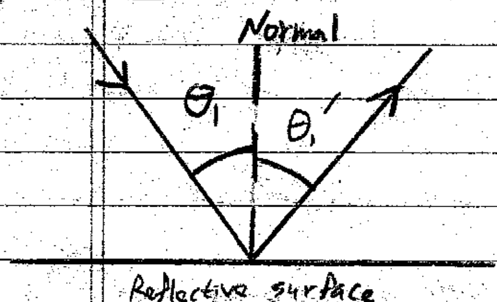
Chapter 34 – Geometrical optics: reflection and refraction –

Visible light has wavelengths $\lambda \sim 0.4 - 0.75$ microns (microscopic).
So, for many applications we may ignore the wave properties of light (just covered in Chapter 33, and to be covered in Chs. 36–37), to understand optics.

The ray approximation ignores the wave nature of light, by assuming that light travels in rays (which are straight lines), always.
(All light waves therefore become parallel plane waves.)

This simplifies optics, by turning it into geometry.
→ Bring a ruler, pencils, and erasers to every class and exam, from now on.

Reflection –



The law of reflection:

$$\theta_{incident} = \theta_{reflected}$$

or:

$$\theta_1 = \theta_1'.$$

(Consequence of conservation of energy.)

Refraction – occurs when light travels from one material (or medium) to another, in which the speeds of light are different.

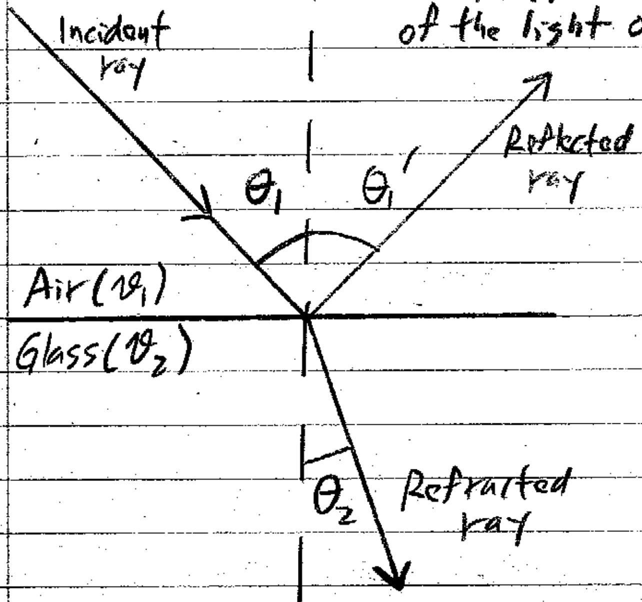
The speed of light in empty space (in a vacuum, or in vacuo)

$$\equiv c = 2.9979 \times 10^8 \text{ m/s} \simeq 3.00 \times 10^8 \text{ m/s}.$$

In any material (e.g. air or glass), the speed of light $v < c$.
Usually, the denser the medium, the slower v is.
So:

$$v_{glass} < v_{water} < v_{air} < c.$$

Refraction — By the ray approximation, assume <u>all</u> the bending of the light occurs at the boundary between the two media.



The law of refraction:

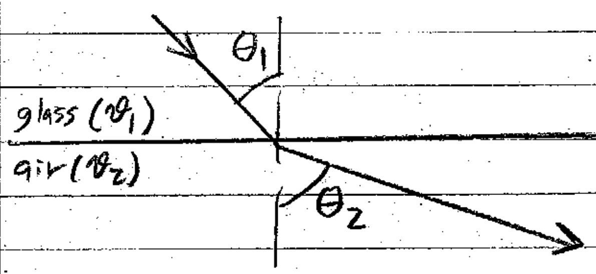
$$\frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1} = \text{constant}$$

Here, $v_1 > v_2$,

so $\theta_2 < \theta_1$.

Demo w/ BB optics slab

For $v_1 < v_2$ (e.g. from glass $\rightarrow$ air), $\Rightarrow \theta_2 > \theta_1$



Index of refraction —

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

$n = 1.000293 \simeq 1.00$ for air
$= 1.333$ water
$\simeq 1.5$ glass
(1.52 crown glass
1.66 flint glass)
2.4 diamond

Snell's law — Willebrord Snell, 1591–1627

$$\Rightarrow \boxed{n_1 \sin\theta_1 = n_2 \sin\theta_2}$$

Chapter 34 (continued)

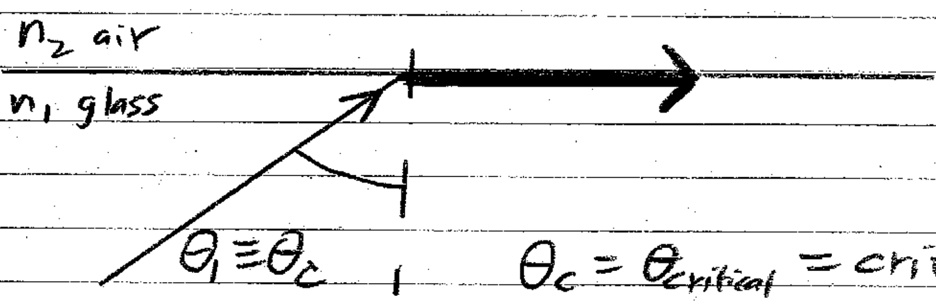
Total internal reflection occurs when:

$\theta_{refracted} = \theta_2 \geq 90^\circ$ when $n_2 < n_1$,

so all the light stays in the glass.

$\boxed{n_2 < n_1}$

Demo w/ BB optics



$\theta_c = \theta_{critical}$ = critical angle

Demo — vanishing rod

From Snell's law: $n_1 \sin\theta_c \geq n_2 \underbrace{\sin 90^\circ}_{=1} = n_2$

$\Rightarrow \boxed{\sin\theta_c \geq n_2/n_1}$ for $n_1 > n_2$.

→ Fiber optics

(→ Diamonds sparkle)

Dispersion, prisms, and rainbows —

For most transparent materials, n changes with λ $[n = n(\lambda)]$

This is called dispersion.

⇒ Violet light (with short λ) bends more than red light (with long λ).

⇒ A prism can break light into its component colors (wavelengths).

Newton used two prisms to make white light → colors → white light.

Therefore, white light is composed of colored light.