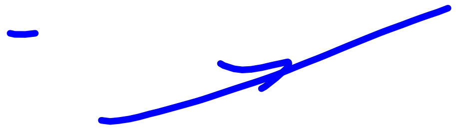
The Ray Model of light

- an idealized & oversimplified model
- the real model includes wave theory & Maxwell's eqns
- ray model & tracing uses approx. solutions to Maxwell's eqns =>

it is valid only if the light waves propagate through & around objects whose dimensions are much greater that the wavelength of the light

light is a wave 



we draw a line-beam of light

Light ray properties

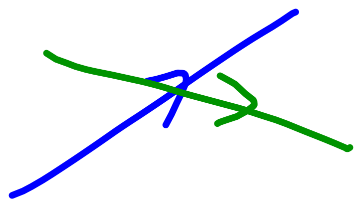
1) Light travels in straight lines.

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

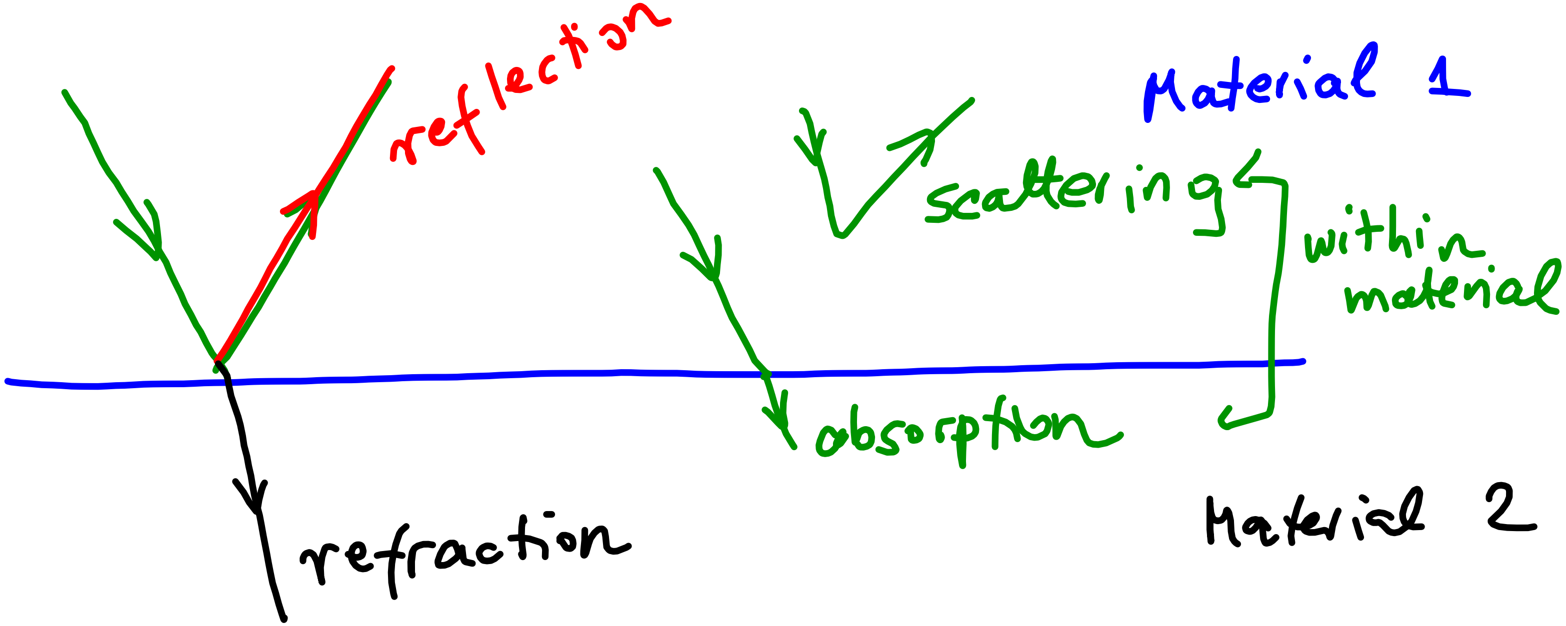
c speed of light in vacuum

n 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 be absorbed



reflection
refraction } occur at interface between materials

4) An object is a source of light rays

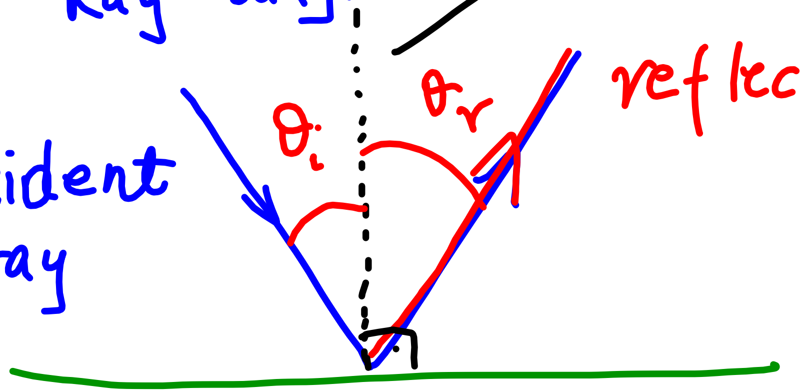
- rays originate from every point of the object & send rays in all directions

=> we see the object when our eye capture bundles of rays from each point on the object

Objects - self-luminous (Light-bulbs, sun, stars)
- reflective (tree, building, you...)

1) Reflection

Ray diagram



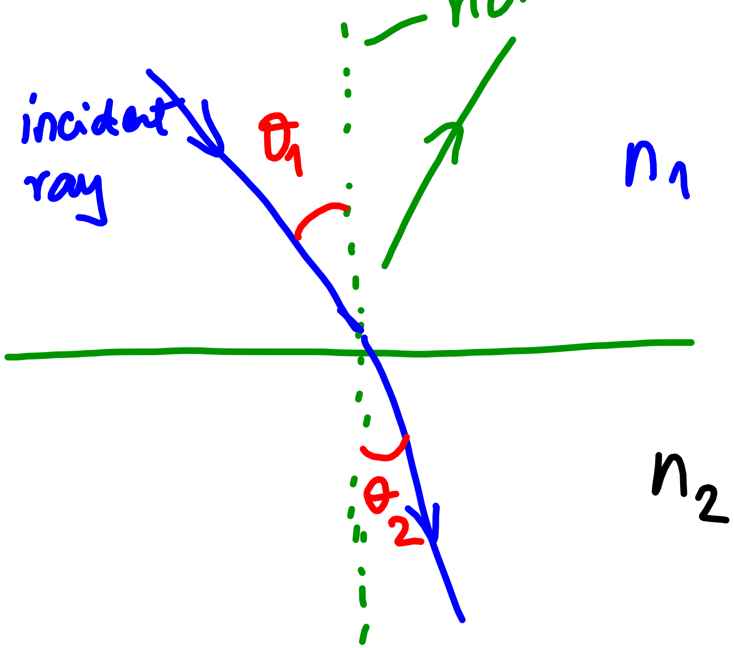
from experiments we know

$$\theta_i = \theta_r$$

θ_i: angle of incidence

θ_r angle of reflection

2) Refraction



air

sea

2 different medias (n_1, n_2)

θ_1 angle of incidence

θ_2 angle of refraction

n_1 index of refraction for air

n_2 sea

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

Again from the experiments we know:

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

Snell's law

2 equations that we covered so far

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

$$V = \frac{c}{n} \quad \text{or} \quad n = \frac{c}{V}$$

$n > 1$

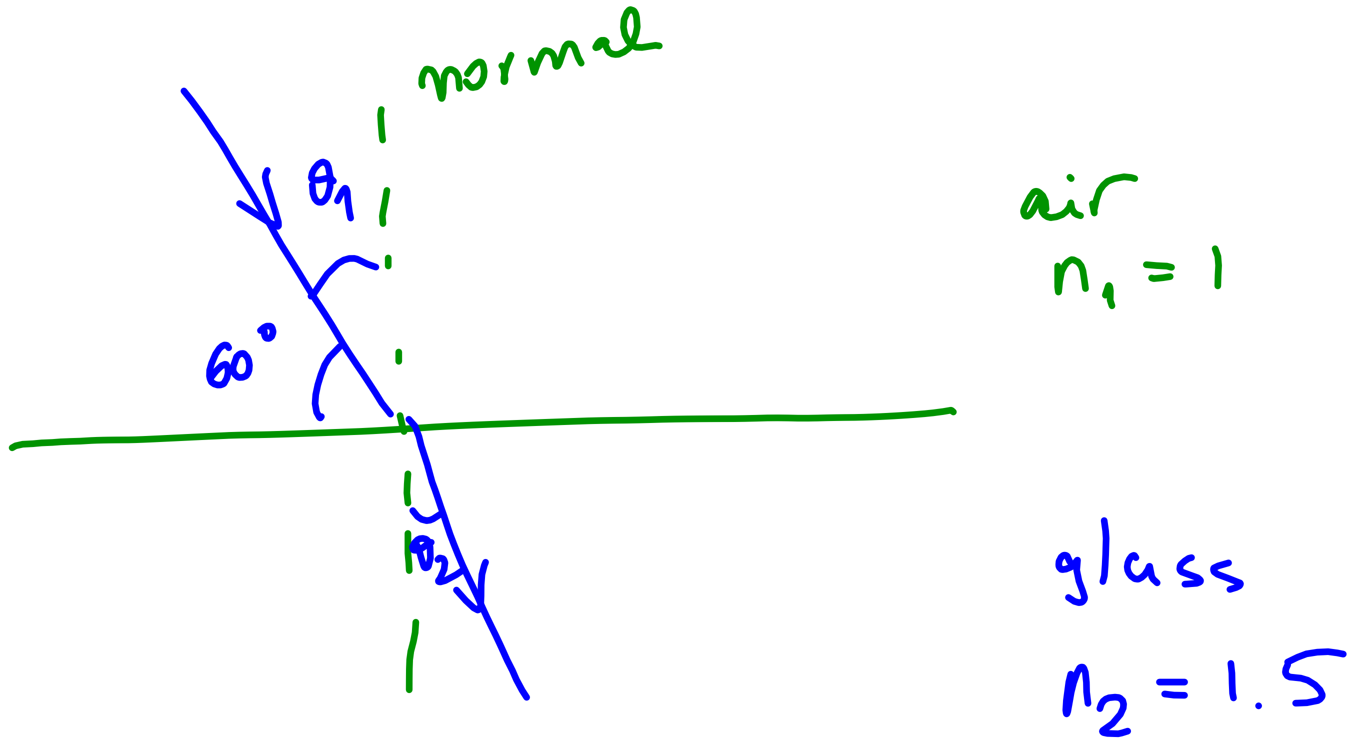
$n = 1$ vacuum

air

Example: Laser beam is aimed at 60° angle at the glass.

What is the laser beam's direction of travel in the glass?

Index of refraction for glass is 1.5.



$\theta_1 = 90^\circ - 60^\circ = 30^\circ$

direction is expressed by θ

$n_1 = 1$

$n_2 = 1.5$

$\theta_1 = 30^\circ$

$\theta_2 = ?$

$\sin\theta_2 = \frac{1}{3}$

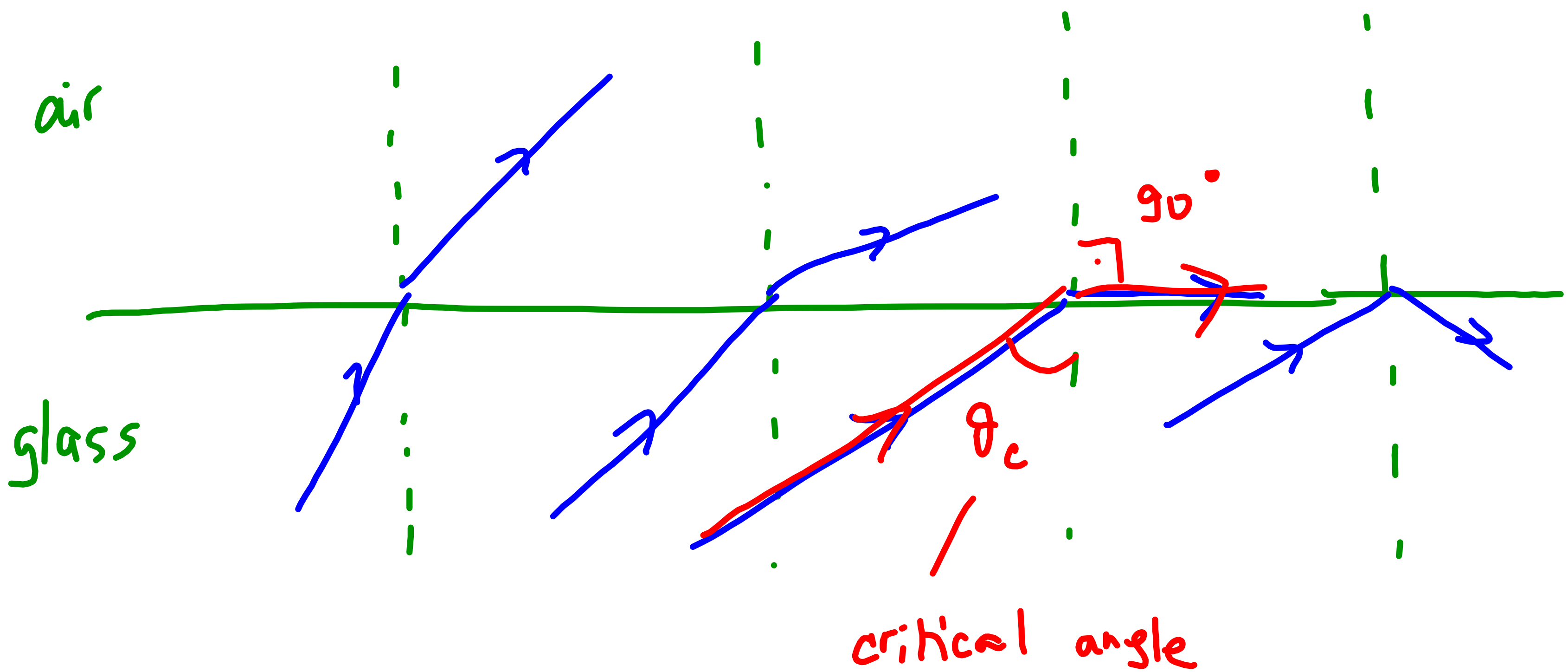
$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\sin\theta_2 = \frac{n_1}{n_2} \sin\theta_1$

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

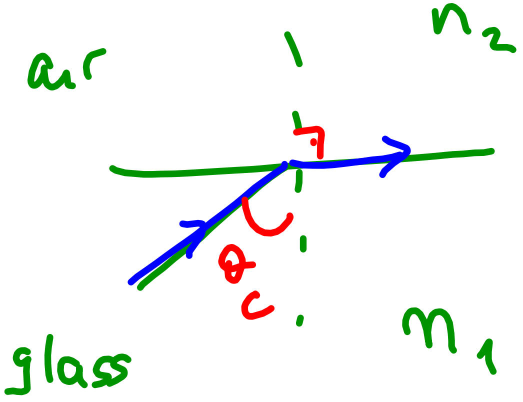
$\theta_2 = 19.45^\circ$

Total internal reflection



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

- we can calculate it



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

$n_1 = 1.5$

$n_2 = 1$

$\theta_2 = 90^\circ$

$\theta_1 = ?$ $\theta_1 = \theta_c$

$$1.5 \sin \theta_c = 1 \cdot \sin 90^\circ$$

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

$$\theta_c = 42^\circ$$

For an angle $\theta \geq \theta_c \Rightarrow$ total internal reflection