ICSE
Living Science
Physics

Class 10

Chapter 4 Refraction of Light

On Board! BOOKS

As per the guidelines of NEP 2020

Revised and Updated

Living Science Physics

Based on the latest ICSE syllabus

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LEARNING OBJECTIVES

Refraction of Light

- ❖ Cause of Refraction
- ❖ Laws of Refraction of Light

Refractive Index of the Medium

- ❖ Absolute Refractive Index
- ❖ Conditions for no Refraction

Principle of Reversibility of Light

- ❖ Refraction of Light through a Rectangular Glass Slab
- ❖ Multiple Images in a Thick Plane Glass Plate or Thick Mirror

Refraction of Light through a Prism

- ❖ Relation between the Refractive Index and the Real and Apparent Depth
- ❖ Applications of Refraction of Light

Critical Angle

- ❖ Factors affecting the Critical Angle

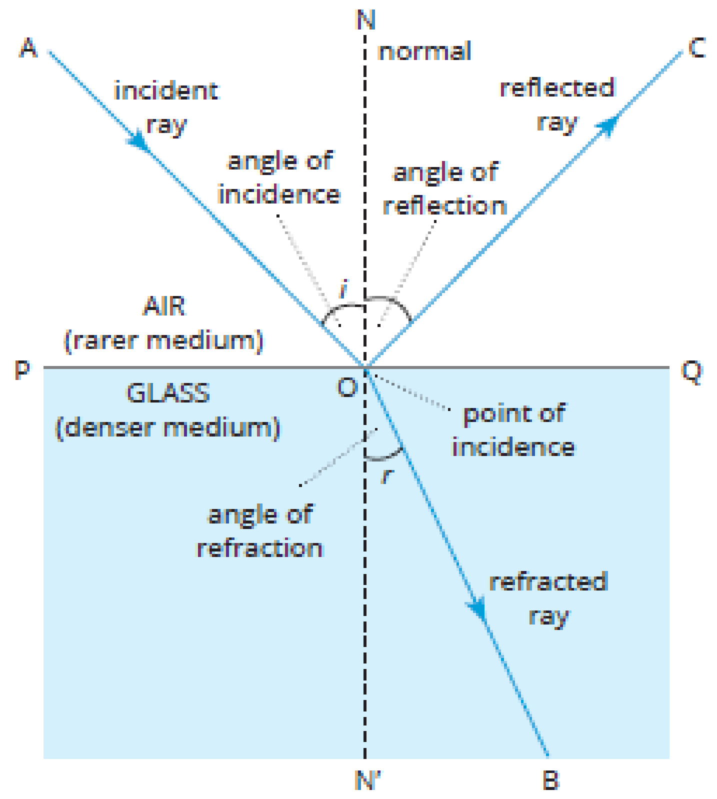
Total Internal Reflection

- ❖ Some Phenomenon due to Total Internal Reflection
- ❖ Application of Total Internal Reflection

What is refraction of light?

The bending of light when it passes obliquely from one transparent medium to another is called refraction of light.

In other words, **the change in the direction of light when it passes obliquely from one transparent medium to another is called refraction of light**.



Partial Reflection and Partial Refraction

A ray of light AO travelling from air into glass is the **incident ray,** OC is the **reflected ray** and OB is the **refracted ray**. At the **point of incidence** O, draw a normal NON′. Now, the angle between the incident ray and the normal (at the point of incidence) is called the **angle of incidence**. The angle AON is the angle of incidence. The angle of incidence is denoted by the letter *i*. The angle between the refracted ray and the normal (at the point of incidence) is called the **angle of refraction**. The angle of refraction is denoted by the letter *r*.

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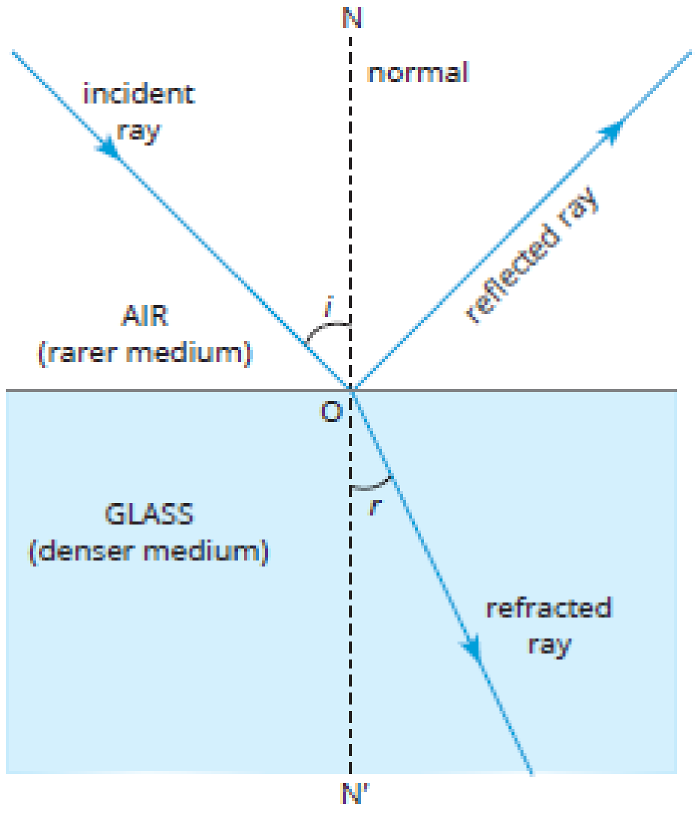
Optically Rarer and Denser Mediums

A medium in which the speed of light is more is known as an optically rarer medium. Air is an optically rarer medium as compared to glass and water. **A medium in which the speed of light is less is known as an optically denser medium**. Glass is an optically denser medium than air and water.

1. When a ray of light travels from a rarer medium to a denser medium, it bends towards the normal.

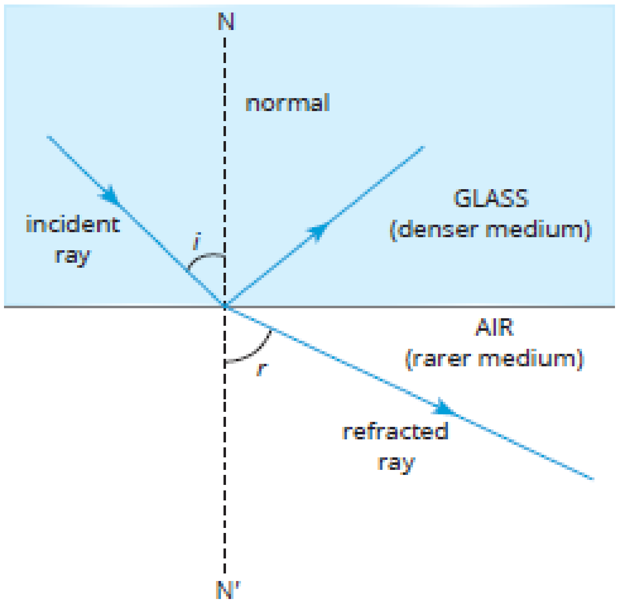
When a ray of light goes from air (rarer medium) into glass (denser medium), it bends towards the normal (at the point of incidence).

In this case, the angle of refraction (*r*) is smaller than the angle of incidence (*i*), i.e. $\angle i > \angle r$



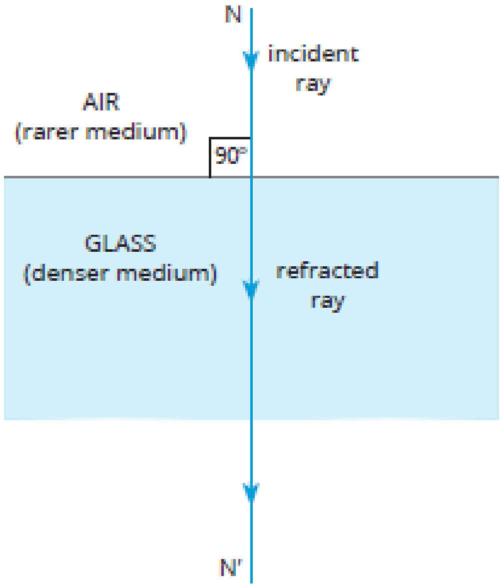
2. When a ray of light travels from a denser medium to a rarer medium, it bends away from the normal.

When a ray of light goes from glass (denser medium) into air (rarer medium), it bends away from the normal (at the point of incidence). In this case, the angle of refraction (*r*) is greater than the angle of incidence (*i*), i.e. $\angle i < \angle r$



3. If the incident ray falls normally (or perpendicularly) on the surface of a glass slab, then there is no bending of the ray of light and it goes straight.

Since the incident ray goes along the normal to the surface, the angle of incidence in this case is zero (0°) and the angle of refraction is also zero (0°), i.e. $\angle i = \angle r$ and $\angle i = \angle r = 0°$.



Laws of Refraction of Light

1. First law of refraction of light: The incident ray, the refracted ray and the normal at the point of incidence, all lie in the same plane.

2. Second law of refraction of light (Snell's law of refraction of light): The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant for a given pair of media (such as 'air and glass' or 'air and water').

$$\sin i / \sin r = \text{constant}$$

Refractive Index of the Medium

Let us consider a ray of light travelling from a medium *a* to another medium *b*. Then, from Snell's law, $\sin i / \sin r = \text{constant}$

This 'constant' is called the **refractive index** of medium *b* with respect to medium *a*. Refractive index of a medium is denoted by the letter *n* or μ (μ is a Greek letter pronounced as mew).

Snell's law can be expressed as: $\sin i / \sin r = {}^{a}n_{b}$ or ${}^{a}\mu_{b}$

Absolute Refractive Index

The refractive index of a medium with respect to air (or vacuum) is called the absolute refractive index of the medium.

Absolute refractive index = sin$i$ / sin r

The absolute refractive index of a medium is also defined as:

Absolute refractive index, μ =

Velocity of light in vacuum (c)/ Velocity of light in the medium (v)

Conditions for no refraction

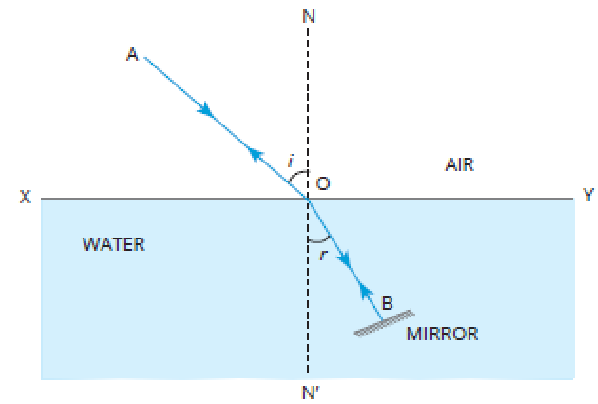
A ray of light will pass undeviated from one medium to another medium in following two conditions.

1. If the light ray is incident normal at the boundary separating the two media, that is $\angle i = 0°$.

2. If the refractive indices of the two media are equal, then also the light ray is not refracted.

Factors affecting the refractive index of a medium

- Nature of the material of the medium
- Physical condition
- Wavelength of the light used



Principle of Reversibility of Light

According to the principle of reversibility of light, **if a reflected or refracted ray is reversed in direction, it will retrace its original path**.

Refraction of Light through a Rectangular Glass slab

1. Applying Snell's law of refraction at point O, we get:

At point O, $^{air}\mu_{glass} = \sin i_1 / \sin r_1$ …………………….. (1)

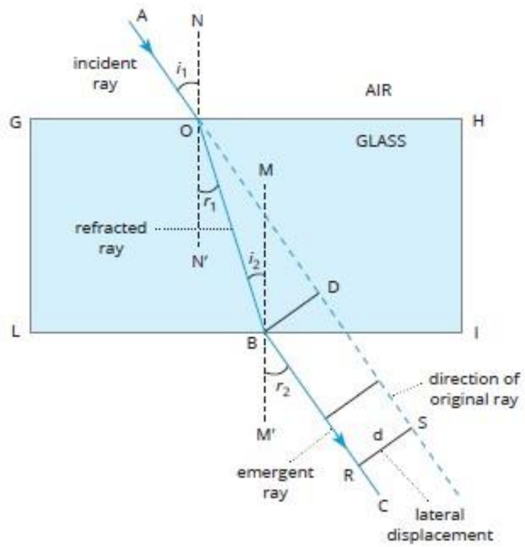
2. Similarly, by applying Snell's law of refraction at point B, we get:

At point B, $^{glass}\mu_{air} = \sin i_2 / \sin r_2$ ……………………. (2)

Multiplying equations (1) and (2), we get:

$^{air}\mu_{glass} \times {}^{glass}\mu_{air} = \sin i_1 / \sin r_1 \times \sin i_2 / \sin r_2$

But $^{air}\mu_{glass} \times {}^{glass}\mu_{air} = 1$ (Principle of reversibility of light)



$\therefore$ sini_1 / sinr_1 $\times$ sini_2 /sin r_2 = 1
Now, $\angle r_1 = \angle i_2$ (Alternate angles, NN′ || MM′)
$\therefore$ sini_1 / sin r_2 = 1
or sini_1 = sin r_2
or $\angle i_1 = \angle r_2$
Since, the angle of emergence (r_2) is equal to the angle of incidence (i_1), therefore, the emergent ray of light, BC is parallel to the incident ray of light, AO.

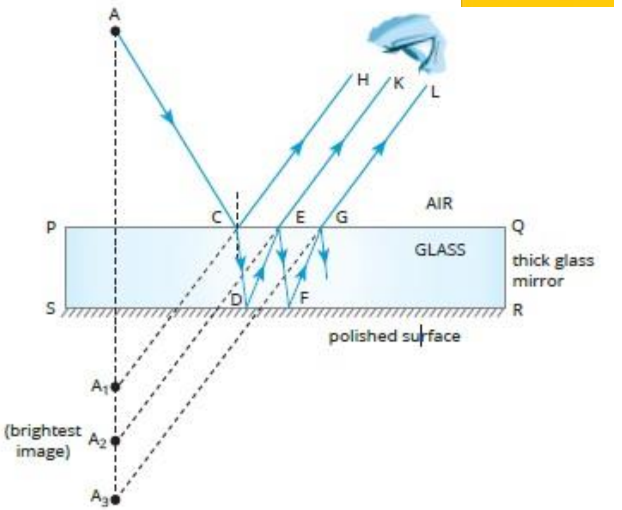
Lateral Displacement

The perpendicular distance between the original path of the incident ray and the emergent ray coming out of the glass slab is called the lateral displacement. In
In above figure the lateral displacement is the perpendicular distance RS.

Lateral displacement depends on the following factors:
1. Lateral displacement is directly proportional to the thickness of the glass slab,
2. Lateral displacement is directly proportional to the incident angle.
3. Lateral displacement is directly proportional to the refractive index of the glass slab.
4. Lateral displacement is inversely proportional to the wavelength of the incident light.

Multiple Images in a Thick Plane Glass Plate or Thick Mirror

When an object is placed in front of a thick plane glass plate or thick plane mirror and viewed obliquely, a number of images are seen. Out of these images, the second image is the brightest and most clear image, while others are of diminishing brightness or get fainter.



The image A2 is the brightest and most clear image because it is due to the major part of light suffering a strong reflection at the silvered surface SR.

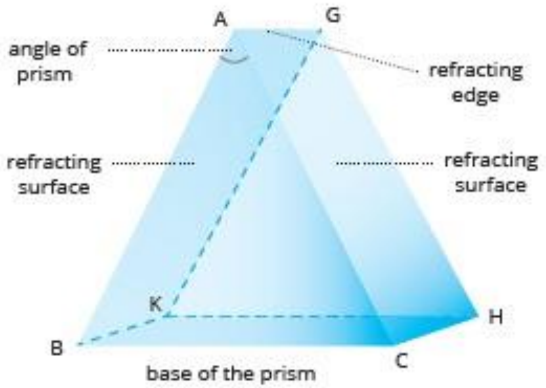
Refraction of Light through a Prism

What is a Prism?

A simple prism is a homogeneous transparent refracting medium bounded by at least two non-parallel plane surfaces inclined at some angle.

•The angle between the two refracting surfaces is called the angle of the prism or the refracting angle of the prism.

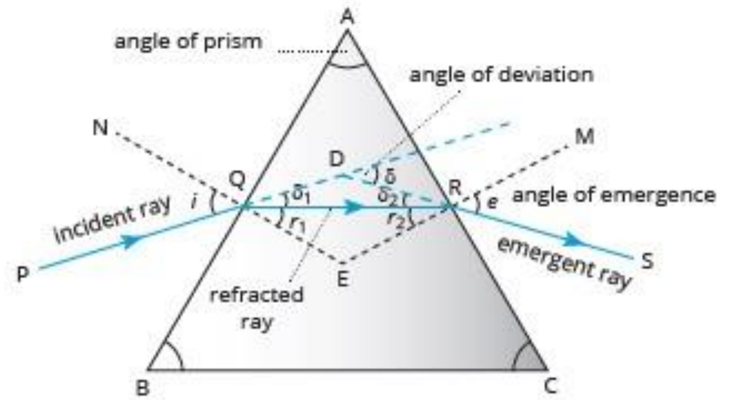
•The line of intersection of the two surfaces is called the refractive edge of the prism.



Refraction through a Prism

•The angle between the emergent ray and the direction of the incident ray is called the angle of deviation.

•The angle of incidence for which the deviation produced by the prism is minimum is called the angle of minimum deviation.



Angle of deviation depends upon

1.The angle of incidence

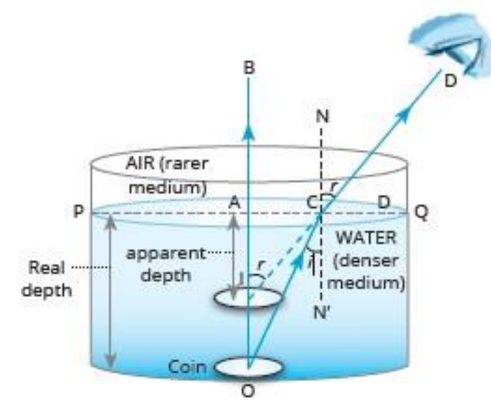
2. The angle of prism

3.The refractive index of the prism material

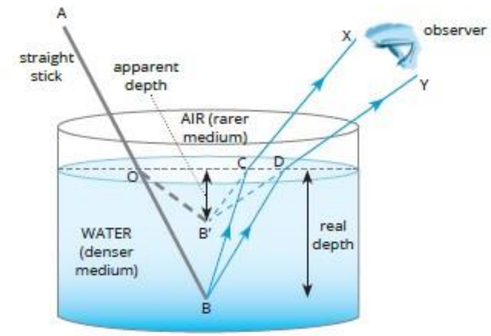
4. The wavelength of light

Refractive Index and the Real and Apparent Depth

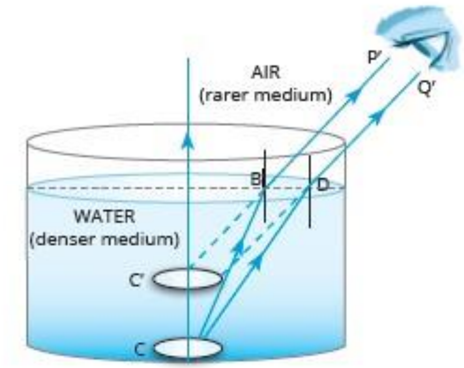
An object which is in a denser medium (say water) when viewed from a rarer medium (say air) appears to be raised. This is due to the phenomenon of refraction of light. Therefore, a coin lying at the bottom of a bucket full of water appears to be raised. Similarly, the bottom of a swimming pool filled with water appears to be raised.



Applications of Refraction of Light

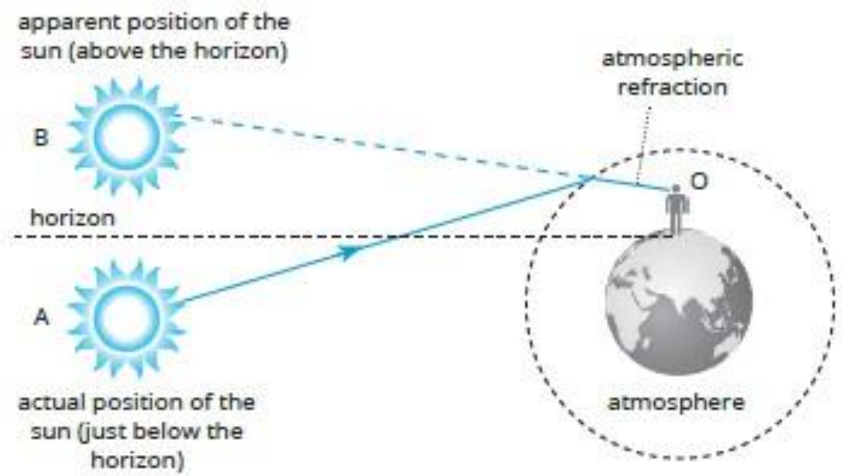


1. **Apparent bending of a stick under water.**
A straight stick AB appears to be bent in water along AOB' due to the refraction of light.



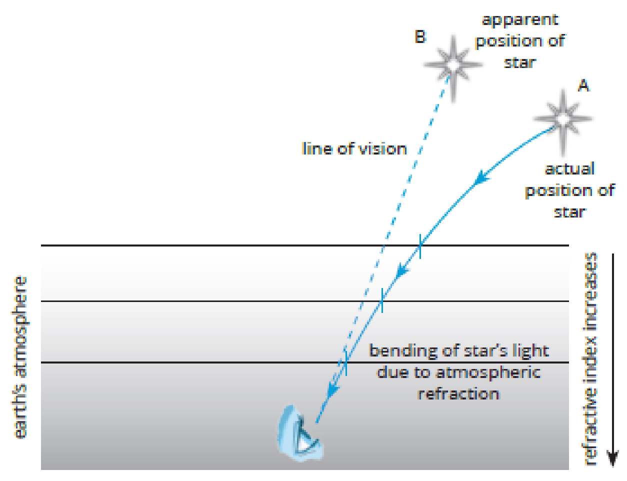
2. **A coin placed at the bottom of a vessel full of water appears to be raised**
Coin is visible and appears to be raised in water due to the refraction of light.

3. **The sun is visible two minutes before the actual sunrise and two minutes after the actual sunset**
Effect of atmospheric refraction at sunrise is seen.



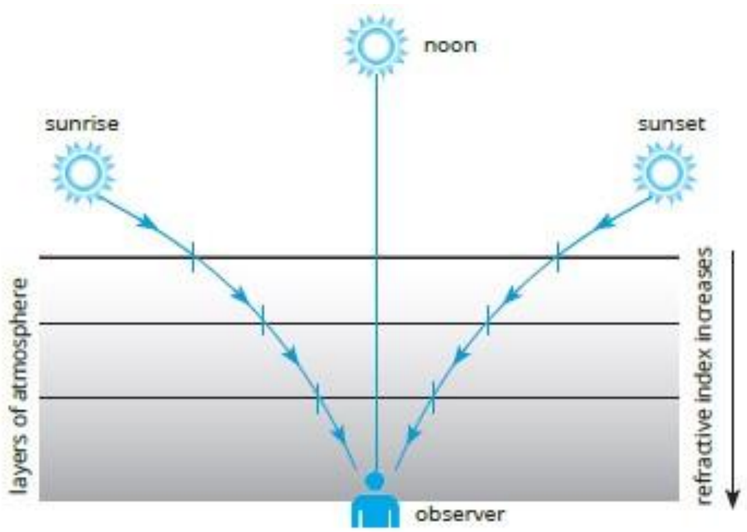
3. **The stars seem higher than they actually are**

A star seems to be higher in the sky, than it actually is, due to atmospheric refraction.



4. **Twinkling of stars**

The continuous changing atmosphere refracts the light from the stars by varying amounts and in different directions from one moment to the next. That is why they appear twinkling.

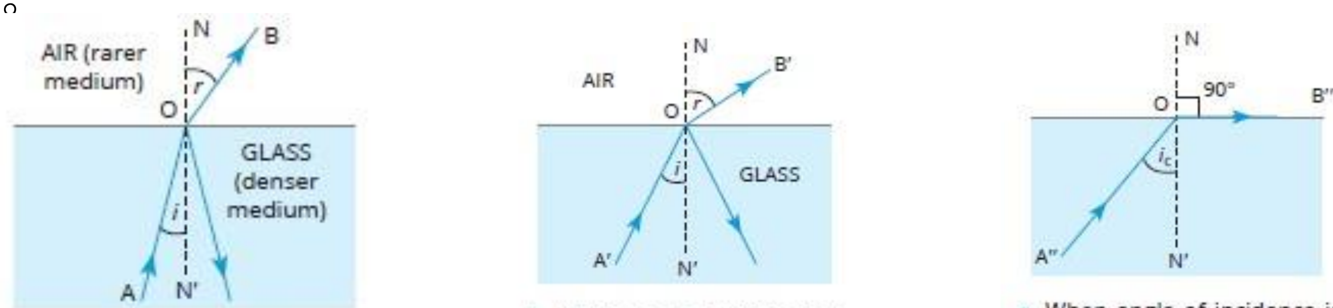


5.**Sun appears oval shaped at sunrise and sunset (i.e flattening of the sun)**

The sun appears oval and larger in size at sunrise and sunset when the sun is near the horizon.

Critical Angle

The critical angle for a medium is the angle of incidence in the denser medium for which the angle of refraction in the rarer medium is 90°. The critical angle is usually denoted by the letter C or i_c. The critical angle for ordinary glass is about 42° with respect to air. This means that when the angle of incidence of a ray of light in glass is 42°, the angle of refraction in air is 90°



a. When angle of incidence *i* is small in glass, light rays bent away from the normal.

b. When angle of incidence *i* increases, the angle of refraction also increases.

c. When angle of incidence is equal to the critical angle C, then angle of refraction is 90°.

Factors Affecting Critical Angle

The critical angle for a given pair of media depends on the following factors:

1. Colour (or wavelength) of light

Greater the wavelength of light, greater will be the critical angle for a pair of media. Thus, the critical angle for a pair of media will be maximum for red colour (greatest wavelength) and minimum for violet colour (least wavelength).

2. Nature of the pair of media

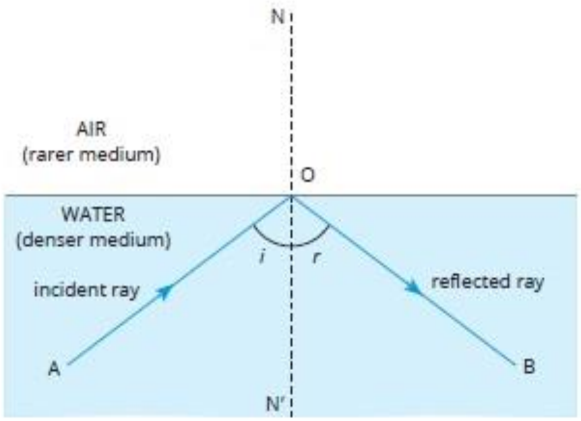
Greater the refractive index, lesser will be the critical angle. Diamond has greater refractive index (2.42) as compared to flint glass (1.57), so the critical angle of diamond (25°) is less than that of flint glass (40°).

3. Temperature

On increasing the temperature of medium, its refractive index decreases, so the critical angle for that pair of media increases.

Total Internal Reflection

When the angle of incidence of a ray of light travelling in a denser medium is greater than the critical angle for the pair of media, then there is no refraction of light into the rarer medium and the ray is reflected back into the denser medium. This phenomenon is called total internal reflection.



Conditions for total reflection

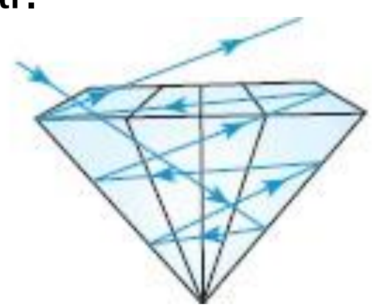
1. The incident light must pass from a denser medium into a rarer medium.
2. The angle of incidence in denser medium must be greater than the critical angle for the given pair of media.

Note: Refer to the book P-85-88 for Total Internal Reflection in Prism

Some Phenomena due to Total Internal Reflection

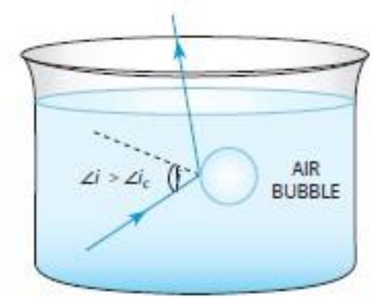
1.Sparkling of a Cut Diamond

The faces of a diamond are cut in such a way, that once a ray of light enters into it, the angle of incidence is greater than the critical angle, i.e. 24° . So, a ray of light entering the diamond suffers repeated total internal reflection at a large number of faces. This ray of light when falls on any face where the angle of incidence is less than 24° , emerges out of the diamond. Thus, at any moment of time, due to total internal reflection, several faces of the diamond appear.



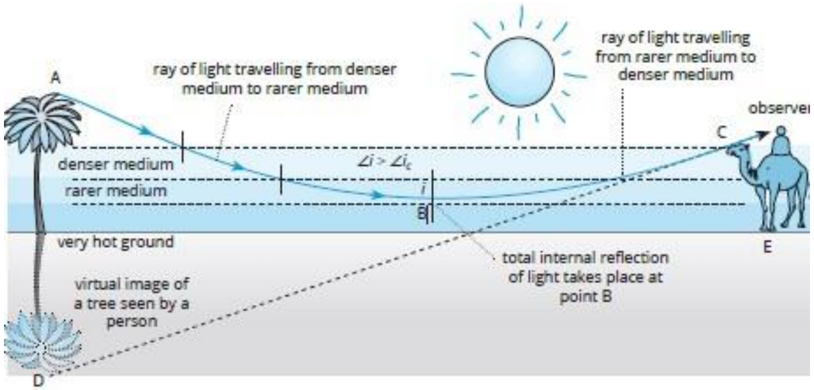
Shining of Air Bubble

The critical angle for water-air interface is 48° . When the light rays propagating in water (denser medium) is incident on the surface of the air bubble (rarer medium) at an angle greater than 48° , total internal reflection takes place (Fig. 4.31). Hence, the air bubble in water shines brightly.



Mirage

Mirage is an optical illusion of water observed generally in deserts, when the inverted image of a distant object (e.g. a tree) is observed along with the object itself on a hot day. It is caused due to the total internal reflection of light in the upward direction in which the inverted image of the distant object appears, as if reflected from the surface of water.



Application of Total Internal Reflection of Light

Optical Fibre

Optical fibres are long, thin strands of very fine quality quartz glass, arranged in bundles called optical cables and are used to transmit light through the phenomenon of total internal reflection over long distances. They are used in the manufacturing of medical instruments called endoscopes which are inserted into the internal organs of human beings. They are also used in telecommunications for transmitting signals and transmit the images of an object. They are used to transmit electrical signals from one place to another.

SUMMARY

1. Refraction of light: The bending of light when it passes obliquely from one transparent medium to another is called refraction of light.

2. Laws of refraction of light:

First law: The incident ray, the refracted ray and the normal at the point of incidence all lie in the same plane.

Second law: The ratio of sine of the angle of incidence to the sine of the angle of refraction is a constant for a given pair of media. This is also called Snell’s law.

3. Refractive index: The ratio of the speeds of light in two media is a constant and is known as their refractive index.

4. Factors affecting the refractive index: a. Nature of the medium **b.** Physical conditions such as temperature, density, etc. **c.** Wavelength of light.

5. Lateral displacement: The perpendicular distance between the original path of incident ray and the emergent ray coming out of a glass slab is called lateral displacement.

6. Factors affecting the deviation produced by a prism: a. Angle of incidence **b.** Angle of prism **c.** The refractive index of the prism.

7. Critical angle: It is the angle of incidence in the denser medium for which the angle of refraction in the rarer medium is 90°.

8. Total internal reflection: When the angle of incidence of a beam of light travelling in a denser medium is greater than the critical angle of the medium, then there is no refraction of light into the rarer medium but all the light is reflected back into the denser medium. This phenomenon is called total internal reflection of light.

9. Conditions for total internal reflection of light: a. The incident light must pass from a denser medium into a rarer medium; **b.** The angle of incidence in denser medium must be greater than the critical angle for the given pair of media.