OPTICS

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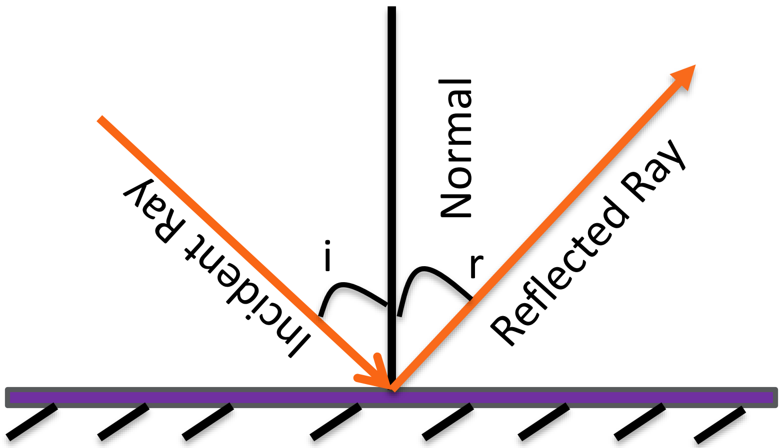
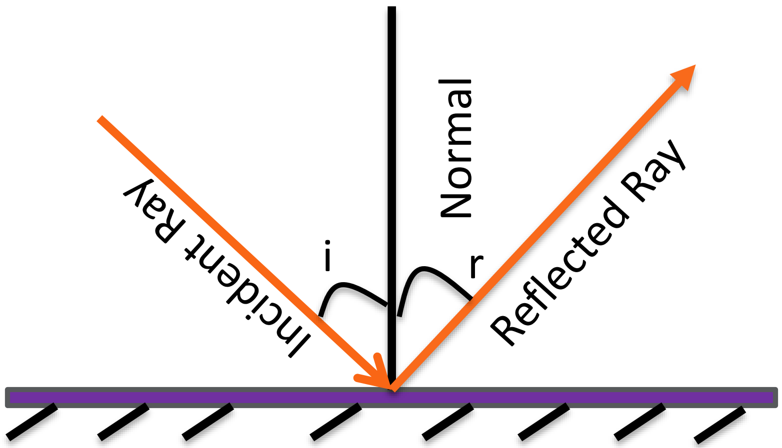
REFLECTION

- The phenomenon of Light in which an incident ray of light is sent back to the same medium after striking a smooth polished surface is called *Reflection*.



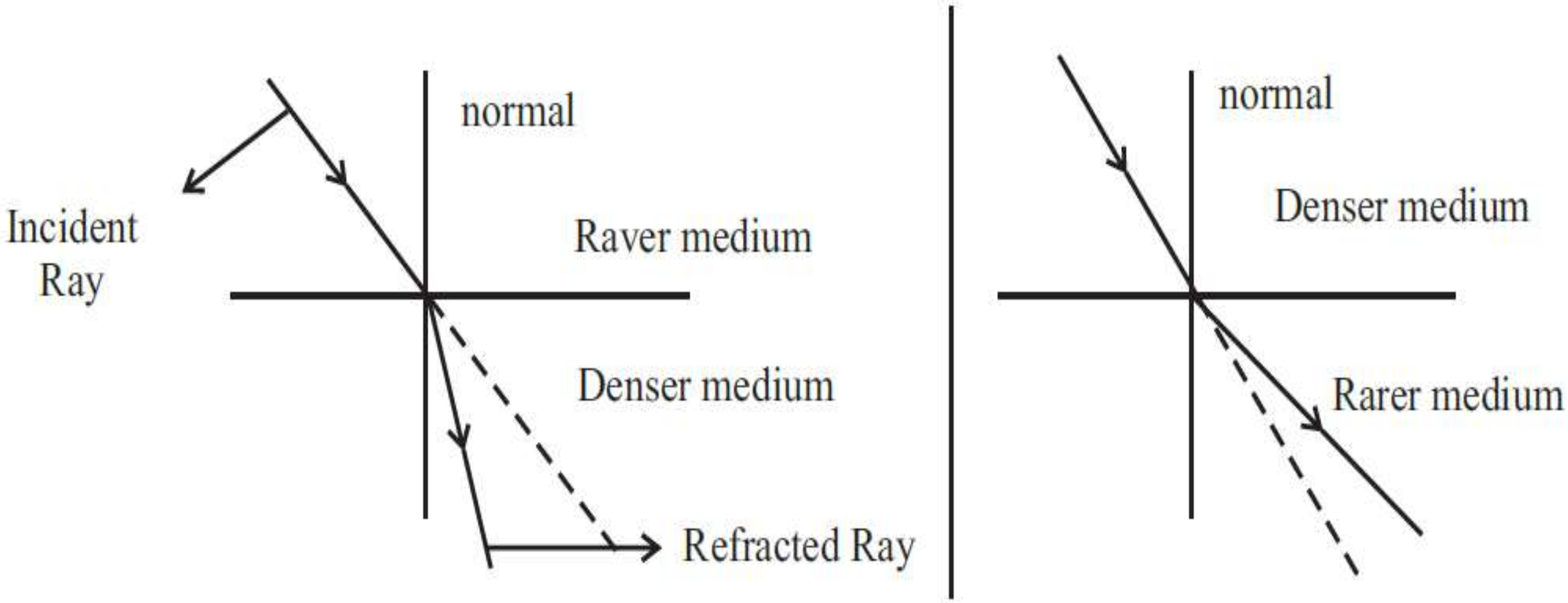
LAWS OF REFLECTION

1. The angle of incidence (i) is equal to the angle of reflection (r).
2. The incident ray, the reflected ray and the normal drawn to the reflecting surface, all lie in one plane.



REFRACTION

- **It is the phenomenon of light (wave) in which there is a change in the velocity of the ray when it passes from one medium to another of different density.**

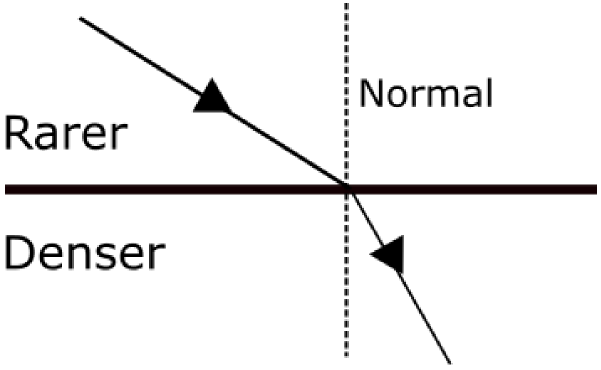


LAWS OF REFRACTION

1. **The ratio of the sine of the angle of incidence to the sine of angle of refraction is always a constant (Called Refractive Index) for a given pair of media and a given wavelength of light.**

$$\frac{Sin\ i}{Sin\ r} = \mu\ (Refractive\ Index)$$

2. The incident ray, the refracted ray and the normal drawn to the interface, all lie in one plane.



Refractive index is also defined as ratio of velocity of light in air to the velocity of light in the medium.

$$1_{\mu_2} = \frac{Velocity\ of\ Light\ in\ Air}{Velocity\ of\ Light\ in\ the\ medium} = \frac{v_0}{v_m}$$

1_{μ_2} is called RI of the 2nd medium wrt the 1st medium.

If the 1st medium is air or vacuum, then $\mu = \frac{C}{V}$

Salient Points

- Greater the refractive index of a medium, smaller is the velocity of light in it.
- A medium with higher value of refractive index is called optical denser medium.
- (Refractive Index)$_{medium}$ = (Absolute Refractive Index)$_{medium}$

NUMERICAL EXAMPLE

Velocity of light in vacuum is $3x10^8$ m/sec. Find out velocity of light in glass having refractive index 1.5 .

<u>Solution</u>

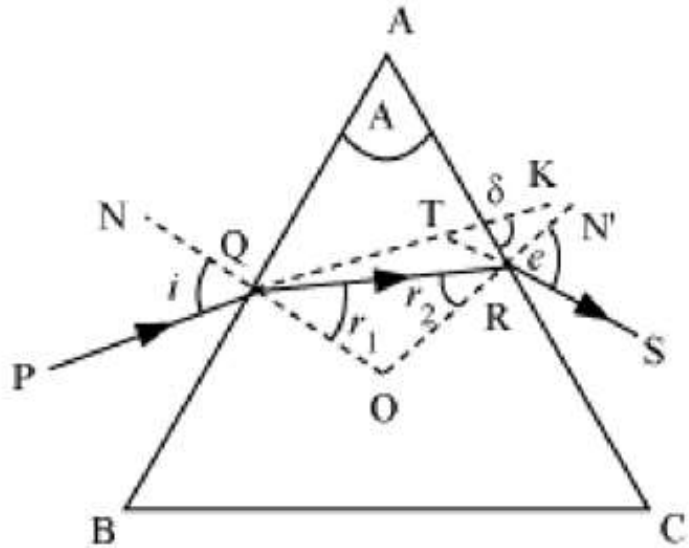
Given Data:

$V_0 =$ 3x108 m/sec

$\mu = 1.5, V_g =?$

We know, $\mu = \frac{V_0}{V_g}$ $\Rightarrow V_g = \frac{V_0}{\mu} = \frac{3x108 \text{ m/sec}}{1.5}$ = 2x108 m/sec

Refraction through a prism



Refractive Index of the medium of a prism

$$\mu = \frac{\sin\frac{A + d_m}{2}}{\sin\frac{A}{2}}$$

Where, A = Angle of Prism

d_m = Angle of minimum deviation.

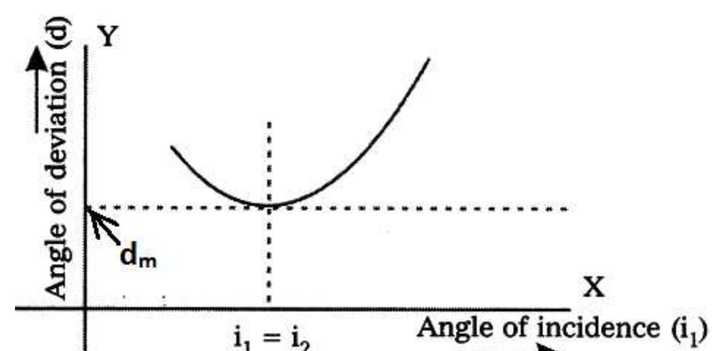
Angle of minimum deviation: It is the minimum value of angle of deviation of an incident ray of light.

Conditions for minimum angle of deviation:

(i) The angle of incidence (i) must be equal to the angle of emergence (e).

(ii) Internal angles of refraction must be same, i.e. $r_1 = r_2$.

The graph of i vs d is of the following nature:

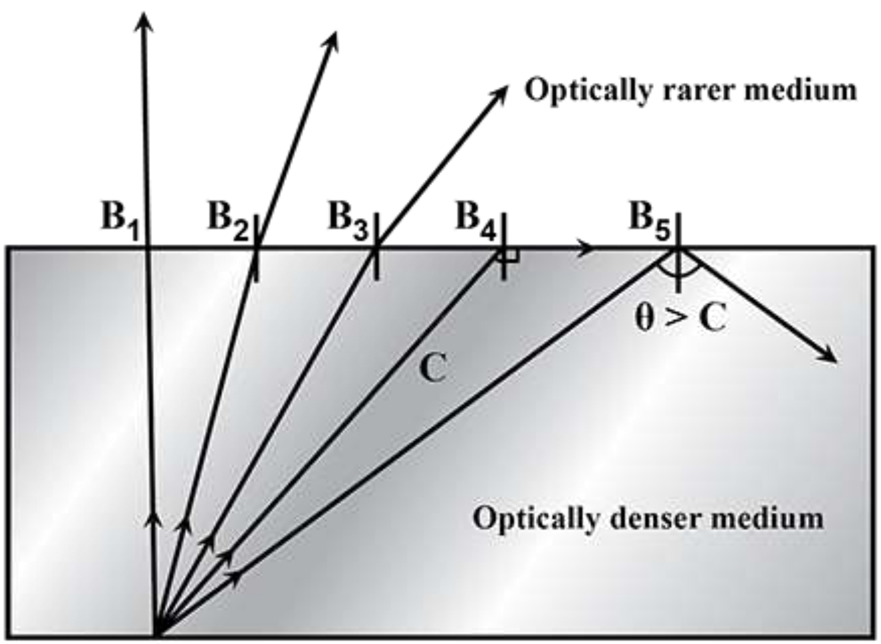


Total Internal reflection

Total Internal reflection

The optical phenomenon in which an incident light ray is sent back to the same medium when the light ray travels from a more optically denser medium at an angle greater than critical angle, to a less optically denser medium is called total internal reflection (TIR).

If a ray of light enters from a denser to a rarer medium, then the ray of light bends away from the normal. If we go on increasing the angle of incidence in the denser medium then the angle of refraction also increases in the rarer medium. At a particular value of angle of incidence, called 'critical angle' (C), the corresponding angle of refraction in the rarer medium becomes just 90^0.



Total Internal Reflection of Light

If the angle of incidence is further increased beyond critical angle, then there will be no refraction, rather reflection occurs. This optical phenomenon is called total internal reflection.

Conditions for TIR:

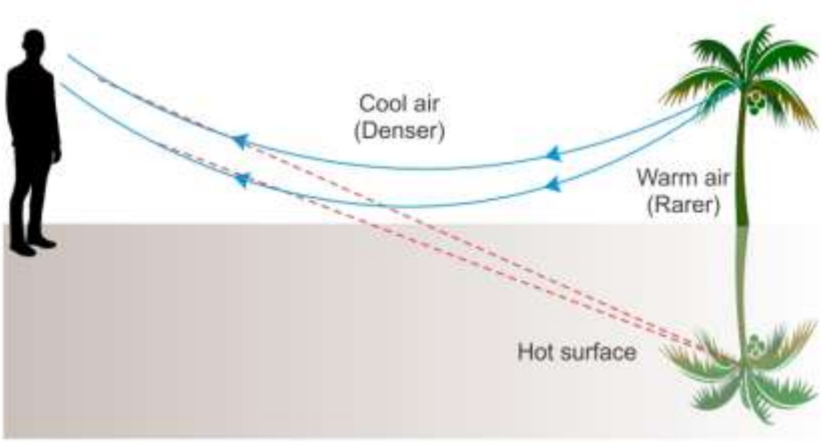
(i) The light ray moves from a more dense medium to less dense medium.

(ii) The angle of incidence must be greater than the critical angle.

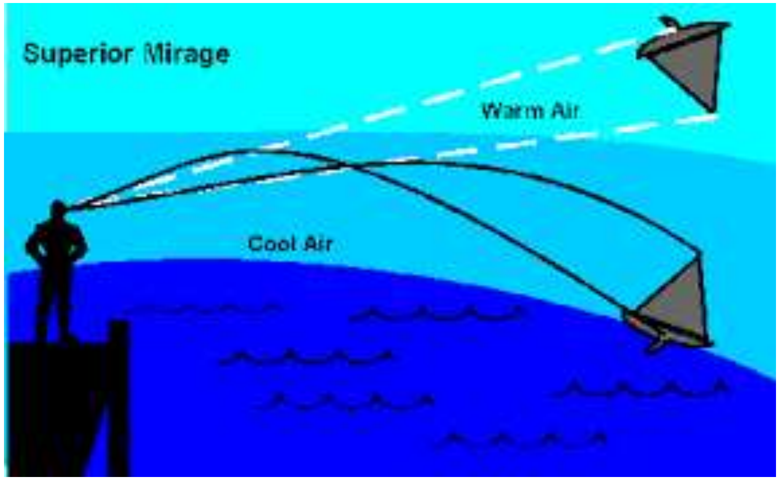
What is Critical angle?

The value of angle of incidence in the denser medium for which the corresponding angle refraction in the rarer medium is just 90^0 is called critical angle.

Examples of TIR

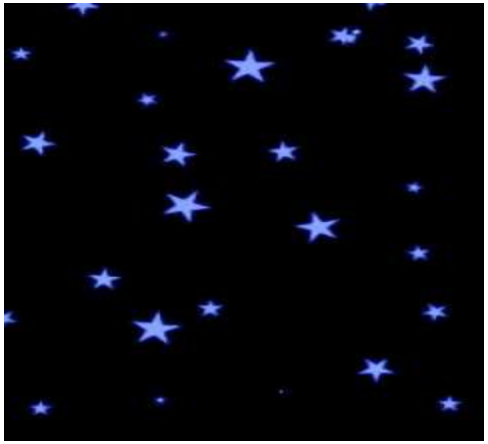


Mirage



Looming

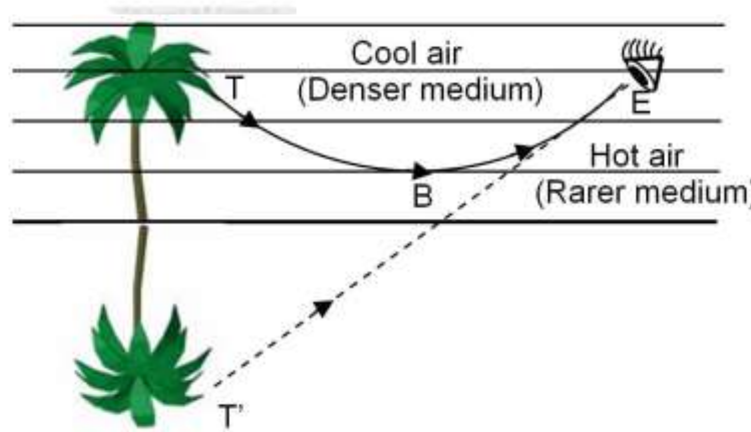
Brilliance of diamond



Twinkling stars

MIRAGE

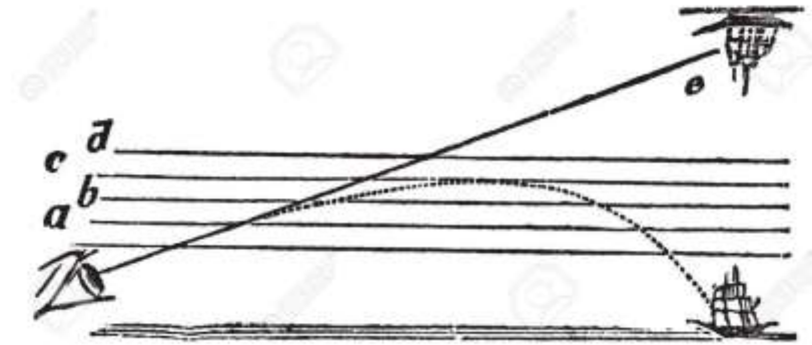
Mirage, in optics the deceptive appearance of a distant object or objects caused by the bending of light rays (refraction) in layers of air of varying density.



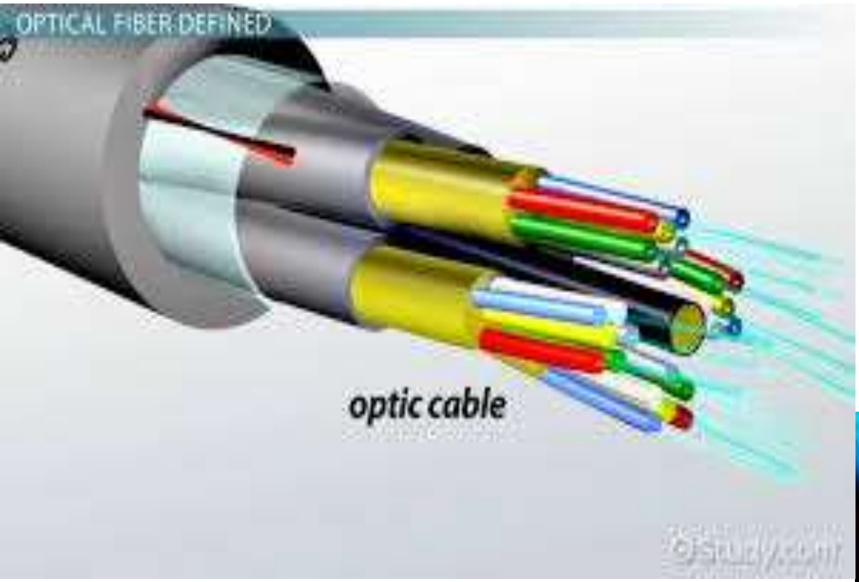
Under certain conditions, such as over a stretch of pavement or desert air heated by intense sunshine, the air rapidly cools with elevation and therefore increases in density and refractive power. Sunlight reflected downward from the upper portion of an object—for example, the top of a camel in the desert—will be directed through the cool air in the normal way. Although the light would not be seen ordinarily because of the angle, it curves upward after it enters the rarefied hot air near the ground, thus being refracted to the observer’s eye as though it originated below the heated surface. A direct image of the camel is seen also because some of the reflected rays enter the eye in a straight line without being refracted. The double image seems to be that of the camel and its upside-down reflection in water. When the sky is the object of the mirage, the land is mistaken for a lake or sheet of water.

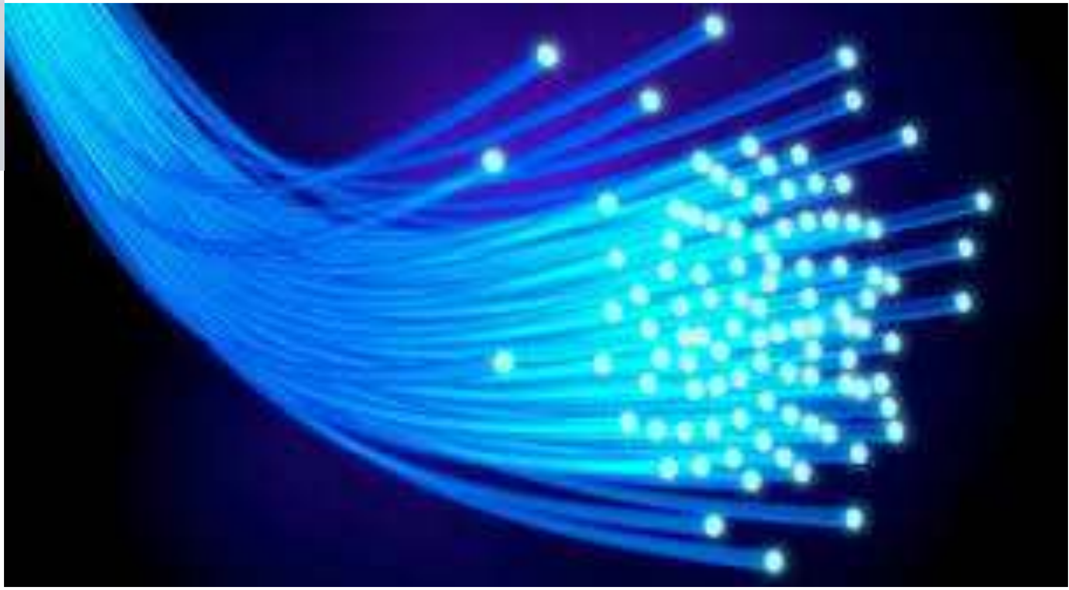
Looming

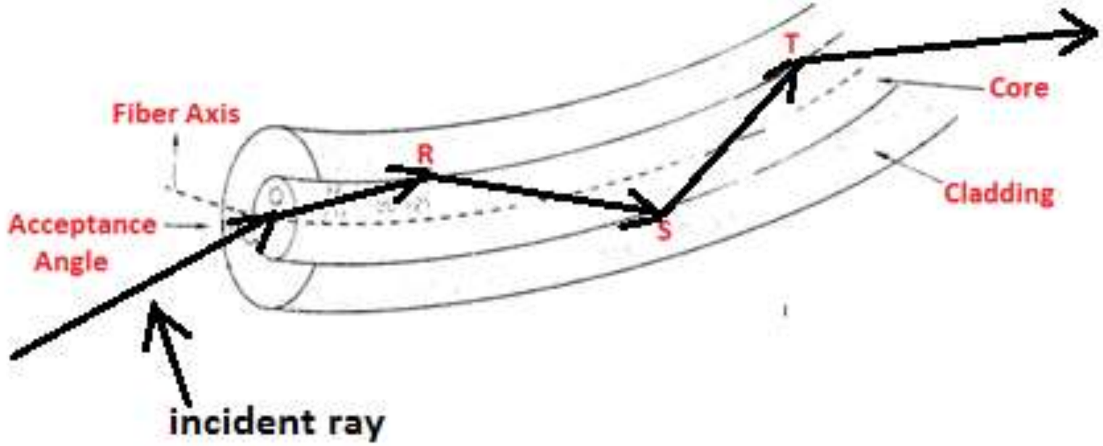
Sometimes, as over a body of water, a cool, dense layer of air underlies a heated layer. An opposite phenomenon will then prevail, in which light rays will reach the eye that were originally directed above the line of sight. Thus, an object ordinarily out of view, like a boat below the horizon, will be apparently lifted into the sky. This phenomenon is called looming. The phenomenon is also called superior mirage.



Optical Fiber







An optical fiber consists of a pure glass core surrounded by a coaxial glass or plastic cladding of lower refractive index. The cladding is surrounded by another coaxial layer called sheath which protects the optical fiber. The light ray is transmitted through the core by total internal reflection at the interface of core and cladding.

The light ray PQ enters the fiber core at an angle θ_A with the fiber axis. This ray is refracted into the core along QR making an angle α with the fiber axis. This light ray incidents at R on the interface of core and cladding at an angle $(90 - \alpha)$ with the normal. If $(90 - \alpha)$ is greater than the critical angle, the ray will be totally internally reflected into the core. In this way the light ray undergoes total internal reflection at every point of incidence in the core and transmits through the fiber.

Properties of Optical Fibers

1. Extremely wide system bandwidth: Fiber systems have greater capacity due to the inherently larger BWs available with optical frequencies.

2. Immunity to electromagnetic interference: Fiber cables are immune to static interference caused by lightning, electric motors, fluorescent light and other external electrical noise sources.

3. Virtual elimination of crosstalk: The light on one glass fiber does not interfere with light on an adjacent fiber.

4. Substantially lighter weight and smaller size: Fibers are smaller and much lighter in weight than their metallic counterparts.

5. More resistive to environmental extremes and non-corrosiveness: Fiber cables operate over a larger temperature variation than their metallic counterparts and fiber cable are affected less by corrosive liquids and gases.

6. Lower cost: The long term cost of fiber optics system is projected to be less than that of its metallic counterpart as the cost of copper is increasing.

7. Conservation of the earth's resources: The supply of copper and other good electrical conductors is limited whereas the principal ingredient of glass is sand and it is cheap and in unlimited supply.

8. Security: Fiber cables are more secure than their metallic counterparts.

9. Safety: In many wired systems, the potential hazard of short circuits requires precautionary designs. Additionally, the dielectric nature of optical fiber eliminates the spark hazard.

Applications of Optical Fibers

- In cable TV connections.
- In Telecommunications and computer networking.
- In medical diagnostic equipment (endoscope).
- In scientific instruments to illuminate objects.
- In military communications because of data security.