RAY OPTICS AND OPTICAL INSTRUMENTS

REFRACTION

REFRACTION OF LIGHT

The phenomenon characterized by the alteration or bending of light rays from their initial trajectory as they traverse the boundary between two distinct mediums is termed refraction. This alteration in the path of light results from a modification in the speed of light as it transitions from one medium to another. Even when light is incident perpendicularly, traversing to the second medium without undergoing bending, the occurrence is still denoted as refraction. In essence, refraction is fundamentally governed by the change in the speed of light as it transitions between different mediums.

The refractive index of a medium is a quantitative measure defined as the ratio by which the speed of light diminishes in comparison to its speed in a vacuum. Symbolized by the Greek letter μ, the refractive index (μ) is expressed as the ratio of the speed of light in a vacuum (c) to the speed of light in the medium (v):

$$\mu = \frac{c}{v} = \frac{speed\ of\ light\ in\ vacuum}{speed\ of\ light\ in\ medium}$$

This formula encapsulates the relationship between the speed of light in a vacuum and its velocity in a given medium.

Interpreting the refractive index involves considering the impact on the speed of light. A higher refractive index signifies a greater reduction in the speed of light within that medium, designating it as a denser medium. Conversely, a lower refractive index implies a lesser reduction in speed, characterizing the medium as rarer. Therefore, the refractive index serves as a quantitative indicator of the density or rarity of a medium concerning its impact on the velocity of light propagation.

Higher the value of Refractive index denser (optically) is the medium.
Frequency of light does not change during refraction
Refractive index of the medium relative to vacuum

$$= \sqrt{\mu_r \in_r}$$

$n_{vacuum} = 1$; $n_{air} \geq 1$;

n_{water} (average value) = 4/3;

n_{giass} (average value) = 3/2

Laws of Refraction

(a) Coplanar Alignment:

The initial law of refraction stipulates that the incident ray, the normal line drawn at the point of incidence on any refracting surface, and the refracted ray all share a common geometric plane. This plane, encompassing these three elements, is referred to as the plane of incidence or, equivalently, the plane of refraction.

In other words, when light undergoes refraction at the boundary between two different mediums, the incident ray (the path of incoming light), the normal (a line perpendicular to the surface at the point of incidence), and the refracted ray (the path of light after refraction) all exist within the same plane. This coplanar alignment is a fundamental geometric principle that governs the behavior of light as it transitions from one medium to another, contributing to the predictable and systematic nature of the refraction process.

(b) $\frac{\sin i}{\sin r}$ = Constant for any pair of media and for light of a given wavelength.

This is known as Snell's Law.

Also, $\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$

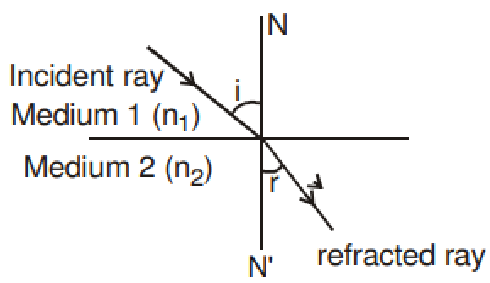
For applying in problems remember

$n_1 \sin i = n_2 \sin r$

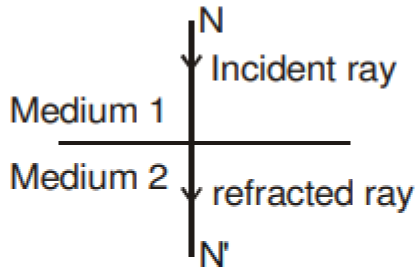
$\frac{n_2}{n_1} = {}_1n_2$ = Refractive Index of the second medium with respect to the first medium.

C = speed of light in air (or vacuum) = 3×10^8 m/s.

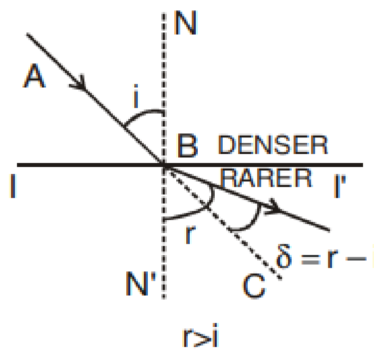
i & r should be taken from normal.



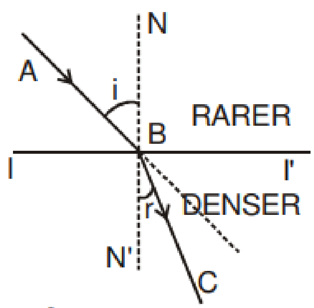
Special cases:
Normal incidence: i = 0
From snell's law: r = 0



As light transitions from a medium of higher refractive index, characterized as denser, to a medium of lower refractive index, characterized as rarer, it undergoes a distinctive refraction wherein it exhibits a deviation away from the normal, a perpendicular line drawn at the point of incidence on the boundary surface.



As light transits from a medium of lower refractive index, commonly denoted as rarer, to a medium of higher refractive index, denoted as denser, it undergoes refraction characterized by a discernible deviation towards the normal—an imaginary line drawn perpendicular to the boundary surface at the point of incidence.



Example.

In the depicted scenario, a light ray impinges upon a glass sphere at an angle of incidence measuring 60 degrees. Determine the angles denoted as r, r′, e, and ascertain the total deviation ensuing from two successive refractions.

Solution.

Applying Snell's law 1 sin 60° $\sqrt{3}\sin r \Rightarrow r = 30^{\circ}$

From symmetry r' = r = 30°

Again, applying Snell's law at second surface

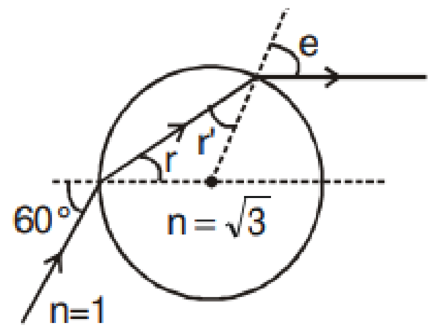
$1 \sin e = \sqrt{3} \sin r \Rightarrow e = 60^\circ$

Deviation at first surface = i – r = 60° – 30° = 30°

Deviation at second surface

= e – r′ = 60° – 30° = 30°

Therefore, total deviation = 60°



Example.

Determine the angle θ formed by the light ray upon refraction from water to air, as illustrated in the figure.

Solution.

Snell's Law

$$\mu_w \sin\theta_w = \mu_a \sin\theta_a \Rightarrow \frac{4}{3}\times\frac{3}{5} = 1\sin\theta_a$$

$$\sin\theta_a = \frac{4}{5} \Rightarrow \theta_a = \sin^{-1}\frac{4}{5}$$