مفردات منهج البصريات

Chapter One (The Nature and Propagation of Light),

wavefrom and rays, Huygens principles. Index of refraction, The electromagnetic Spectrum, problems.

Chapter Two (Reflection and Refraction)
Reflection and refraction at plane surface, The laws of reflection and refraction.

Updates

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Chapter Three (Spherical Surfaces) Focal points and focal lengths.
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The parallel Ray method, Oblique-Ray methods, Magnification.
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Chapter Four (Lenses) Thin lenses, focal points and focal lengths , Image formation, Conjugates points and planes, the parallel - Ray method

Update

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Refrences

كتب البصريات المتوفرة في مجانية تعليم الكلية +Fundamental of optics
والمكتبة المركزية + مواقع الانترنيت

(The Nature and Propagation of Light)

Different theories on the nature of light have been proposed. The important theories are as follows:

- Newton's Corpuscular Theory
- Huygens' Wave Theory
- Maxwell's Electromagnetic Theory
- Planck's Quantum Theory

1-Newton's Corpuscular Theory

- According to Sir Issac Newton's Corpuscular Theory, a luminous body continuously emits tiny, light and elastic particles called corpuscles in all directions. When these particles fall on the retina of the eye, they produce the sensation of vision.

This theory could explain a number of phenomena concerning light like rectilinear propagation, reflection and refraction.

2-Huygens' Wave Theory

-

- In 1967 Christian Huygens proposed the wave theory of light. According to this, a luminous body is a source of disturbance in hypothetical medium called ether. The disturbance from the source is propagated in the form of waves through space and the energy is distributed equally in all directions. Even though this theory could satisfactorily explain several optical phenomena, the presence of ether could not be detected.

3-Maxwell's Electromagnetic Theory

- Electromagnetic theory of light was put forward by James Clerk Maxwell in 1873. According to this theory, light consists of fluctuating electric and magnetic fields propagating in the form of electromagnetic waves. But this theory failed to explain the photoelectric effect.

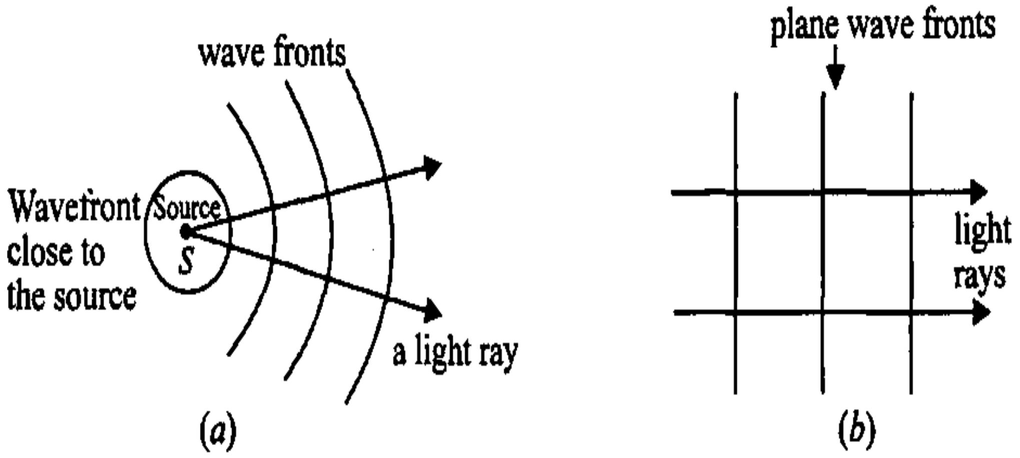
4-Planck's Quantum Theory

- According to Max Planck's Quantum theory, radiation is not continuous but is made up of tiny packets of energy called photons. However, this theory could not explain other optical phenomena.
- From all the above theories it is clear that certain optical phenomena can be explained clearly only if light is considered to be made up of particles, while certain other phenomena can be explained only if we consider light as a wave. Thus light appears to have a dual nature.It is interesting to compare the two classical theories of light and see which phenomena can be explained by each theory. The following table does this.

Wave theory		Corpuscular theory
Reflection		Reflection
Refraction		Photoelectric effect
Diffraction		
Interference		

1- Wave front and Rays

- For an electromagnetic wave, the wavefront is represented as a surface of identical phase, and can be modified with conventional optics. For instance, a lens can change the shape of optical wavefronts from planar to spherical



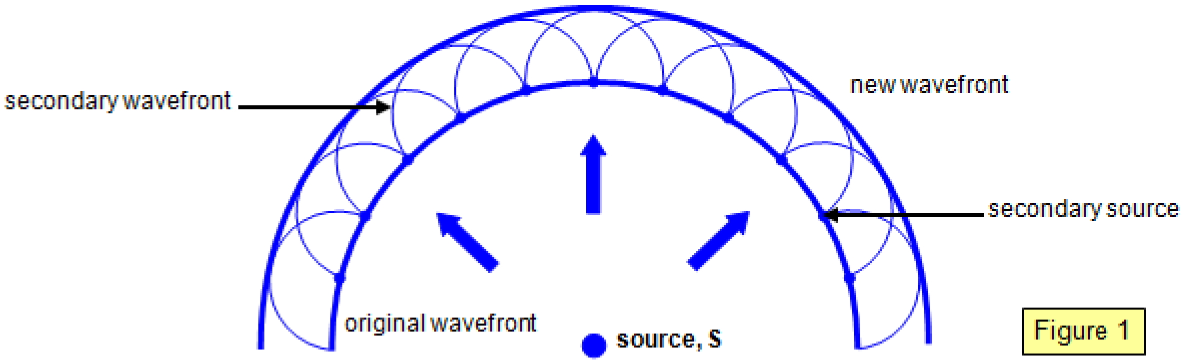
This direction of travel, because it is uniform all across the plane wave , is called a ray

A ray is a thin beam of light that travels in a straight line. A wave front is the line (not necessarily straight) or surface connecting all the light that left a source at the same time

geometrical optics, which is the study of electromagnetic waves that can be approximated using rays

What is the Huygens principle of wavefronts?

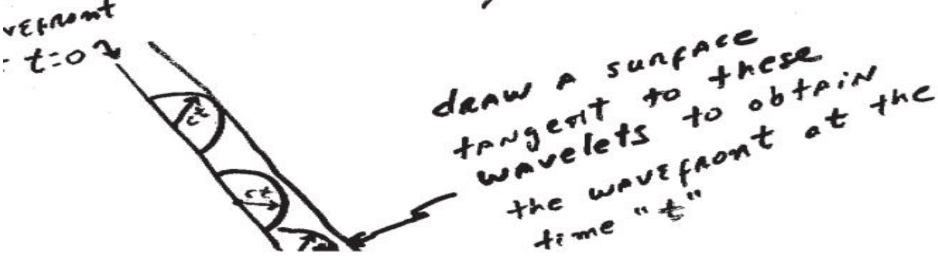
Wave theory of Huygens



2- Huygens principle

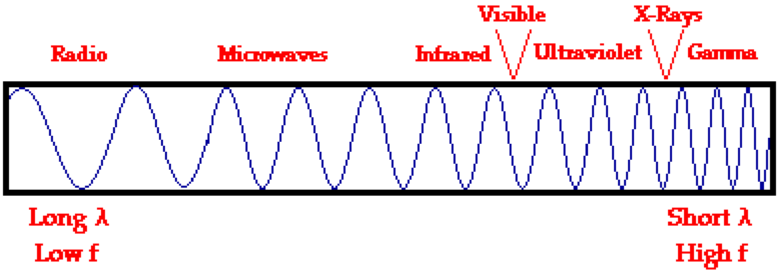
every point on the wavefront of light is a source of secondary wavefronts or wavelets and direction of propogation of these wavelets is the direction of propogation of the main wavefront ".

All points of a wavefront serve as point sources of spherical second. wavelets. After a time t, the new position of the wavefront will be that of a surface tangent to these secondary wavelets

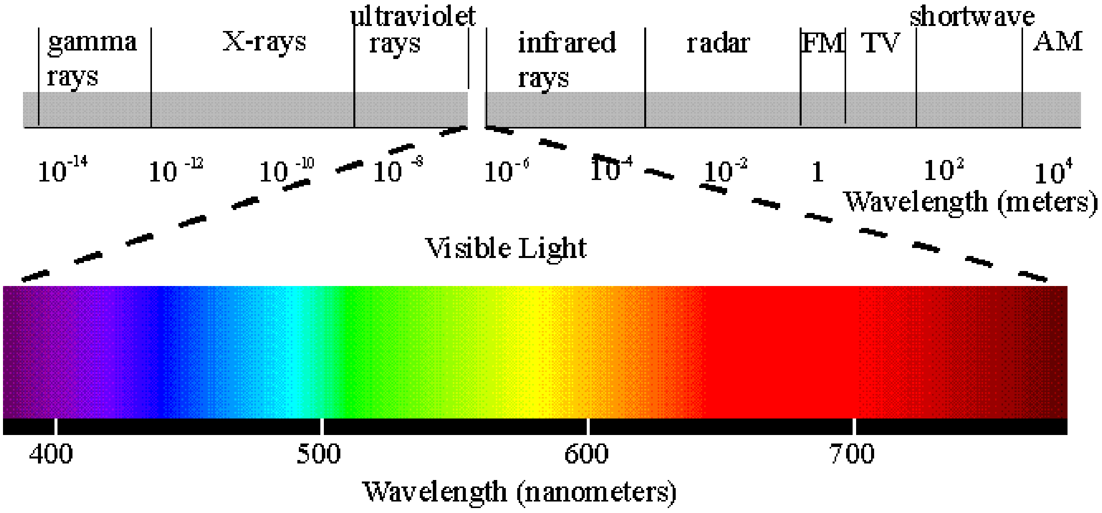


3- the electromagnetic spectrum

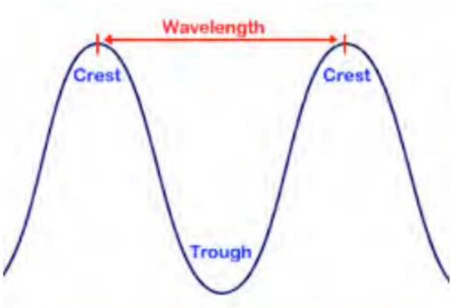
Electromagnetic waves exist with an enormous range of frequencies. This continuous range of frequencies is known as the **electromagnetic spectrum**. The entire range of the spectrum is often broken into specific regions. The subdividing of the entire spectrum into smaller spectra is done mostly on the basis of how each region of electromagnetic waves interacts with matter. The diagram below depicts the electromagnetic spectrum and its various regions.

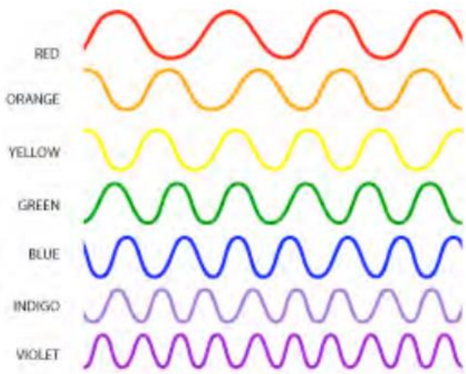


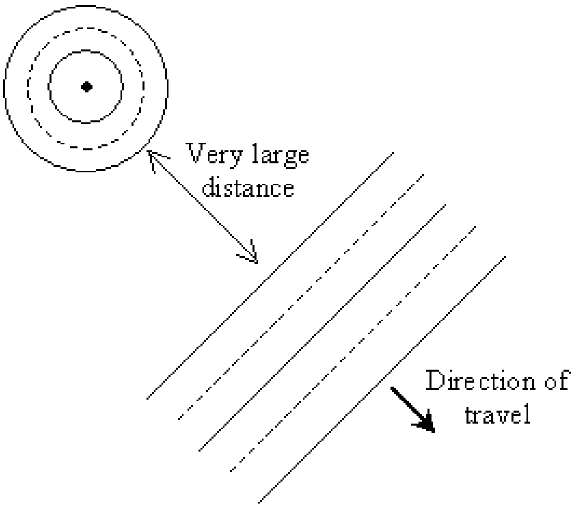
$$E=hf=h\,c/\lambda$$



**Each color has a different wavelength and frequency, but ·
SAME SPEED in air**

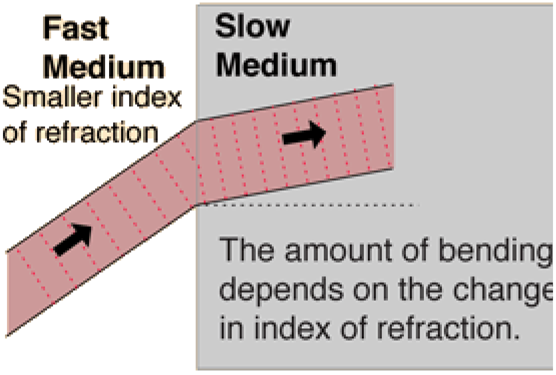






2- index of refraction

The index of refraction is defined as the speed of light in vacuum divided by the speed of light in the medium.



index of refraction

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

velocity of light in vacuum

velocity of light in the medium

The indices of refraction of some common substances are given below with a more complete description of the indices for optical glasses given elsewhere. The values given are approximate and do not account for the small variation of index with light wavelength which is called dispersion.

Material	**n**	**Material**	**n**
Vacuum	1.000	Ethyl alcohol	1.362
Air	1.000277	Glycerine	1.473
Water	4/3	Ice	1.31
Carbon disulfide	1.63	Polystyrene	1.59
Methylene iodide	1.74	Crown glass	1.50-1.62
Diamond	2.417	Flint glass	1.57-1.75

he refractive index *n* of an optical medium is defined as the ratio of the speed of light

in vacuum, *c* = 299792458 m/s, and the phase velocity *v* of light in the medium

The phase velocity is the speed at which the crests or the phase of the wave moves, which may be different from the group velocity, the speed at which the pulse of light or the envelope of the wave moves. in vacuum.

Sample Problem 1:

The speed of light in an unknown medium is measured to be 2.76 x 10^8 m/s. (a) What is the index of refraction of the medium? (b) Does it match any of the materials listed in your *Table*?

Solution:

(a) The index is found to be

$n = c/v$ = (3.00 x 108 m/s)/(2.76 x 108 m/s) = 1.09.

(b) This does not equal any of the indices of refraction listed in the table. It is closest to air, which suggests it is some slightly denser gas.

Chapter 2 : Reflection and Refraction

1- Optical path :

In a medium of constant refractive index, *n*, the OPL for a path of physical length *d* is just

$$\Delta = n\ d$$

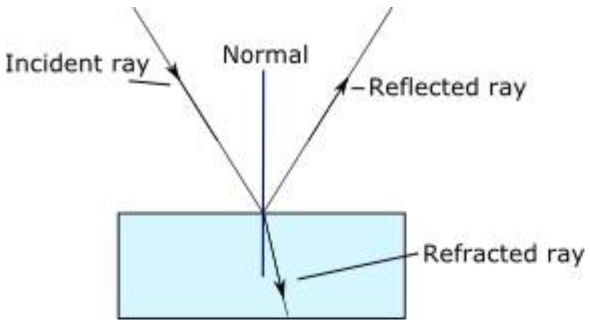
If the refractive index varies along the path, the OPL is given by

Opt= n1d1+n2d2………..

where *n*(*s*) is the local refractive index as a function of distance, *s*, along the path *C*.

An electromagnetic wave that travels a path of given optical path length arrives with the same phase shift as if it had traveled a path of that *physical* length in a vacuum. Thus, if a wave is traveling through several different media, then the optical path length of each medium can be added to find the total optical path length. The optical path difference between the paths taken by two identical waves can then be used to find the phase change. Finally, using the phase change, the interference between the two waves can be calculated.

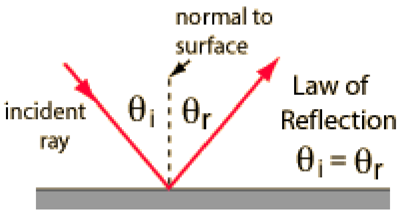
Fermat's principle states that the path light takes between two points is the path that has the minimum optical path length

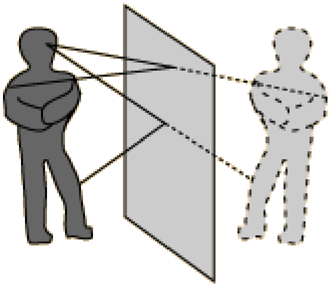


Law of Reflection

Reflection is the change in direction of a wavefront at an interface between two different media

A light ray incident upon a reflective surface will be reflected at an angle equal to the incident angle. Both angles are typically measured with respect to the normal to the surface. This law of reflection can be derived from Fermat's principle.



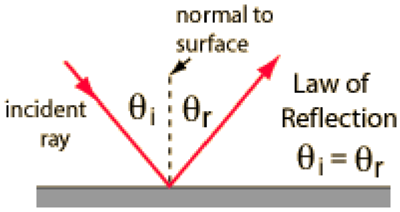


The law of reflection gives the familiar reflected image in a plane mirror where the image distance behind the mirror is the same as the object distance in front of the mirror.

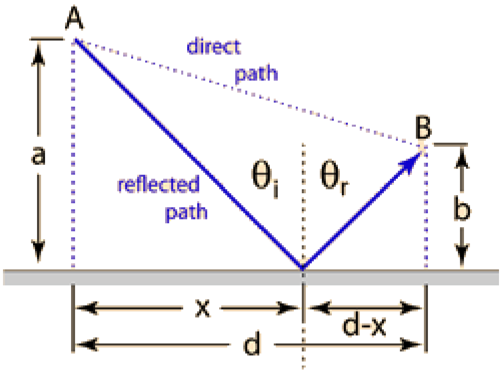
Def. Normal. A line drawn perpendicular to a plane.

Def. Angle of incidence. The angle between the incident ray and the normal drawn to the point of incidence. See. Fig. 1.

Def. Angle of reflection. The angle between the reflected ray and the normal drawn to the point of incidence. See Fig. 1.



Fermat's Principle: Light follows the path of least time. Of course the straight line from A to B is the shortest time, but suppose it has a single reflection. The law of reflection can be derived from this principle as follows:



The pathlength from A to B is

$$L = \sqrt{a^2 + x^2} + \sqrt{b^2 + (d-x)^2}$$

Since the speed is constant, the minimum time path is simply the minimum distance path. This may be found by setting the derivative of L with respect to x equal to zero.

$$\frac{dL}{dx} = \frac{1}{2}\frac{2x}{\sqrt{a^2 + x^2}} + \frac{1}{2}\frac{2(d-x)(-1)}{\sqrt{b^2 + (d-x)^2}} =$$

This reduces to

$$\frac{x}{\sqrt{a^2 + x^2}} = \frac{(d-x)}{\sqrt{b^2 + (d-x)^2}}$$

which is

$$\sin\theta_i = \sin\theta_r$$

$$\theta_i = \theta_r$$ Law of Reflection

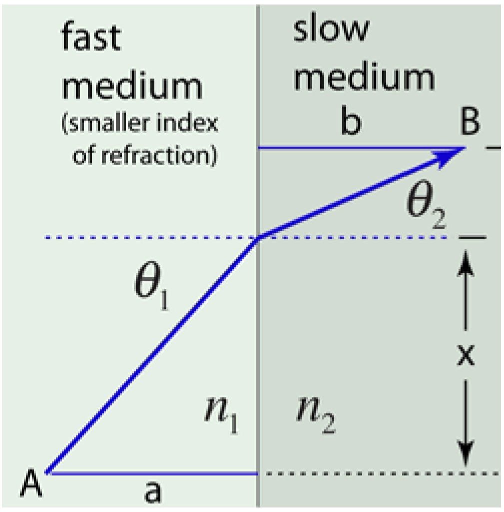
Fermat's Principle and Refraction

Fermat's Principle: Light follows the path of least time. Snell's Law can be derived from this by setting the derivative of the time =0. We make use of the index of refraction, defined as n=c/v.

$$t = \frac{\sqrt{a^2 + x^2}}{v} + \frac{\sqrt{b^2 + (d-x)^2}}{v'}$$

$$\frac{dt}{dx} = \frac{x}{v\sqrt{a^2 + x^2}} - \frac{(d-x)}{v'\sqrt{b^2 + (d-x)^2}}$$

$$0 = \frac{\sin\theta_1}{v} - \frac{\sin\theta_2}{v'}$$



Snell's Law $$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1}$$

Now assume we want light to propagate from point A to point B across the boundary between medium 1 and medium 2.

For the path shown in the figure on the right the time required is

$$t = \frac{\sqrt{x^2 + d^2}}{(c/n_1)} - \frac{\sqrt{(D-x)^2 + d^2}}{(c/n_2)}.$$

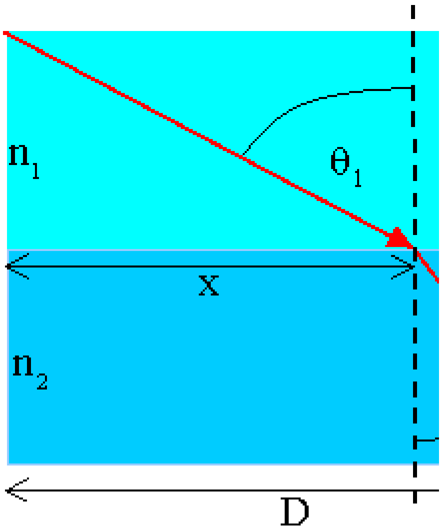
Setting dt/dx = 0 we obtain

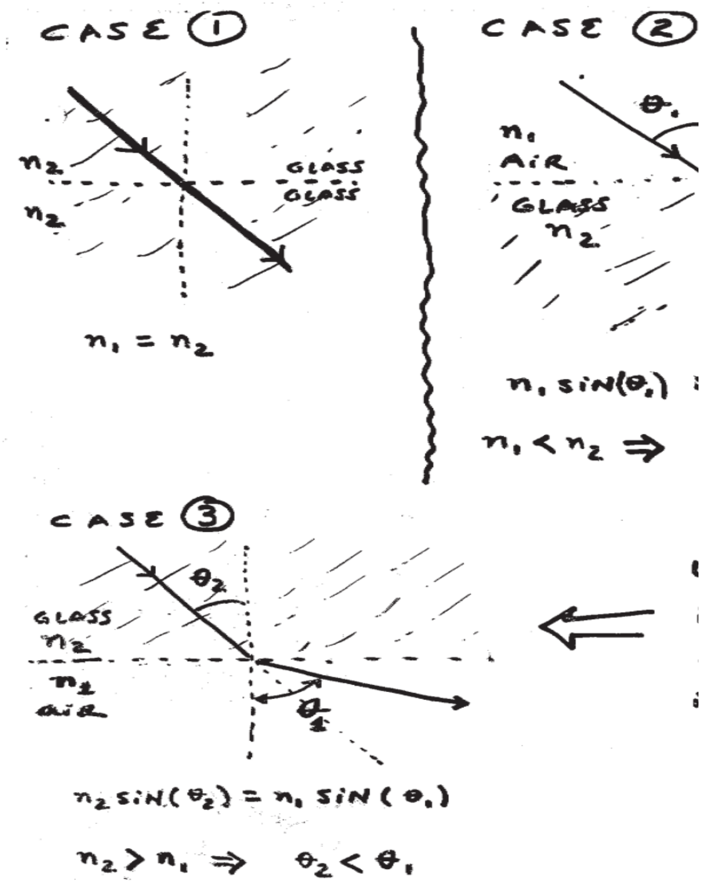
$$n_1 \frac{x}{\sqrt{x^2 + d^2}} = n_2 \frac{D - x}{\sqrt{(D-x)^2 + d^2}},$$

or

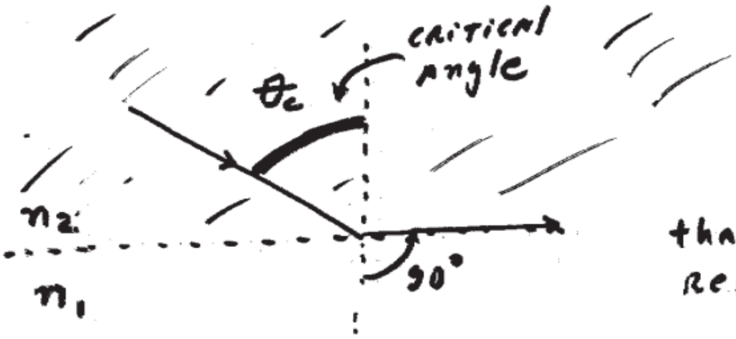
$$n_1 \sin\theta_1 = n_2 \sin\theta_2.$$

Fermat's principle yields Snell's law





CASE 1
n_2
GLASS
GLASS
n_2
$n_1 = n_2$
CASE 2
θ_1
n_1
AIR
GLASS
n_2
$n_1 \sin(\theta_1)$
$n_1 < n_2 \Rightarrow$
CASE 3
θ_2
GLASS
n_2
n_1
air
θ_1
$n_2 \sin(\theta_2) = n_1 \sin(\theta_1)$
$n_2 > n_1 \Rightarrow \theta_2 < \theta_1$



that is refracted angle
$\theta_1 = 90$
in this case

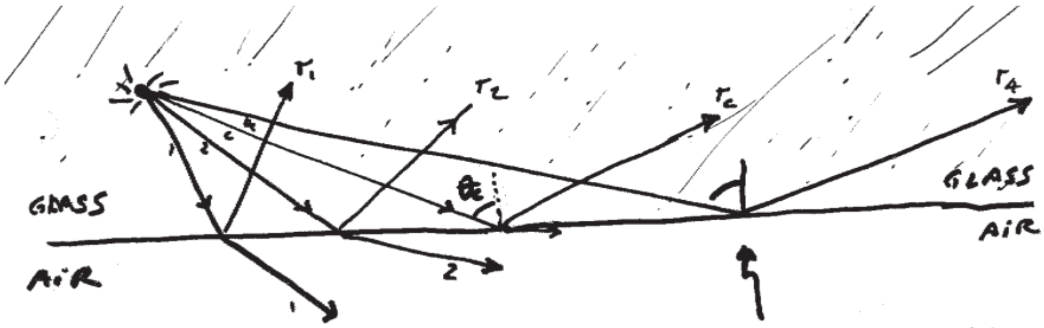
Given n_2 and n_1 the critical angle θ_c can be obtained from the Snell's law

$$n_2 \sin(\theta_c) = n_1 \underbrace{\sin(90^\circ)}$$

$$\boxed{\theta_c = \sin^{-1}\left(\frac{n_1}{n_2}\right)}$$

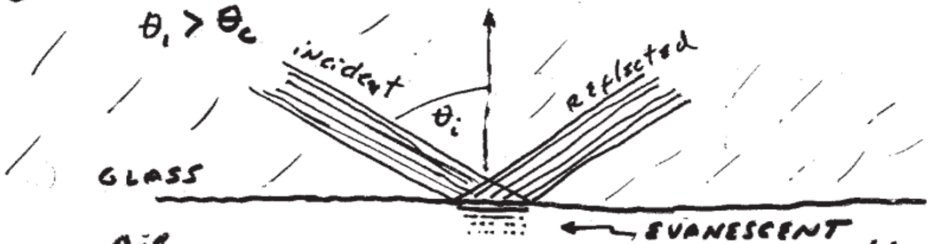
Notice this result requires $n_1 < n_2$

What happens if we make the incidence angle greater than θ_c ?



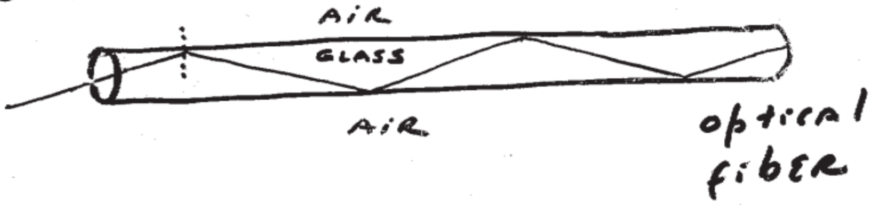
"TOTAL INTERNAL REFLECTION"

- $\theta_i > \theta_c$



← EVANESCENT ELECTRIC field
(the further away from the interface, the weaker the field. It decreases exponentially

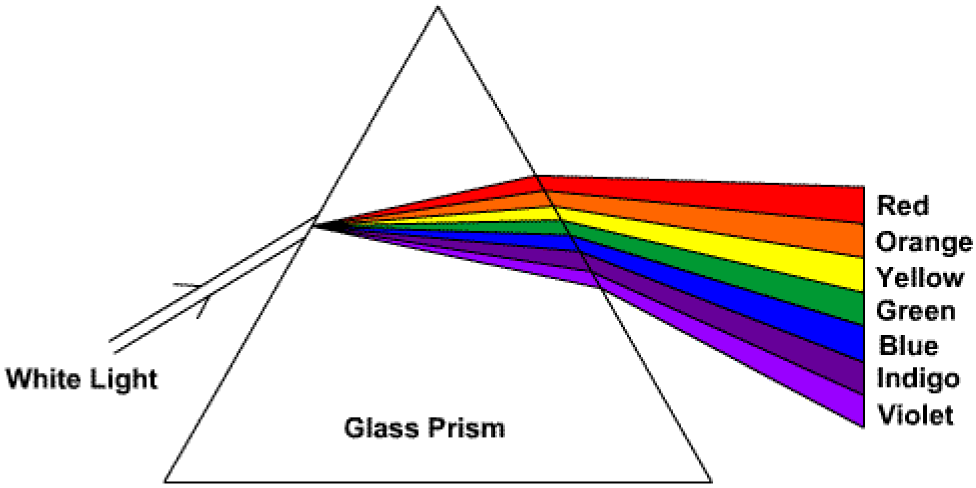
- WAVEGUIDE



optical fiber

Color dispersion

The refractive index of materials varies with the wavelength (and frequency) of light This is called dispersion and causes prisms and rainbows to divide white light into its constituent spectral colors.[26] As the refractive index varies with wavelength, so will the The refractive index of materials varies with the wavelength (and frequency) of light This is called dispersion and causes prisms and rainbows to divide white light into its constituent spectral colors. As the refractive index varies with wavelength,



A prism of glass separates white light into its spectral components in such a manner that colors associated with shorter wavelengths are more refracted than the colors associated with longer wavelengths. so that "violet light" is less refracted than "red light." This phenomenon is fundamentally different from conventional anomalous dispersion effects, which are invariably accompanied by significant loss and are typically very narrow band.

Prism

A prism is an optical element. It has polished flat surfaces that refract light. The traditional geometric shape of a prism has a triangular base and two rectangular sides. It is called triangular prism.

A prism can be made from materials like glass, plastic and fluorite. It can be used to split light into its components.

How a Prism Works

When light travels from one medium to another medium, it is refracted and enters the new medium at a different angle. The degree of bending of the light's path depends on the angle that the incident beam of light makes with the surface of the prism, and on the ratio between the refractive indices of the two media. This is called Snell's law.

$$i.e, n = \frac{sin\ i}{sin\ r}$$

where, n is the refractive index of the material of the prism.
i is the angle of incidence.
r is the angle of refraction.

The refractive index of many materials varies with the wavelength of the light used. This phenomenon is called dispersion. This causes light of different colors to be refracted differently and to leave the prism at different angles, creating an effect similar to a rainbow. This can be used to separate a beam of white light into its constituent spectrum of colors.

Incident ray

The light ray which travels through the rarer medium and strikes the refracting surface of the prism is known as incident ray.

Refracted ray

When the incident ray strikes the prism it is refracted and it known as refracted ray. Refracted ray lies within the prism.

Emergent ray

When the refracted ray strikes the other surface of the prism it is again refracted and moves out of the prism and is known as emergent ray.

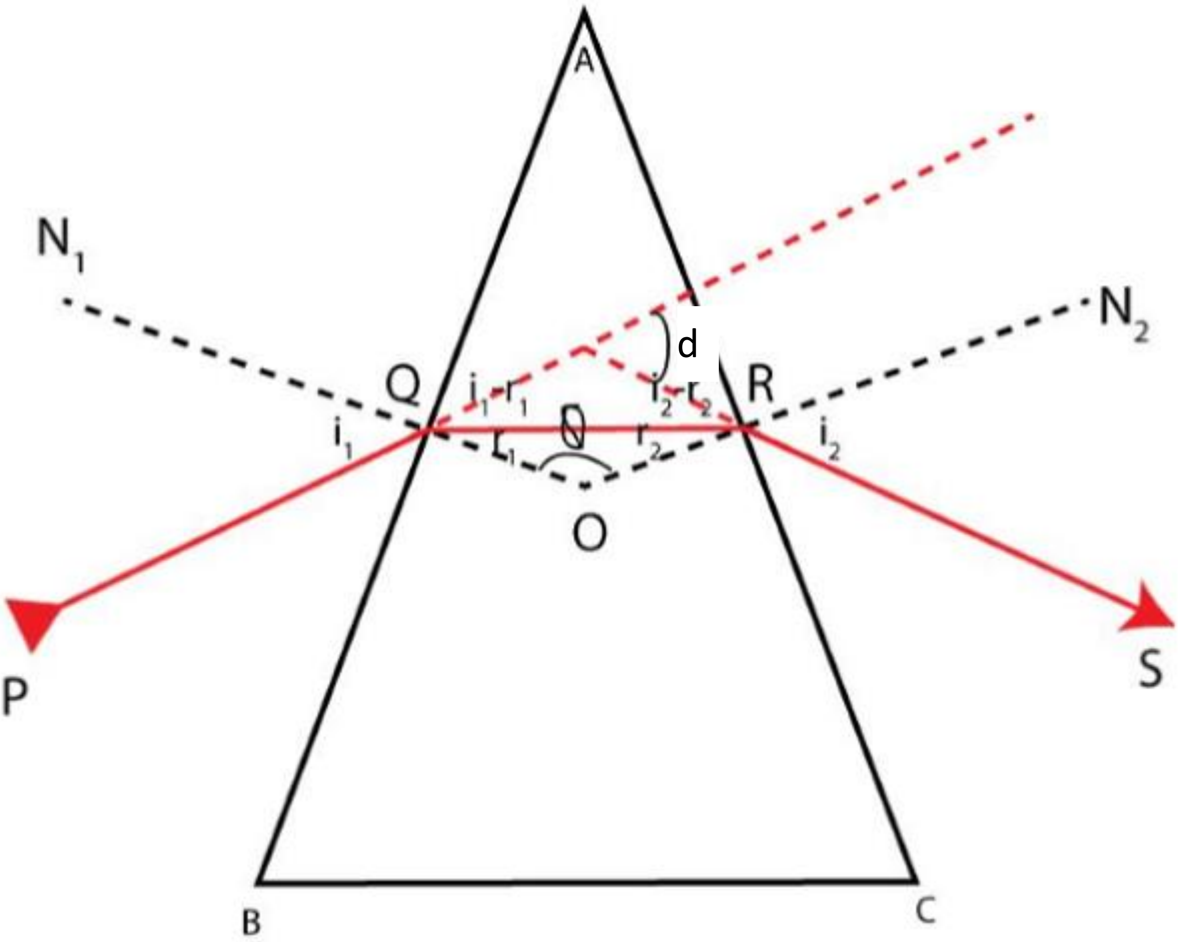
Angle of deviation

Angle between the incident ray and emergent ray is known as angle of deviation.

Angle of prism

The angle between the two inclined refracting surfaces is known as angle of prism.

refracted ray and RS as the emergent ray as shown in figure –



From figure we can observe that –

$$\angle A + \angle Q = 180^{o}$$

And

$$r_1 + r_2 + \angle Q = 180^{o}$$

Hence, Angle of prism is given by –

$$A = r_1 + r_2$$

From figure we can observe that –

$$Dmin = (i_1 - r_1) + (i_2 - r_2)$$

$$D_{min} = (i_1 + i_2) - (r_1 + r_2)$$

$$D_{min} = i_1 + i_2 - A$$

Refractive index of material of prism is given by −

$$\sin i / \sin r = n$$

For small angle $\sin i \approx i$

$$i / r = n$$

$$\therefore i = nr$$

Hence, Angle of deviation is given by −

$$D_{min} = nr_1 + nr_2 - A$$

$$\therefore D_{min} = n(r_1 + r_2) - A$$

$$\therefore D_{min} = nA - A$$

$$\therefore D_{min} = A(n - 1)$$

When a prism is in the condition of minimum deviation, the angle of incidence i_1 is equal to the angle of emergence i_2

Similarly, angle $r_1 = r_2$

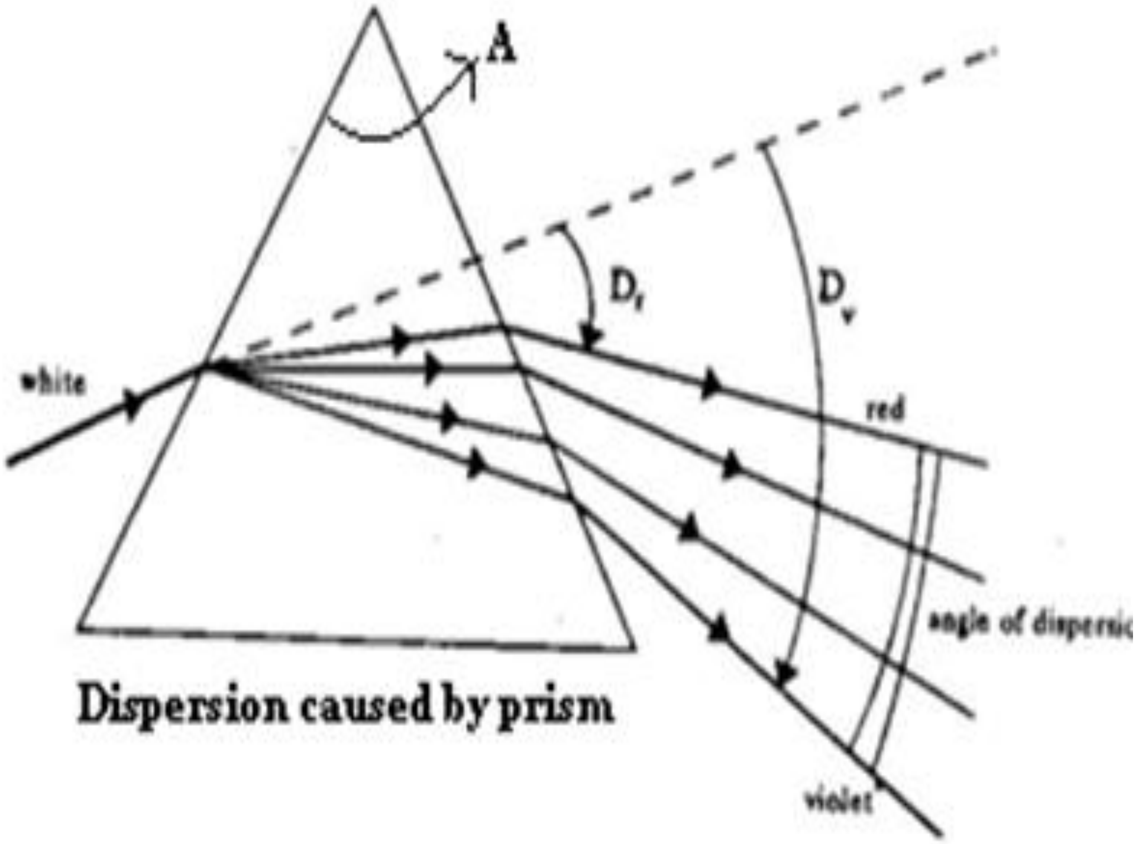
Then,

$$A = 2r \text{ or } r = A/2$$

$$D_{min} = 2i - A \text{ or } i = D_m + A/2$$

$$n = \sin i / \sin r$$

$$\therefore \mu = \sin(\delta_m + A/2) / \sin A/2$$



Dispersion caused by prism

The refractive index of a medium is different for light rays of different wavelengths. Larger the wavelength, the lesser is the refractive index. As a result light of different wavelengths deviate differently, splitting white light into its constituent colours. This is called dispersion.

i.e $n_{red} < n_{violet}$ $\lambda_{red} > \lambda_{violet}$

For a small refracting angle A, the deviation D is

Given by:

$D \approx (n - 1) A$

The angle between the red and violet rays called angle of dispersion is given by:

$\phi = D_v - D_r = (n_v - n_r) A$