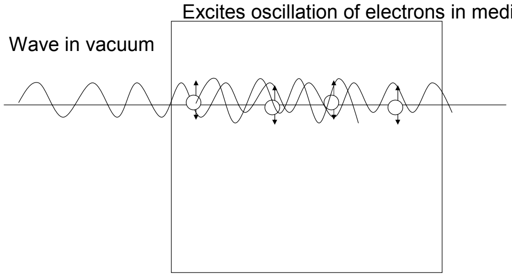
$$\theta_1 = \theta_1' \qquad \theta_2 = \theta_2'$$

$$\theta_2 + \theta_1' = 90^o$$

$$\theta_2' + \theta_1 = 90^o$$

$$\theta_2' = 90 - \theta_1$$

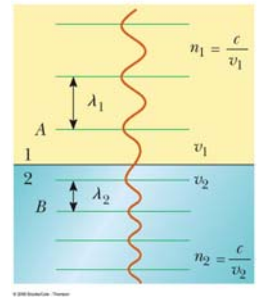
Speed of light in a medium



Superposition of waves leads to slower speed in the medium compared to vacuum.

Transmission across an interface

The speed of the wave changes.
The frequency remains the same.
The wavelength changes



Refraction

- Refraction is the bending of light when it passes across an interface between two materials.
- The bending is due to the differences in the speed of light in different media.
- The index of refraction of a material n_i is the ratio of the speed of light in a vacuum c to the speed of light in the material v_i

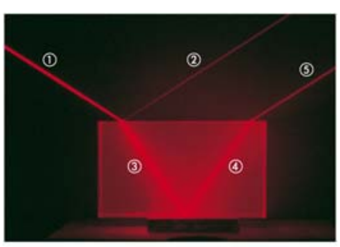
$$n_i = \frac{c}{v_i}$$

TABLE 22.1

Indices of Refraction for Various Substances, Measured with Light of Vacuum Wavelength λ_0 = 589 mn

Substance	Index of Refraction	Substance	Index of Refractio
Solids at 20°C		**Liquids at 20°C**	
Diamond (C)	2.419	Benzene	1.501
Fluorite (CaF_2)	1.434	Carbon disulfide	1.628
Fused quartz (SiO_2)	1.458	Carbon tetrachloride	1.461
Glass, crown	1.52	Ethyl alcohol	1.361
Glass, flint	1.66	Glycerine	1.473
Ice (H_2O) (at 0°C)	1.309	Water	1.333
Polystyrene	1.49		
Sodium chloride (NaCl)	1.544	**Gases at 0°C, 1 atm**	
Zircon	1.923	Air	1.000 29
		Carbon dioxide	1.000 45

Refraction and Reflection

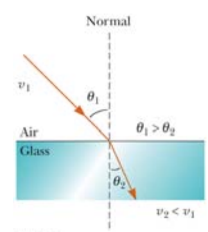


The light beam (3) is refracted at the interface.

Snell's Law of Refraction

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

Going from air to glass



$n_2 > n_1$

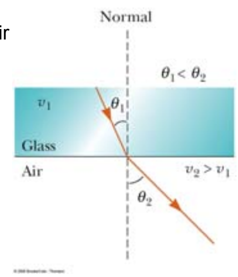
$\theta_2 < \theta_1$

(sinθ increases with θ)

Going from glass to air

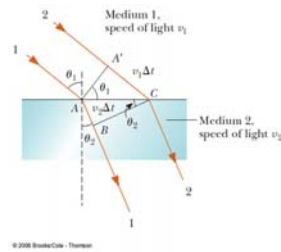
$n_2 < n_1$

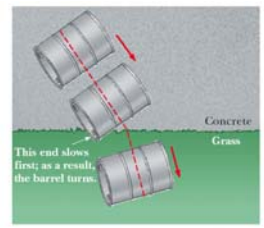
$\theta_2 > \theta_1$



Physical picture for Snell's Law

One end of the wave front slows down.
The wave front changes direction.





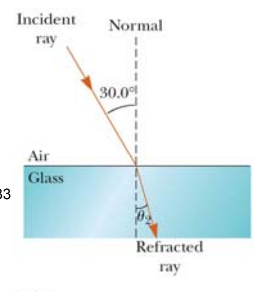
Example 22.2

Find the angle of refraction for an angle of incidence of 30° in going from air to glass (n_{glass} =1.52)

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

$$\sin\theta_2 = \frac{n_1 \sin\theta_1}{n_2} = \frac{1.00(\sin 30)}{1.52} = 0.33$$

$$\theta_2 = 19.3°$$



Example 22.4

Show that light going through a flat slab is not deviated in angle.

First interface

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

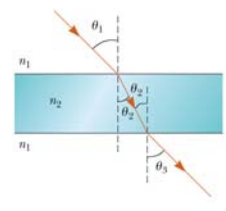
Second interface

angle of incidence = θ_2

$$n_2 \sin\theta_2 = n_3 \sin\theta_3$$

then $n_1 \sin\theta_1 = n_3 \sin\theta_3$

since $n_1 = n_3$ $\theta_1 = \theta_3$



Refractive index matching

- A transparent object can be made invisible if the index of refraction of the surrounding media is made the same as that of the object.