Chapter 13. LIGHT

New word list:

Plane mirror
Normal line
Angle of incidence/reflection/refraction
Laterally inverted
total internal reflection(TIR)
Critical angle
Optical fibre
Spectrum
Dispersion
Chromatic
monochromatic
Prism

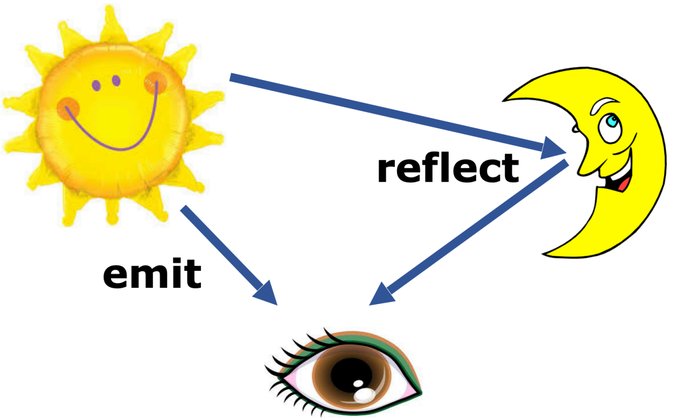
Light

- Light ray travels in **straight lines**, changes its direction when hitting a shinny surface, like **particles** - [evidence: reflection, refraction]
- Light can also travel as **waves** - [evidence: diffraction]
- Can travel through empty space
- Speed of light in vacuum is the **fastest speed** in the universe
- Light is a form of radiation, transfers energy
- Light has visible and invisible region

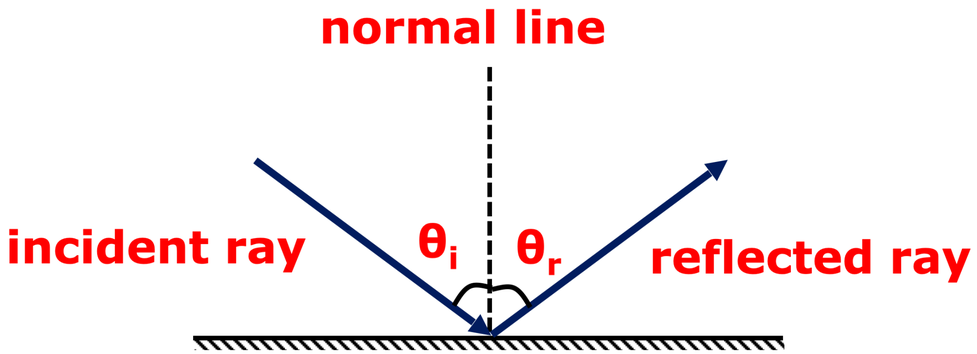
Reflection

Def: the change of **direction** of a ray when it strikes a surface without passing through it

Reflection law: $\theta_i = \theta_r$



A ray of light strikes a plane mirror

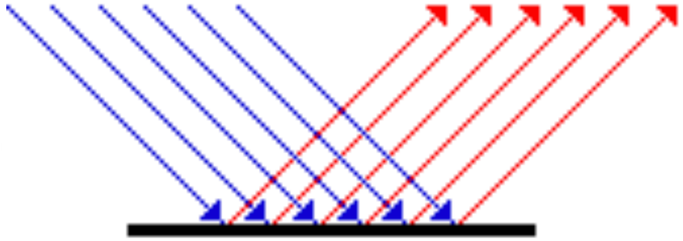


θ_i——angle of incidence

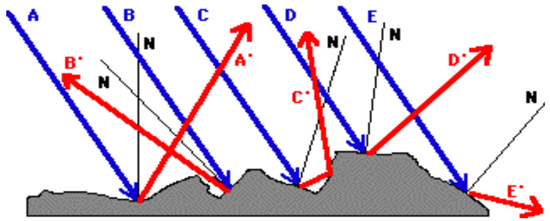
θ_r—— angle of reflection

Reflection

Specular

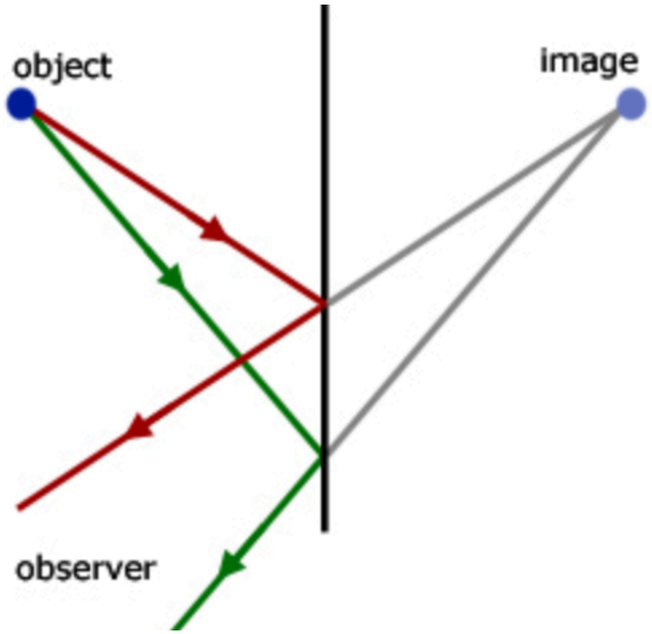


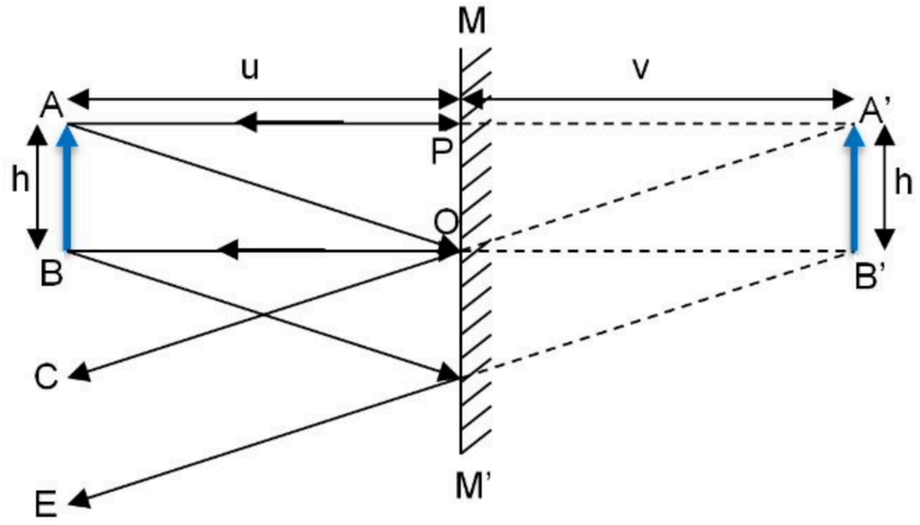
Diffuse Reflection



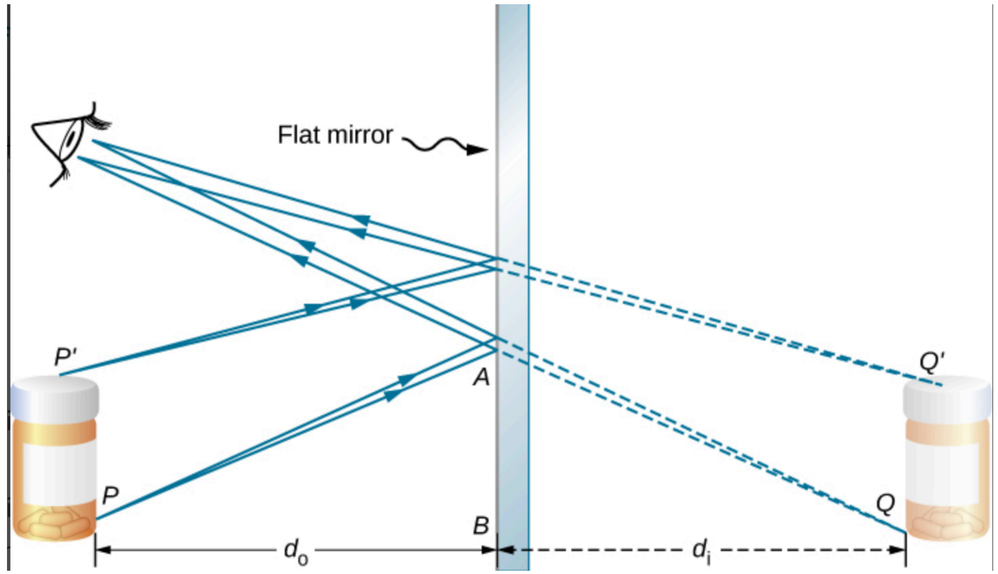
The Law of Reflection is Always Observed
(regardless of the orientation of the surface)

The image in a plane mirror





The image in a plane mirror



The image in a plane mirror

- The **same size** as object
- The **same distance** behind mirror as the object is in front of it
- **Laterally inverted**
- **Virtual image**

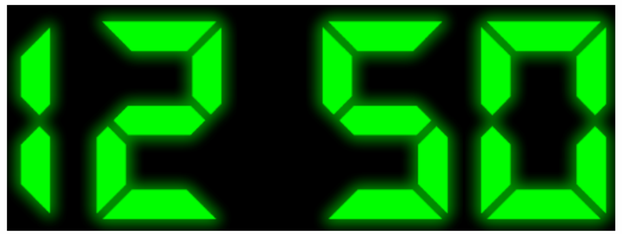
Reflection

Actual Time
3:20

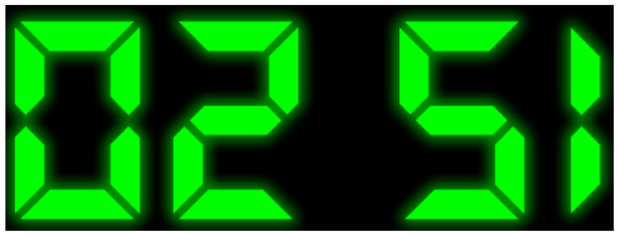
Time shown in the mirror
8:40

Reflection

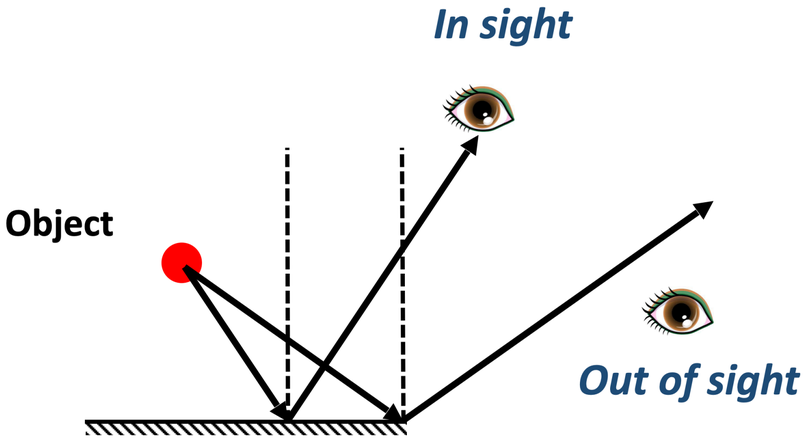
The actual time

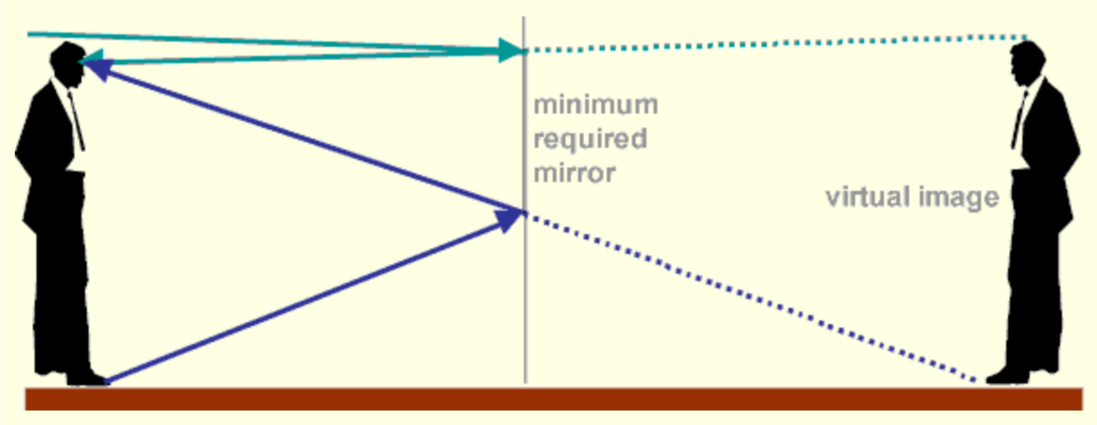


Time shown in the mirrc



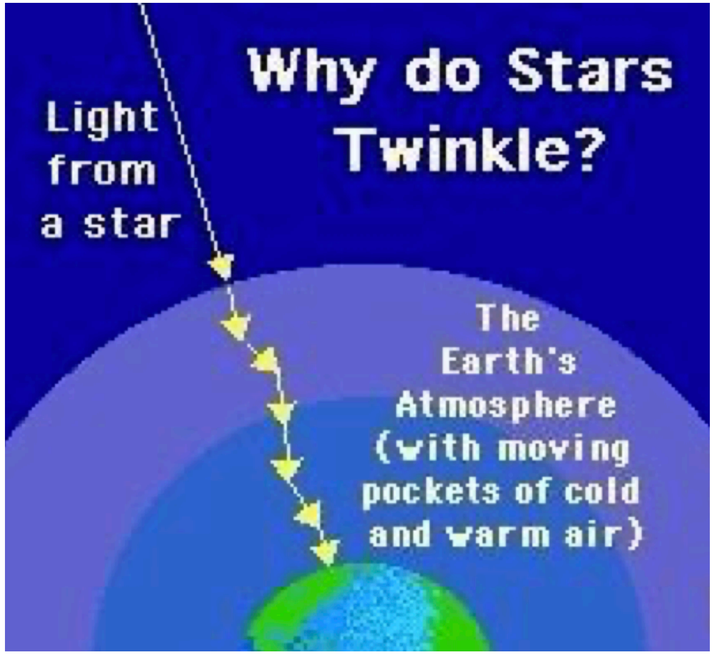
In/out of sight:





Refraction

Refraction is the bending of the path of a light wave as it passes from one material to another material. (Incident angle = 0 => No bending)



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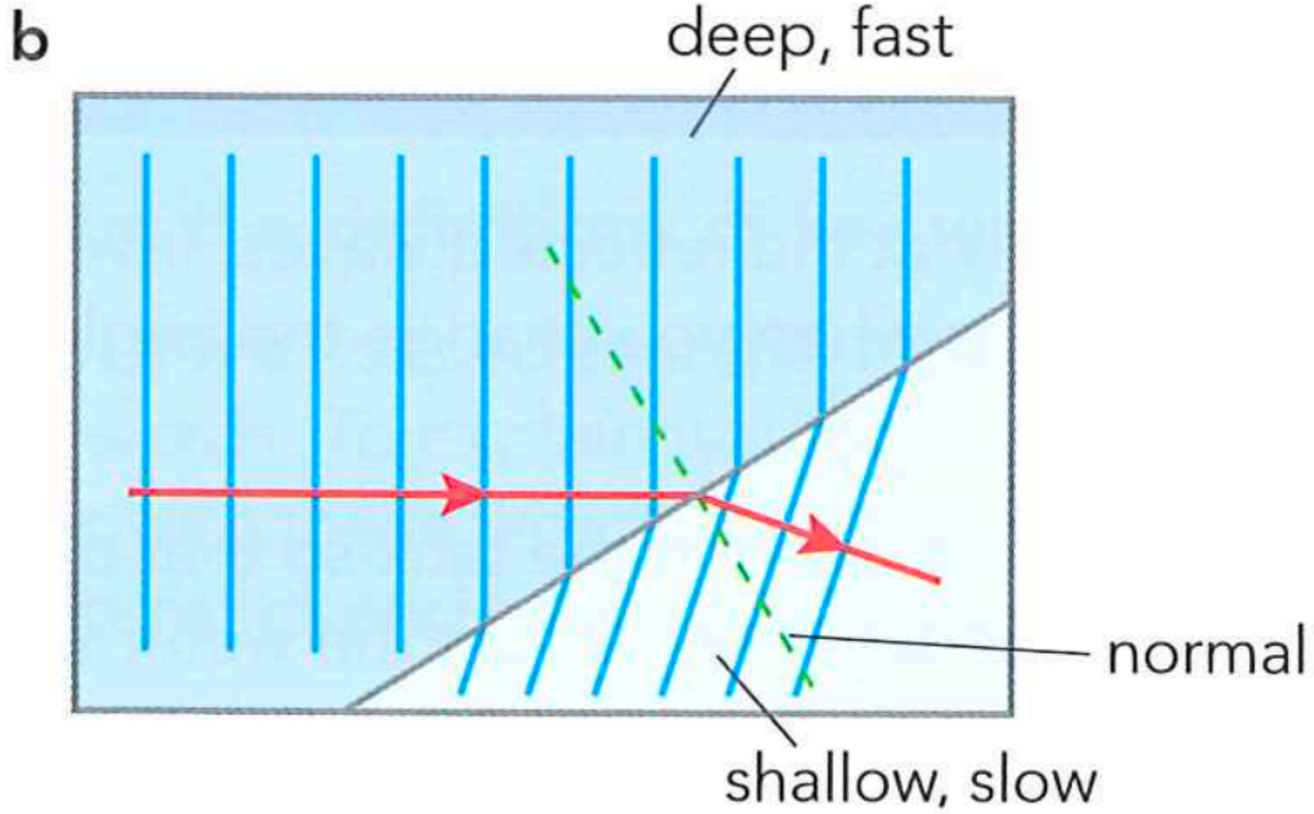
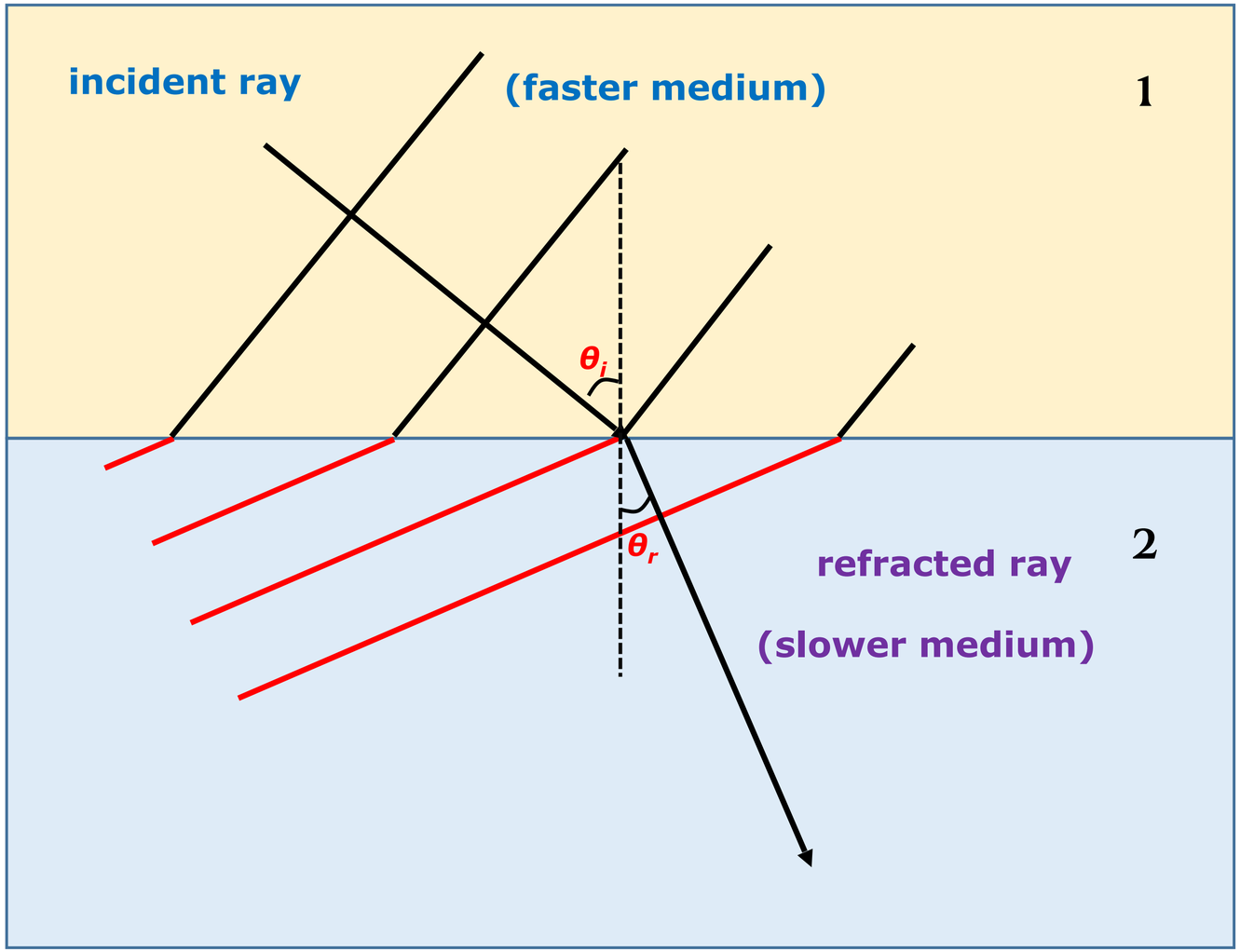


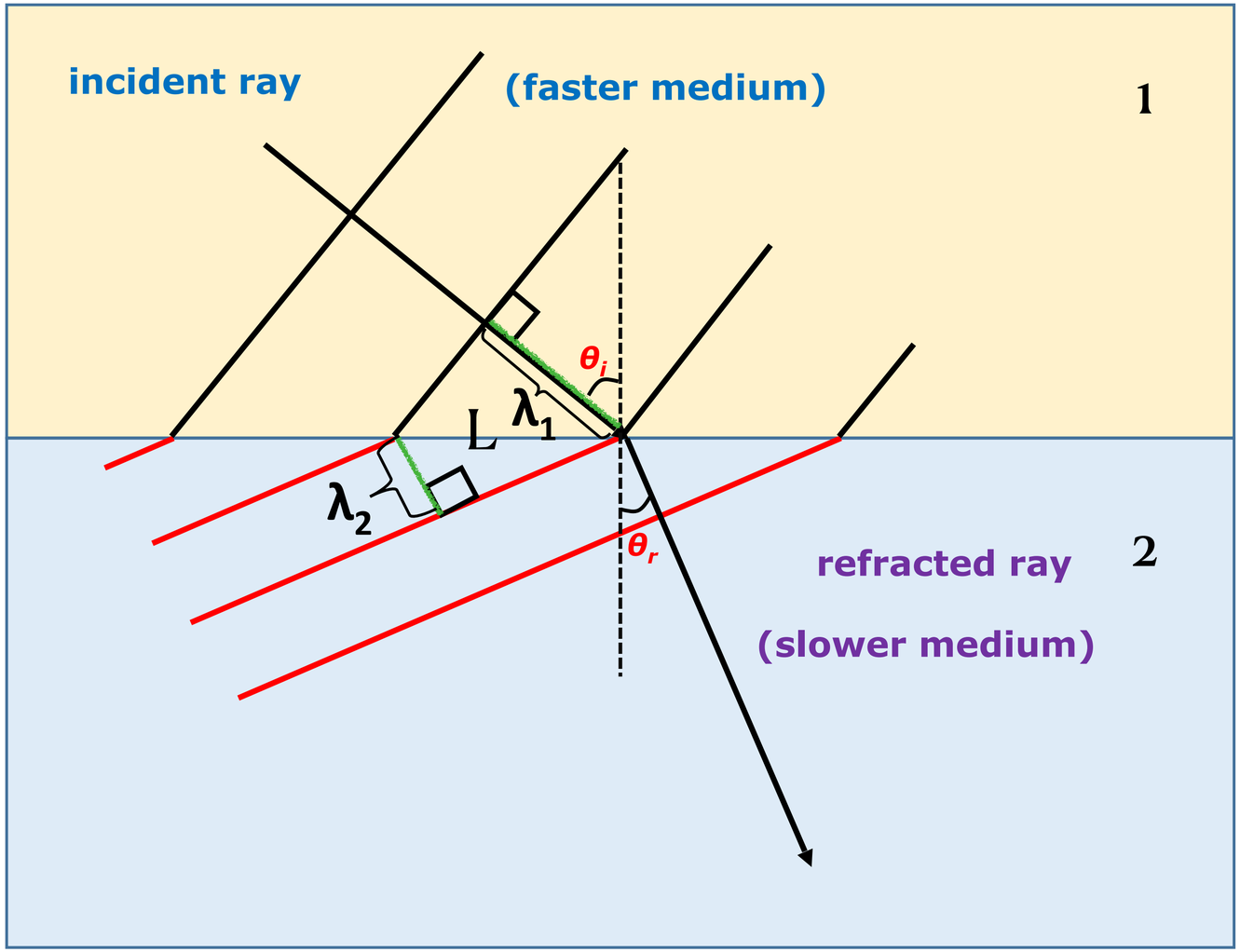
Refraction



What's the relation btw θ_i and θ_r ?

And how they are related to v_1 and v_2

Refraction



$\lambda_1 = L \times \sin\theta_i$

$\lambda_2 = L \times \sin\theta_r$

$\lambda_1 / \lambda_2 = \sin\theta_i / \sin\theta_r$

$$\frac{\lambda_1}{\lambda_2} = \frac{\sin\theta_i}{\sin\theta_r}$$

$$v_1 = \lambda_1 f$$

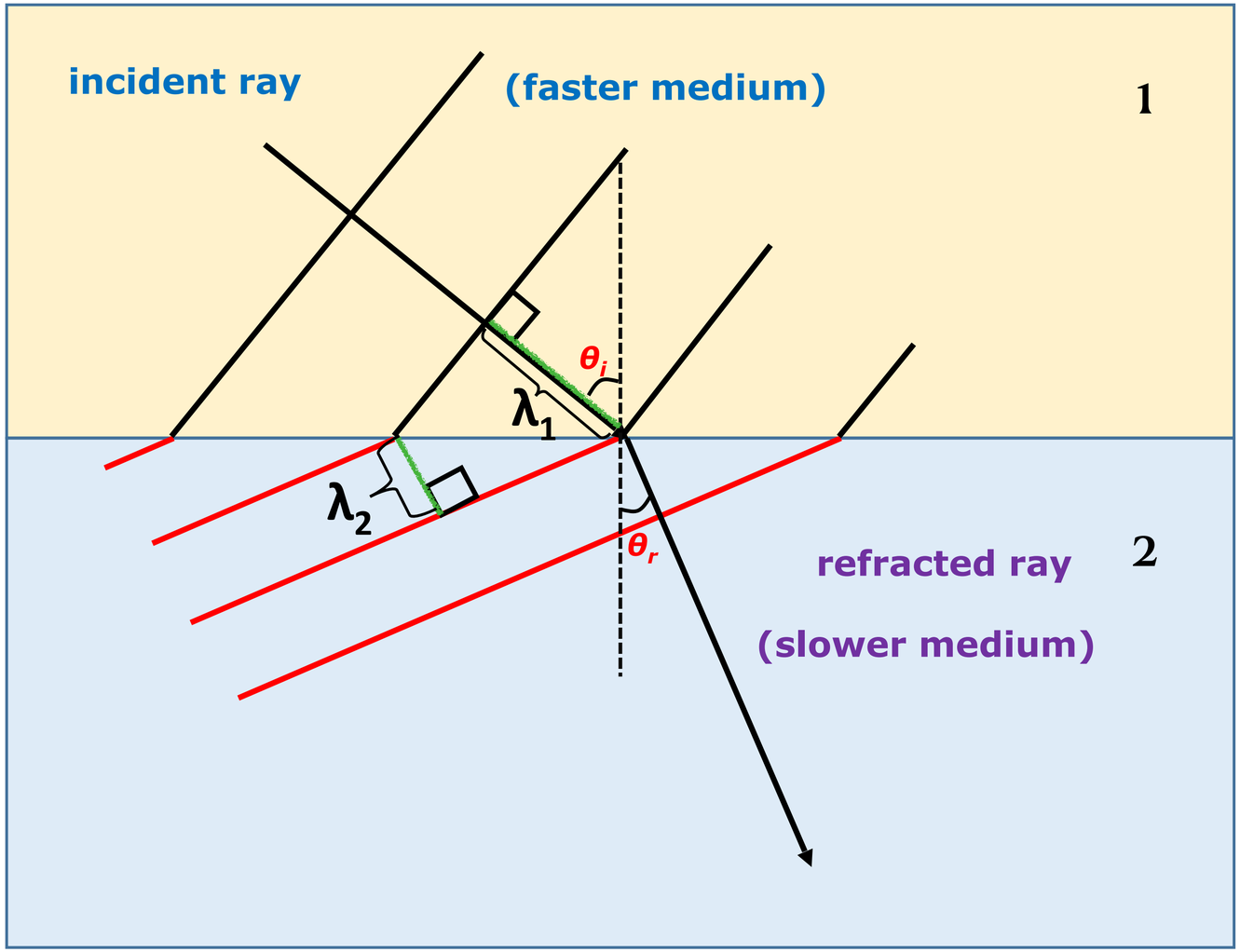
$$v_2 = \lambda_2 f$$

$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{\sin\theta_i}{\sin\theta_r}$$

refractive index of medium(n) ——

$$n = \frac{c}{v} = \frac{\textit{Speed of light in vacuum}}{\textit{Speed of light in medium}}$$

Reflection



$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{\sin\theta_i}{\sin\theta_r}$$

refractive index of medium(n) ——

$$n = \frac{c}{v} = \frac{\textit{Speed of light in vacuum}}{\textit{Speed of light in medium}}$$

$$n_1 = \frac{c}{v_1} \qquad n_2 = \frac{c}{v_2}$$

$$\frac{v_1}{v_2} = \frac{\sin\theta_i}{\sin\theta_r} = \frac{n_2}{n_1}$$

Refraction

refractive index of vacuum: $n_{vacuum} = c/c = 1$

$n_{air} \approx n_{vacuum} = 1$

Material	Speed of light / m/s	$\frac{\text{speed in vacuum}}{\text{speed in material}}$
vacuum	2.998×10^8	1 exactly
air	2.997×10^8	1.0003
water	2.308×10^8	1.33
Perspex®	2.000×10^8	1.5
glass	$(1.800–2.000) \times 10^8$	1.5–1.7
diamond	1.250×10^8	2.4

$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_2}{n_1}$$

From air to medium:

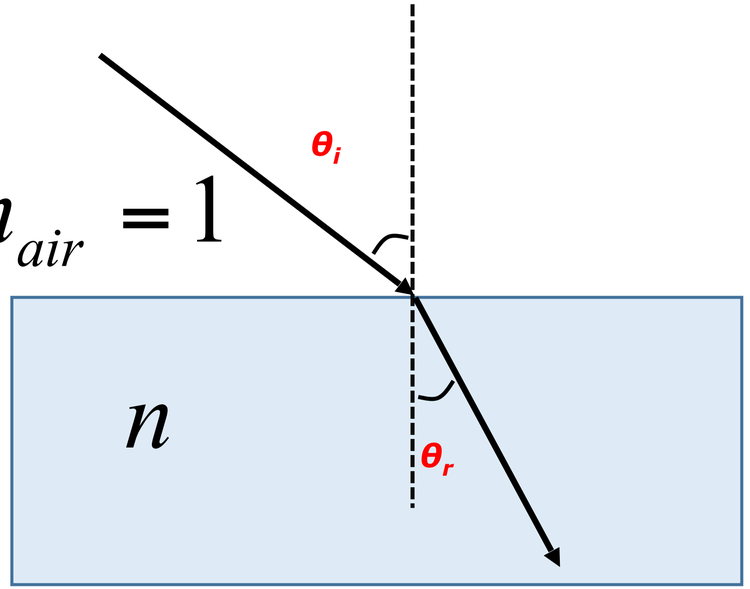
$$\frac{\sin\theta_i}{\sin\theta_r} = n_{medium}$$

From medium to air:

$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{1}{n_{medium}}$$

Refraction

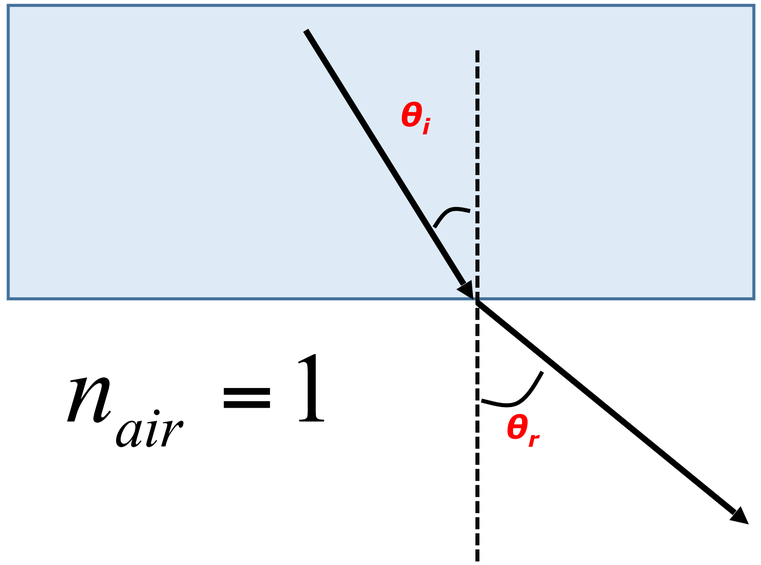
Less dense



More dense

$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{n}{n_{air}} = n$$

refract towards the normal



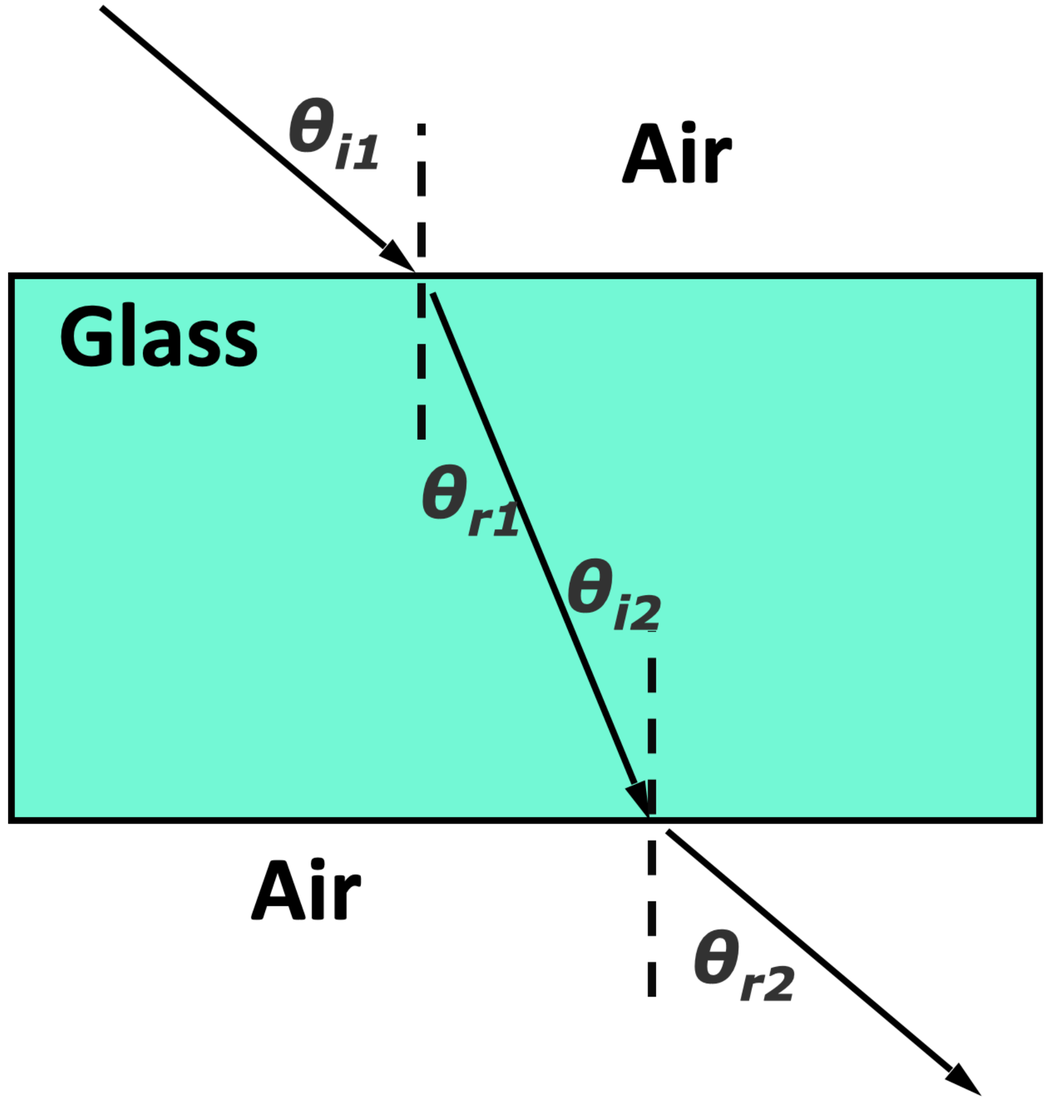
More dense

Less dense

$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_{air}}{n} = \frac{1}{n}$$

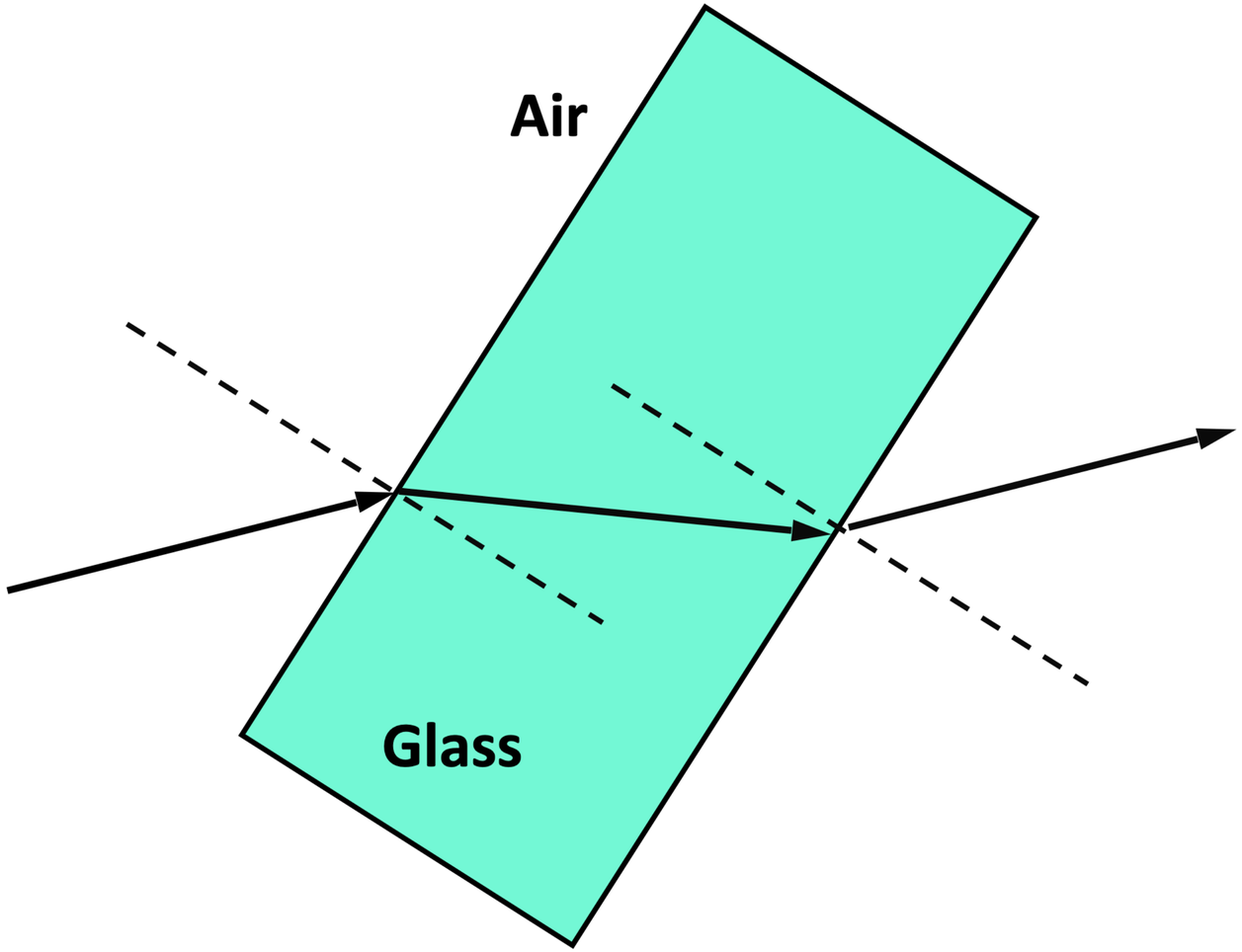
refract away from the normal

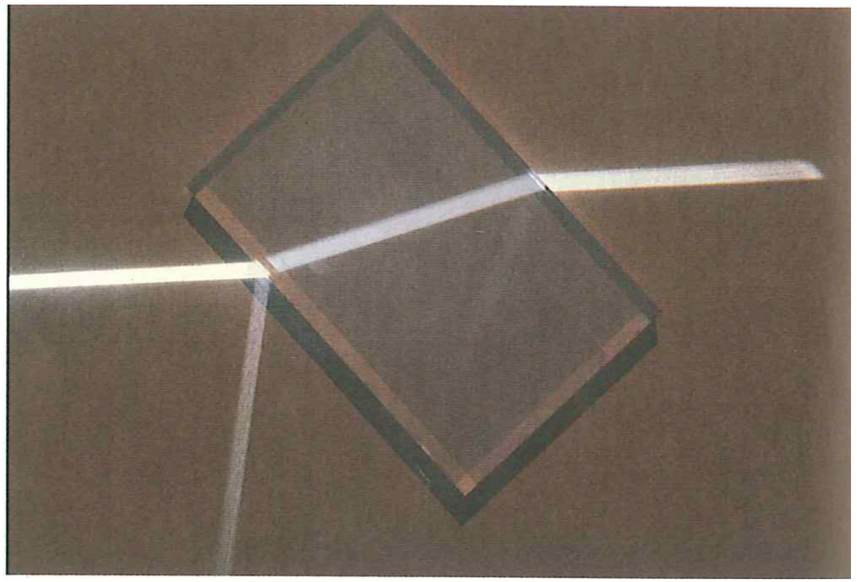
Refraction



$\theta_{r2} = \theta_{i1}$?

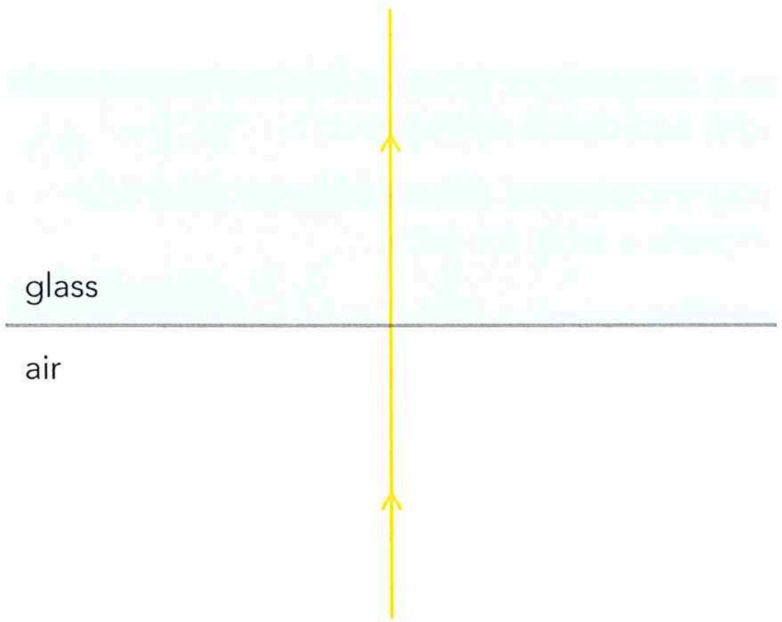
Reflection

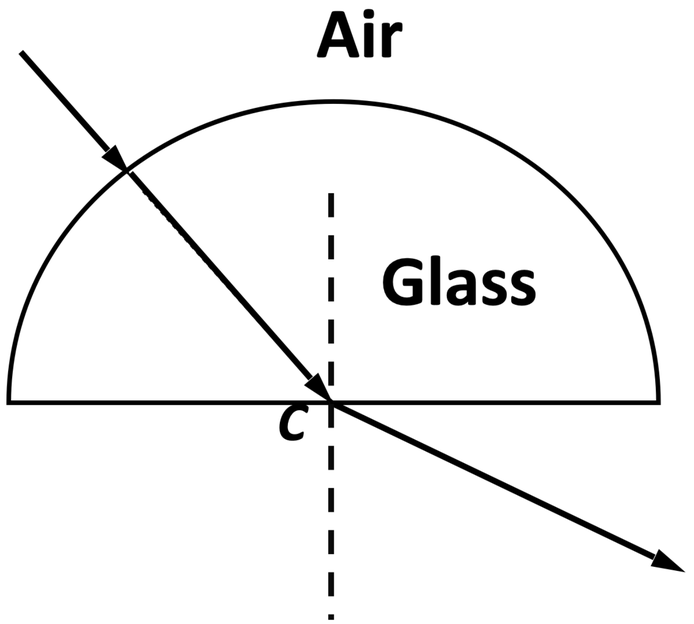




Return to its original direction, only **shifted**

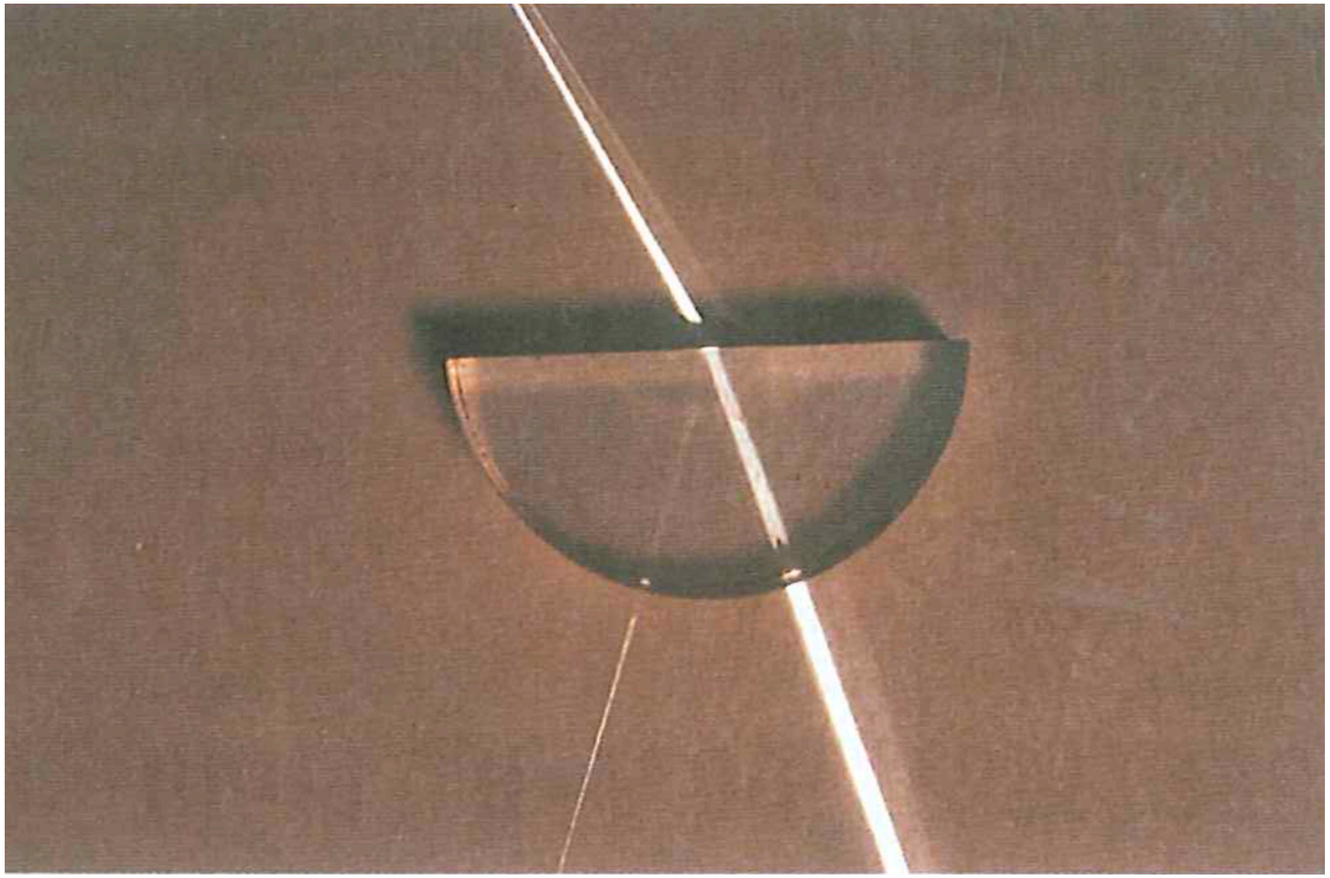
Refraction



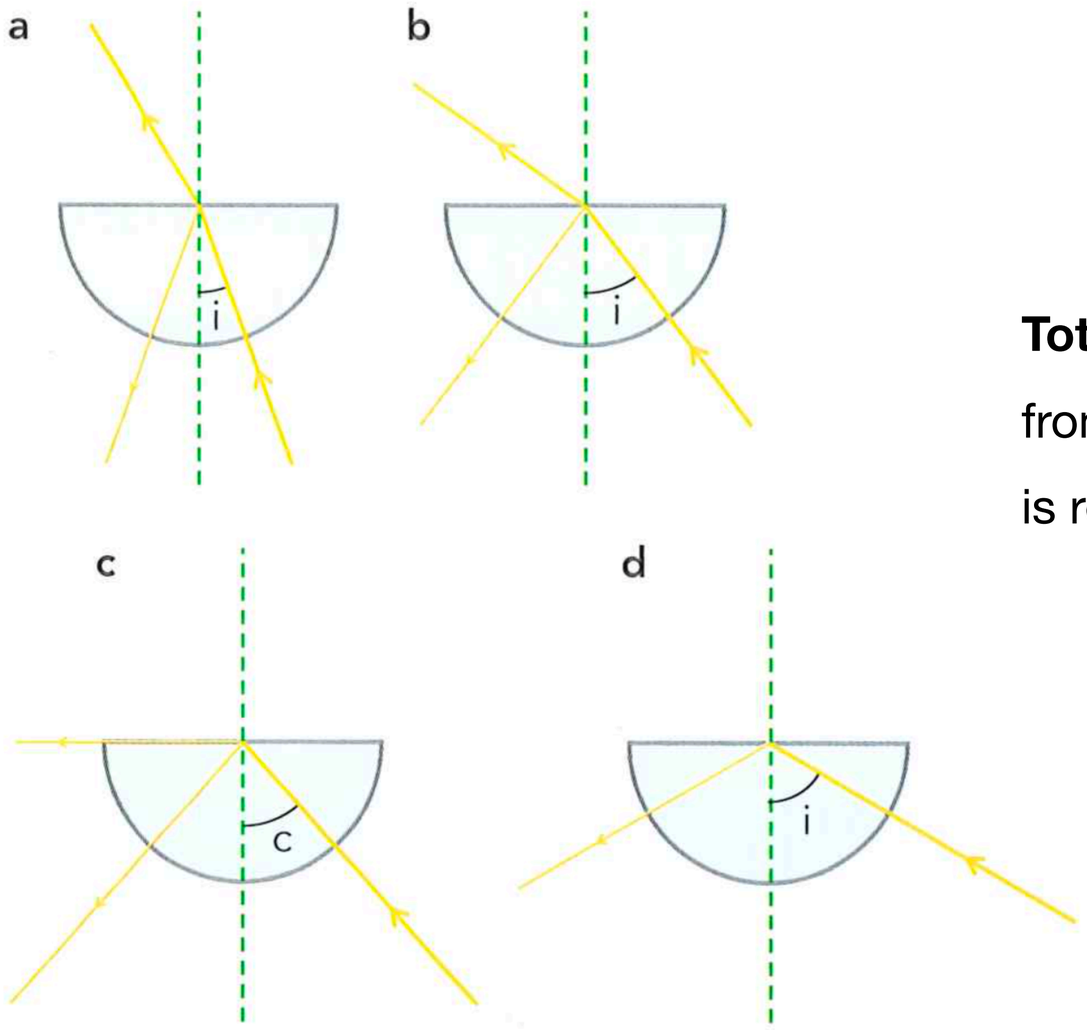


No bending when incident angle = 0

Refraction



Total Internal Reflection

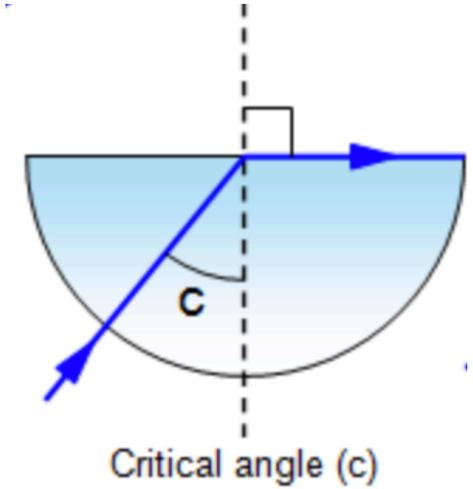


Critical angle

Total internal reflection: when light travels from a more dense(large n) material, all light is reflected, NO refracted ray.

Total Internal Reflection

Critical angle: the angle of incidence in the material at which angle of refraction is 90 degrees/the angle of incidence **above** which total internal reflection occurs



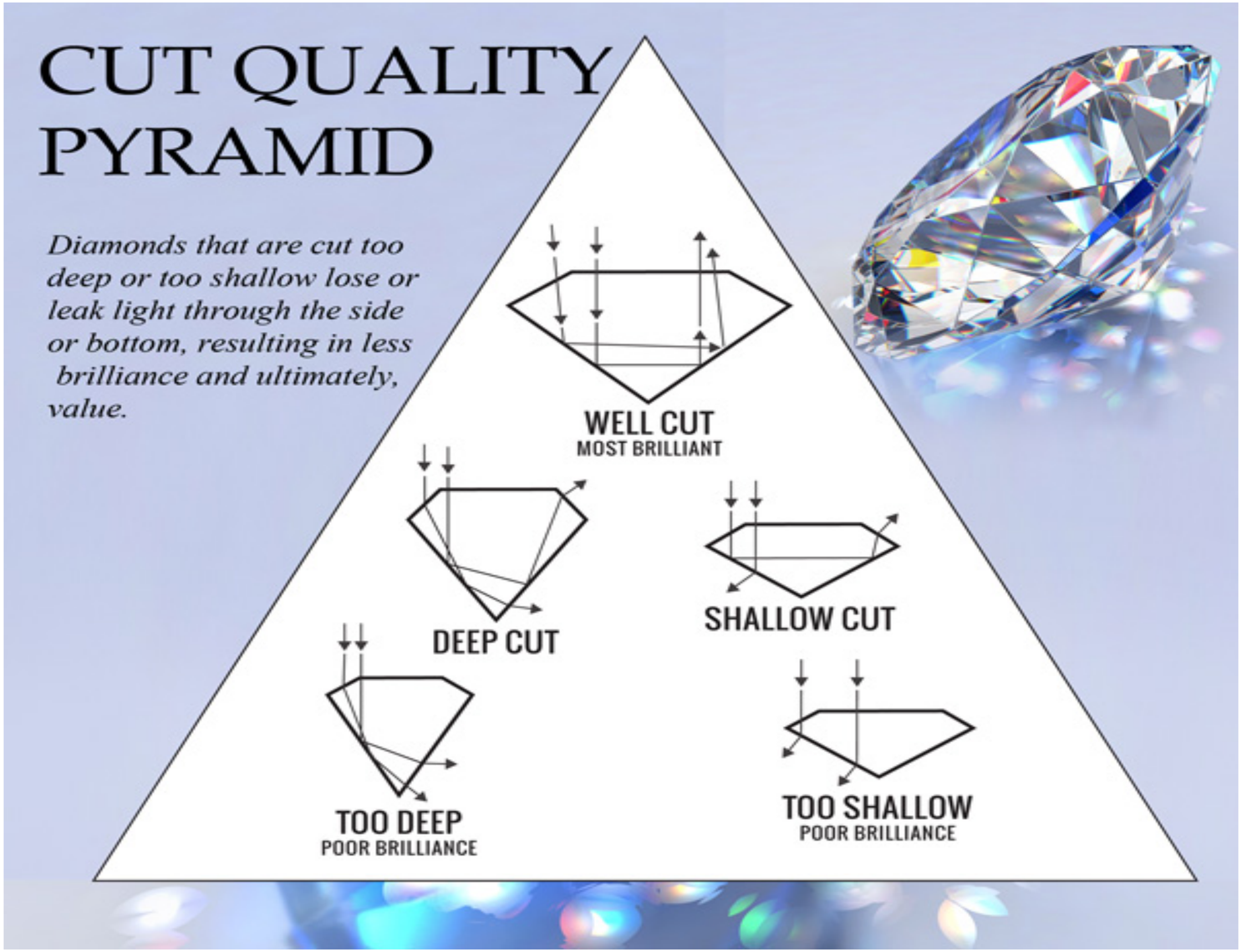
$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{\sin\theta_c}{\sin 90^o} = \sin\theta_c = \frac{1}{n}$$

Total Internal Reflection

TIR only takes place when :

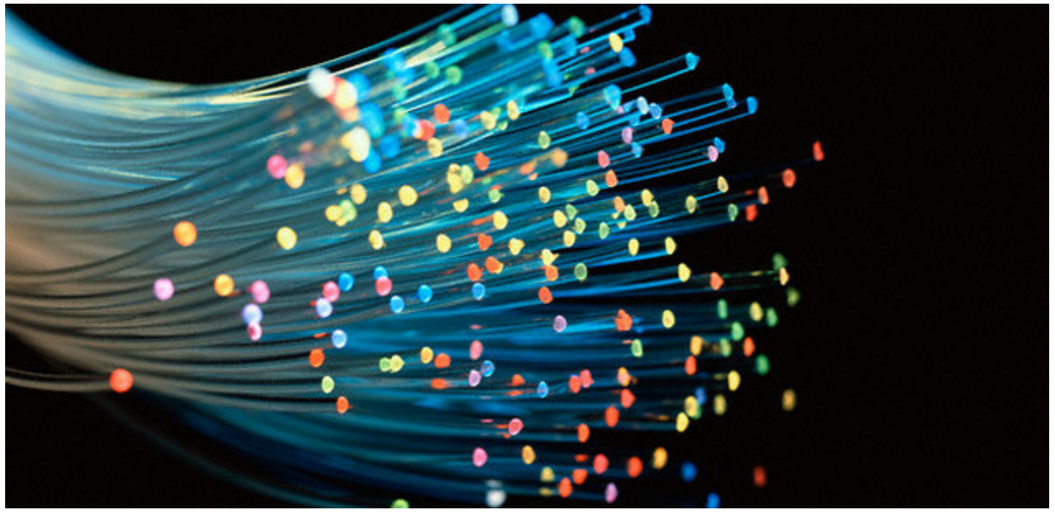
- the light is in the **more dense** medium and approaching the **less dense** medium.
- the angle of incidence is **greater** than the **critical angle.**

Total Internal Reflection

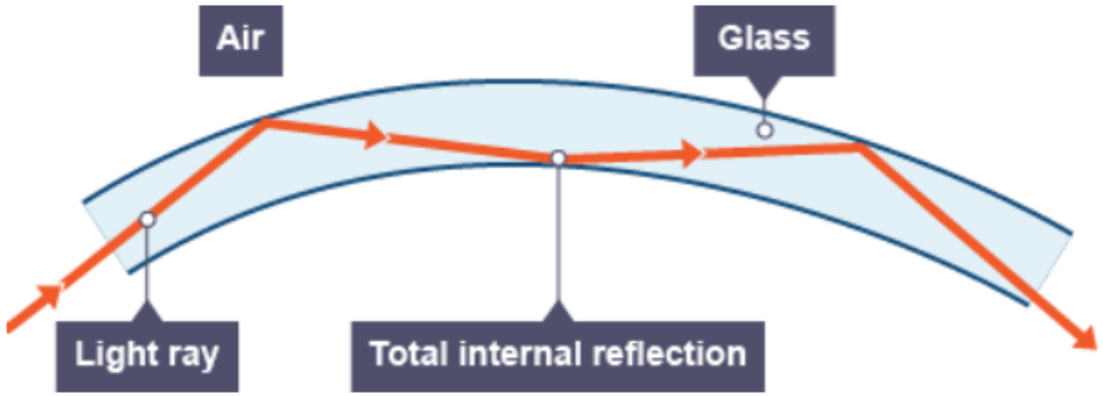


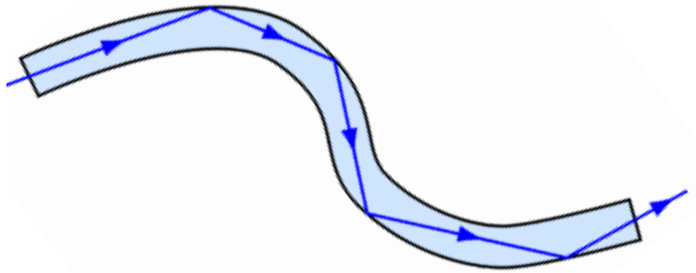
Total Internal Reflection

Optical Fibre



Total Internal Reflection

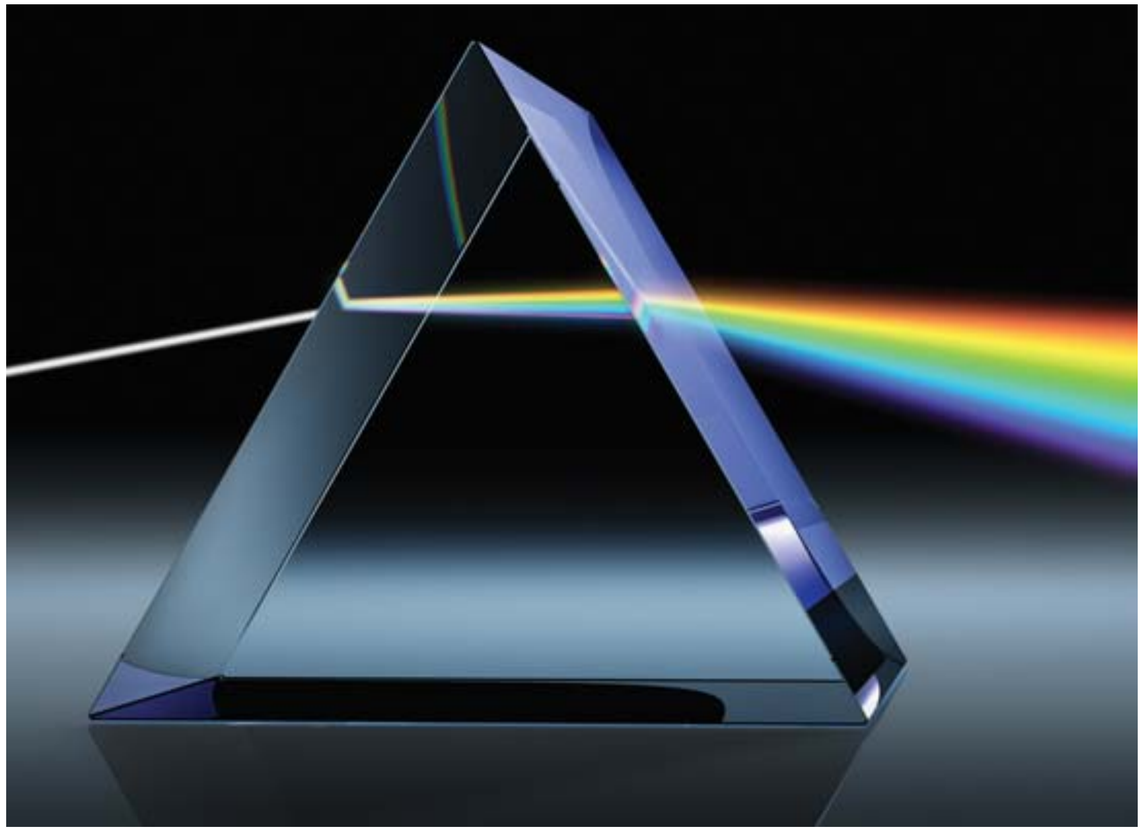




Dispersion

Dispersion

DISPERSION: the separation of different wavelengths of light because they are refracted through different angles



	Wavelength	Frequenzy
Red	~ 625 – 740 nm	~ 480 – 405 THz
Orange	~ 590 – 625 nm	~ 510 – 480 THz
Yellow	~ 565 – 590 nm	~ 530 – 510 THz
Green	~ 520 – 565 nm	~ 580 – 530 THz
Blue	~ 445 – 520 nm	~ 675 – 580 THz
Indigo	~ 425 – 445 nm	~ 700 – 675 THz
Violet	~ 380 – 425 nm	~ 790 – 700 THz

Chromatic —— colorful

Frequency determines color of light!

Monochromatic: light of a single **frequency**

Dispersion

- The speed of light in **vacuum** is a constant
- In a medium (not vacuum), light with higher the frequency travels slower.
- **Red** light travels the **fastest**

  Violet light travels the **slowest**.

Dispersion

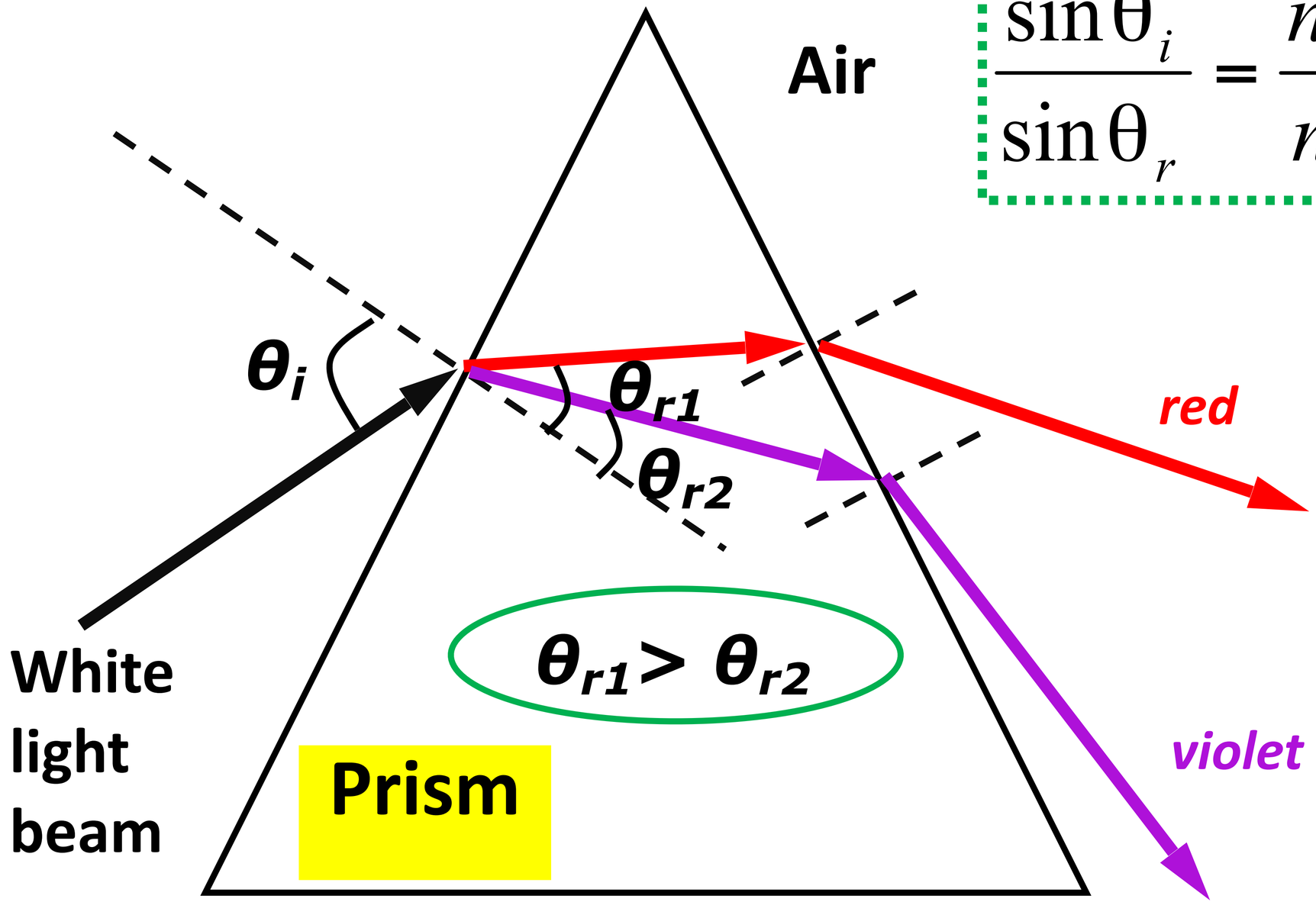
$$n = \frac{c}{v}$$

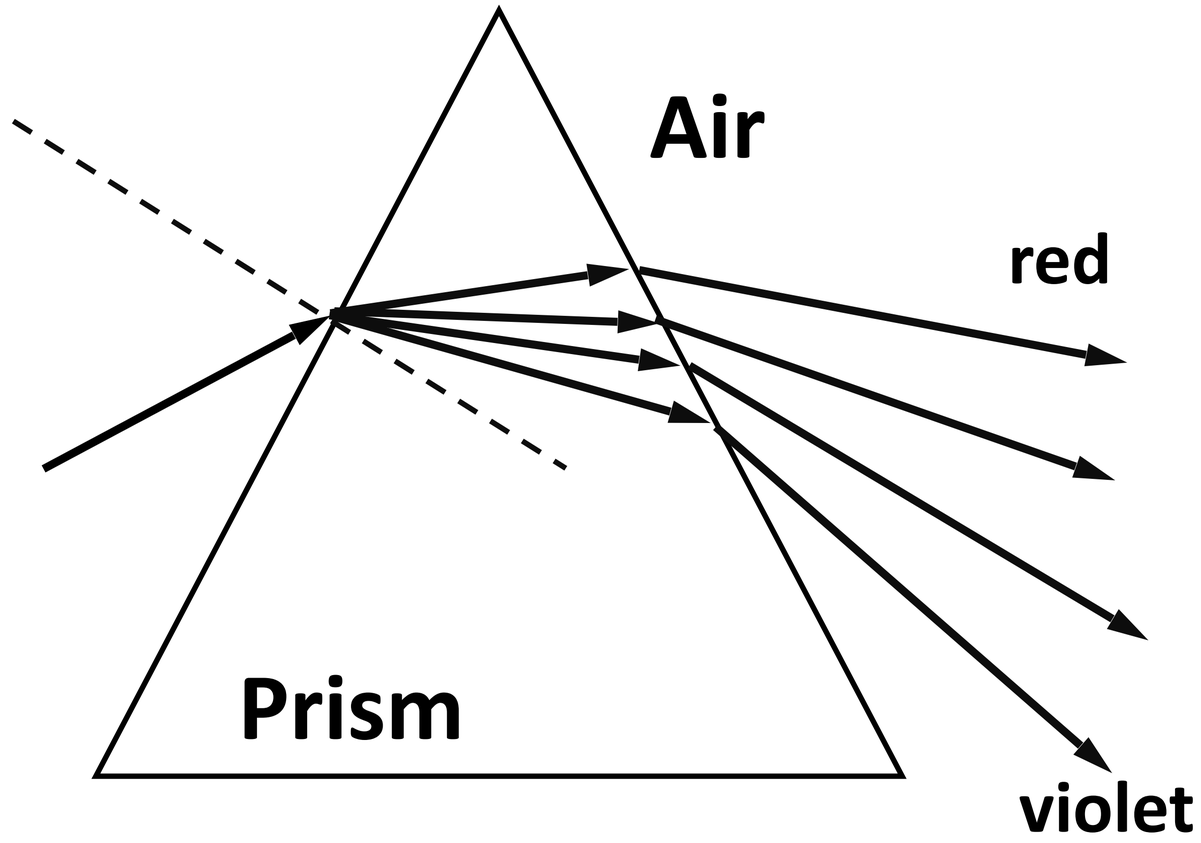
$v_{red} > v_{yellow} > v_{green} > v_{blue} > v_{violet}$

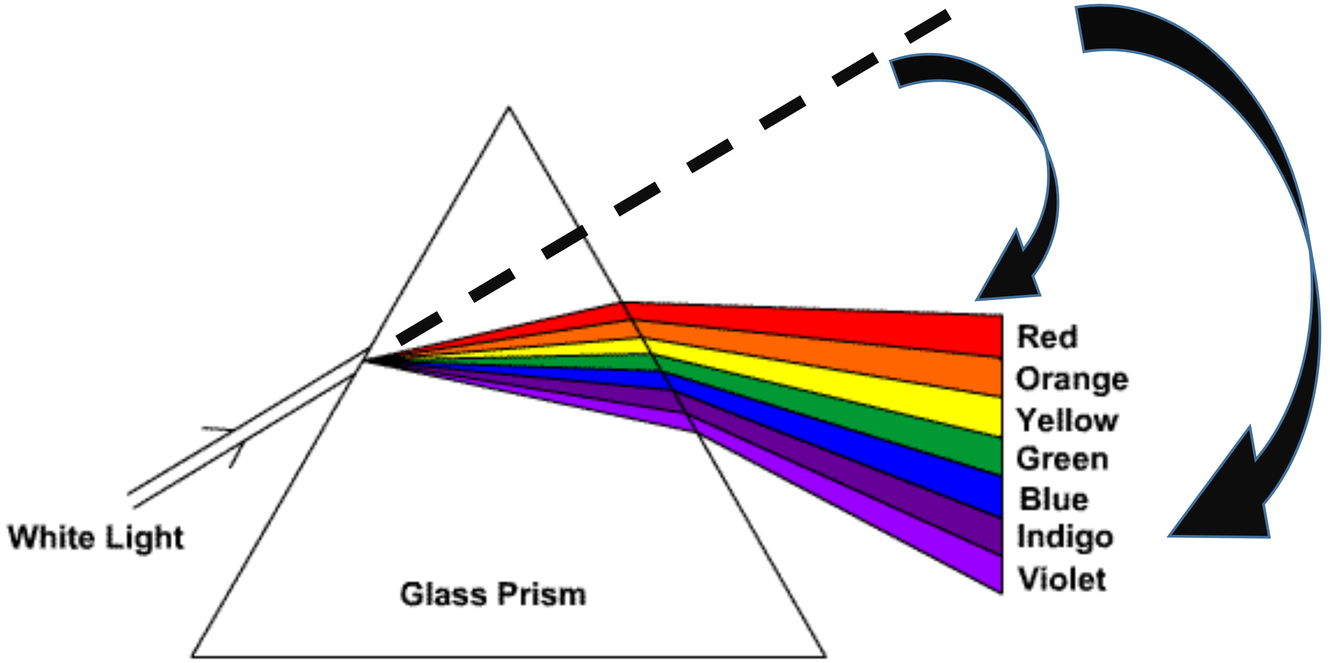
$$n_{red} = \frac{c}{v_{red}} < n_{violet} = \frac{c}{v_{violet}}$$

One medium has different refractive index of different frequency of light

$$n_{red} < n_{yellow} < n_{green} < n_{blue} < n_{violet}$$


Air
$\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_2}{n_1}$
θ_i
θ_{r1}
θ_{r2}
red
violet
White light beam
$\theta_{r1} > \theta_{r2}$
Prism


Air
red
Prism
violet


White Light
Glass Prism
Red
Orange
Yellow
Green
Blue
Indigo
Violet