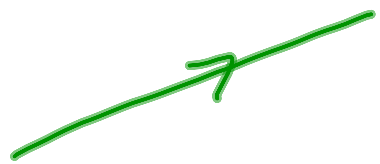
The Ray Model of light

- an idealized and oversimplified model of light that is useful
- the real model would include wave theory & Maxwell's eqns
- ray model & tracing uses approximate solutions to Maxwell's eqns => those are valid

as long as the light waves propagate through and around objects whose dimensions are much greater than the lights' wavelength (ex. lenses mirrors)

- we will draw a beam of light as one light ray



arrow - direction of travel

light ray properties

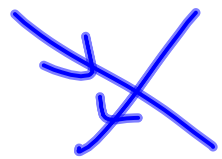
1) light travels in straight lines. Its speed is

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

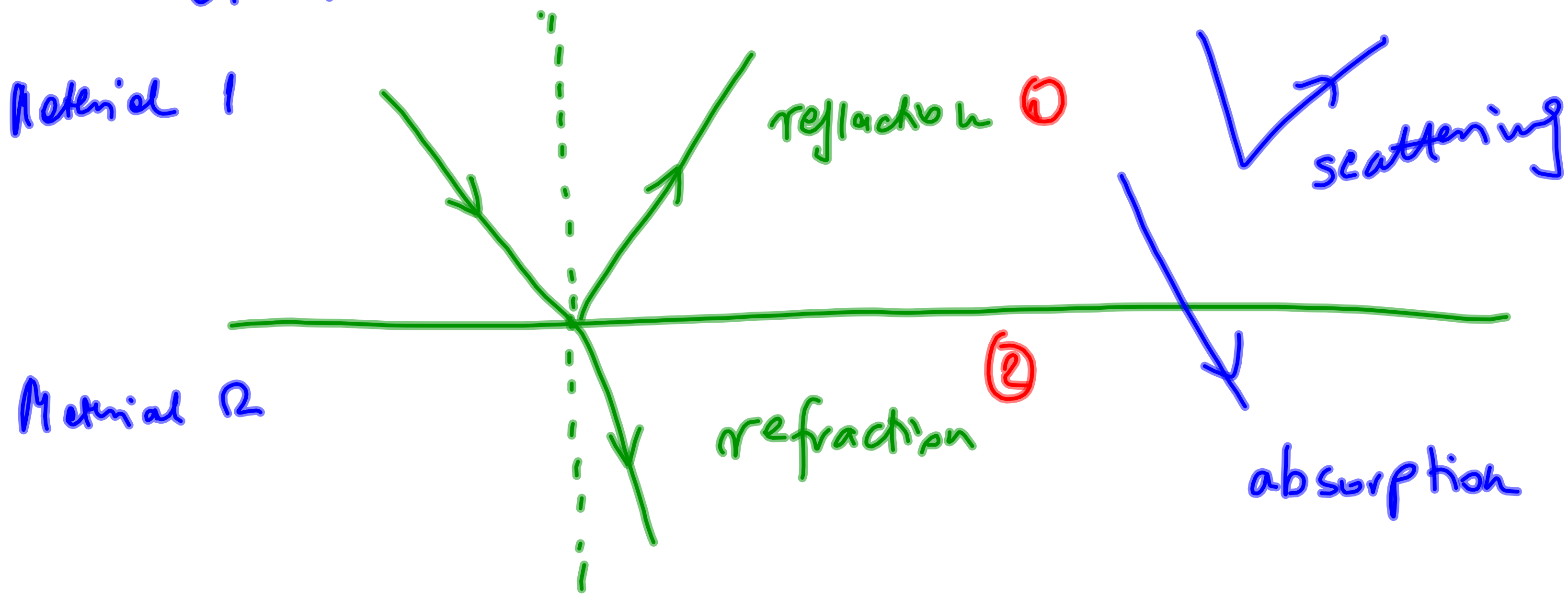
where c is a speed of light in vacuum

n is the index of refraction of the material

2) light rays can cross without impacting each other



3) light ray travels forever unless it interacts with matter that causes it to change direction or to be absorbed.



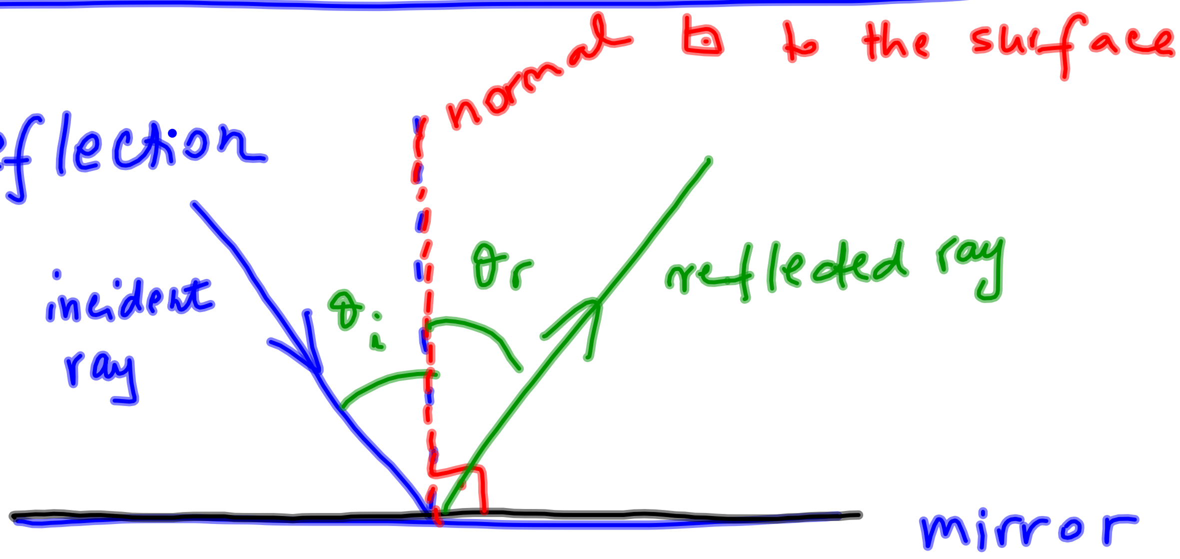
4) An object is a source of light rays

- rays originate from every point of the object & each point sends rays in all directions => we get to see the object when our eyes capture bundles of rays from each point on the object

Objects
- self-luminous (sun, light-bulbs)
- reflective (tree, building, chair...)
  we all reflect

Examples of light travel

1) Reflection



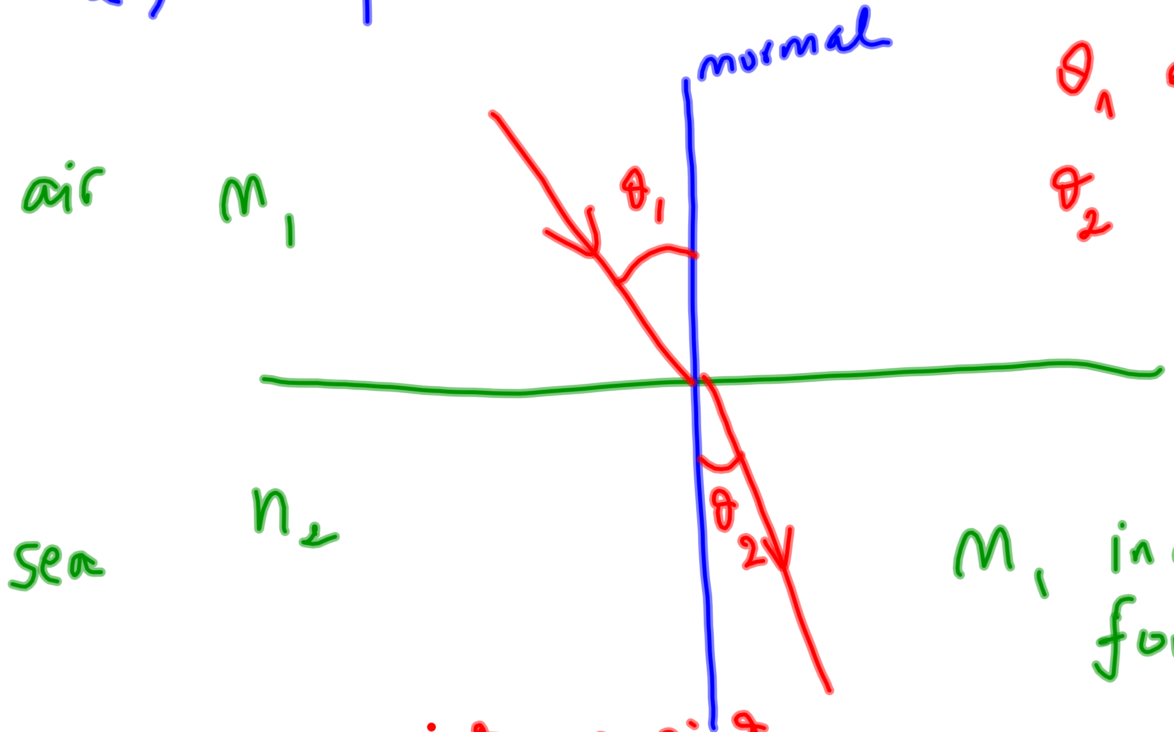
θ_i angle of incidence

θ_r angle of reflection

$$\theta_i = \theta_r$$

experimental result

2) Refraction



θ_1 angle of incidence

θ_2 angle of refraction

$$\theta_1 \neq \theta_2$$

n_1 index of refraction for air

n_2 for sea

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

Part of the ray reflects & part is transmitted to other media, but as it crosses the boundary it changes direction ⇒

REFRACTION

Again from experiments we know:

(1) $$n_1 \sin\theta_1 = n_2 \sin\theta_2$$ Snell's law

② $v = \frac{c}{n}$ or $n = \frac{c}{v} \Rightarrow$

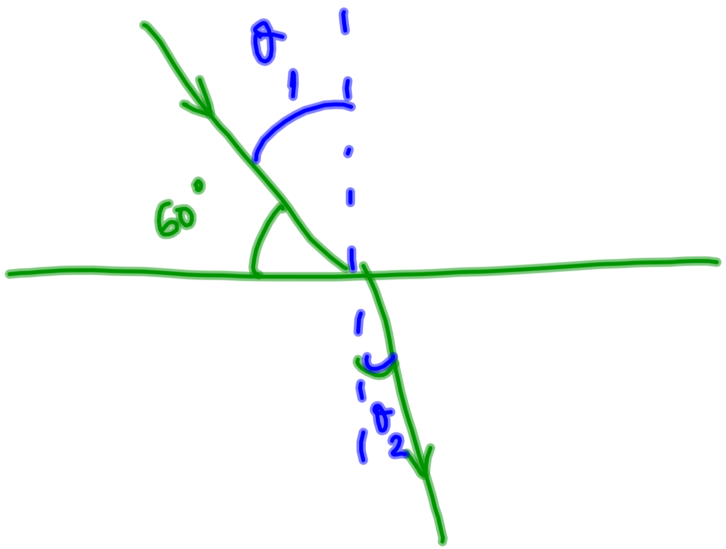
Note: n has no units

$n > 1$

$n = 1$ for vacuum

Example: Laser beam is aimed at 60° angle at the glass. What is the laser beam's direction of the travel in the glass? Index of refraction for air is 1 & for glass is 1.5.

- direction of travel is expressed θ
- PICTURE



air $n_1 = 1$

glass $n_2 = 1.5$

$\theta_1 = 30^\circ$

$n_1 = 1$

$n_2 = 1.5$

$\theta_2 = ?$

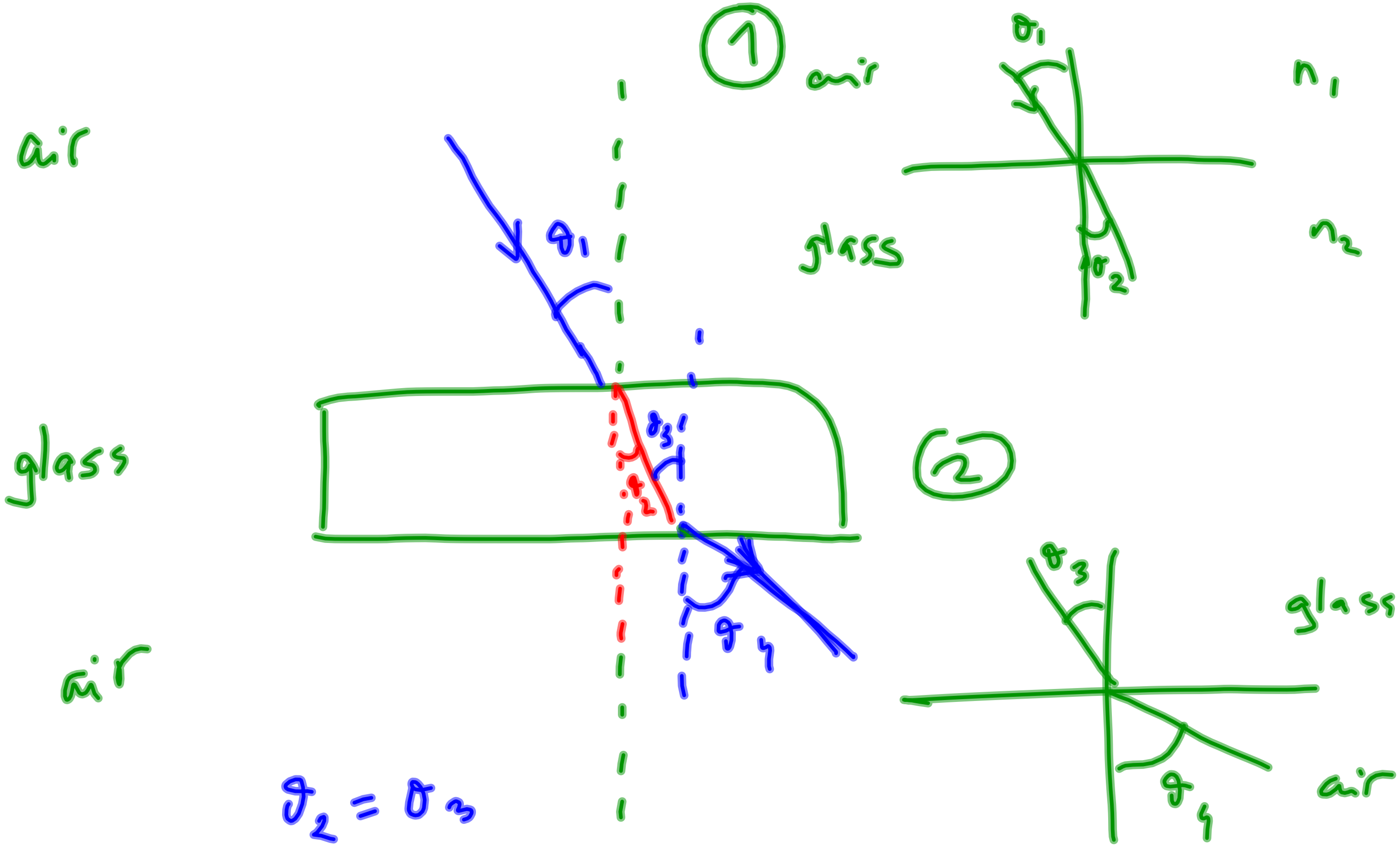
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\sin\theta_2 = \frac{n_1}{n_2}\sin\theta_1 = \frac{1}{1.5}\sin 30^\circ =$$

$$= \frac{1}{1.5}\cdot\frac{1}{2}$$

$$\theta_2 = \sin^{-1}\left(\frac{1}{1.5\cdot 2}\right)$$

$$= 19.45^\circ$$

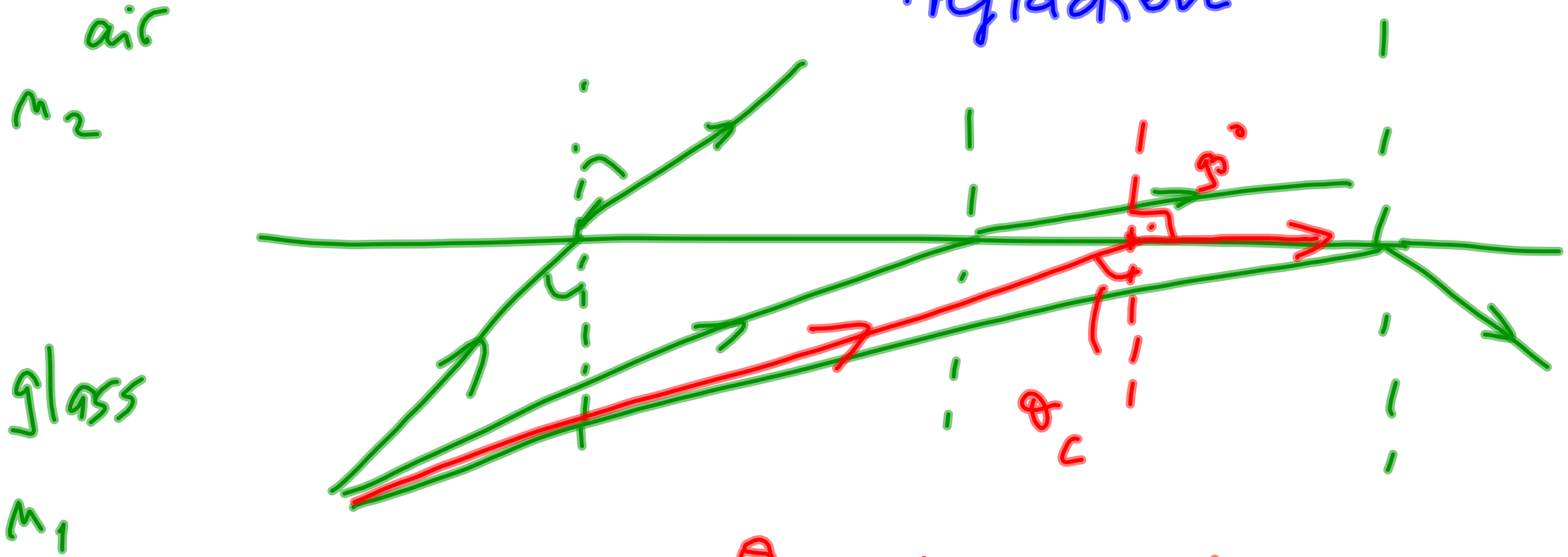


$\vartheta_2 = \vartheta_3$

Total internal reflection

We are looking for an angle at which the light that should be refracted just skims along the interface

$\theta_1 \geq \theta_c$ total internal reflection



θ_c critical angle

- air => glass => no critical angle as $n_2 > n_1$

– we can calculate θ_c

glass => air

$n_1 = 1.5$

$n_2 = 1$

$\theta_1 = \theta_c$

$\theta_2 = 90°$

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

$1.5 \sin\theta_c = 1 \sin 90°$, 1

$\sin\theta_c = \frac{1}{1.5} = \frac{2}{3}$

$\theta_c = 42°$

- Dispersion : Index of refraction is different for different λ wavelength

n is bigger for shorter λ

- scattering - reflection does not depend on λ
  - colors scatter equally
- absorption - depends on λ → creates colors in objects