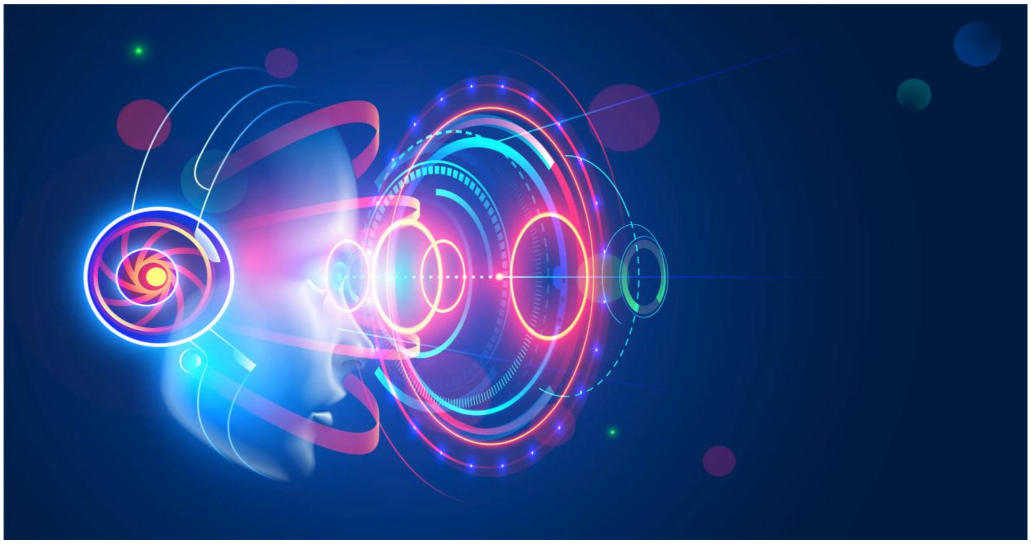
Al-Mustaqbal University

Department of Optics Techniques

Medical and optical physics 1

First stage

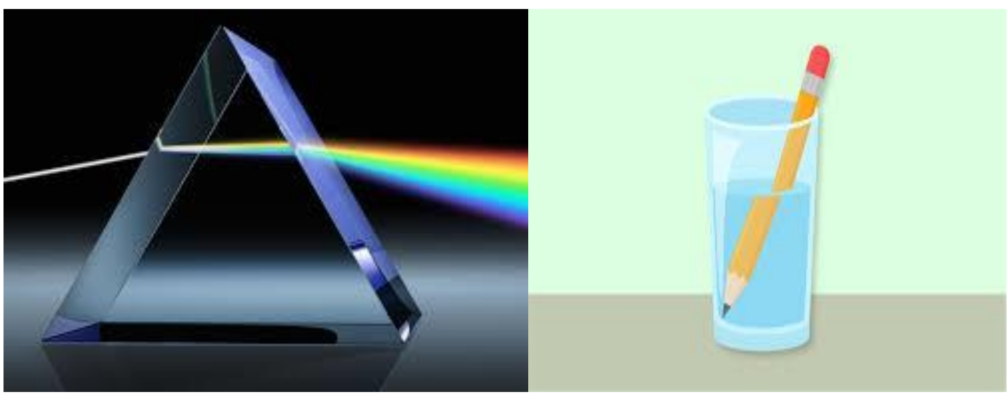
Assist. Lec. Hala Mohammed Subhi



Refraction

➢ Lecture 7

Introduction: - When electromagnetic radiation, in the form of visible light, travels from one substance or medium into another, the light waves may undergo a phenomenon known as **refraction**, which is manifested by a bending or change in direction of the light. Refraction occurs as light passes from one medium to another only when there is a difference in the **index of refraction** between the two materials. The effects of refraction are responsible for a variety of familiar phenomena, such as the apparent bending of an object that is partially submerged in water and the mirages observed on a hot, sandy desert. The refraction of visible light is also an important characteristic of lenses that enables them to focus a beam of light onto a single point.



Definition of refraction: Refraction is the bending of light as it passes from one medium to another. The bending is caused by the change in speed of light in different media.

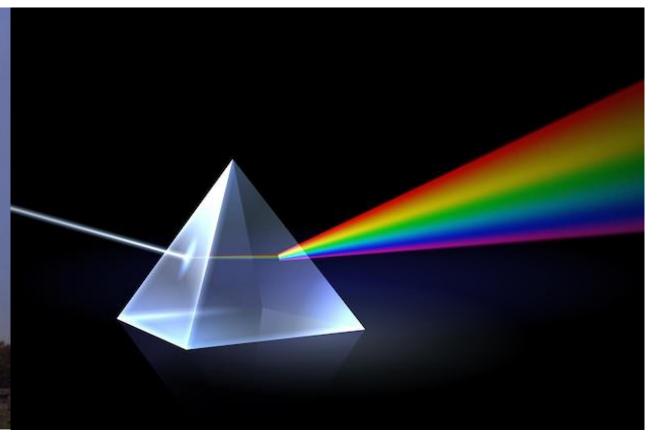
- When light travels from a medium with a lower refractive index (such as air) to a medium with a higher refractive index (such as water), it slows down and bends towards the normal. The normal is the line perpendicular to the surface of the boundary between the two media. When light travels from a medium with a higher refractive index to a medium with a lower refractive index, it speeds up and bends away from the normal.

- The mechanism of refractive involves two key concepts:

  1- The angle of incidence is the angle between the incident ray and the normal.

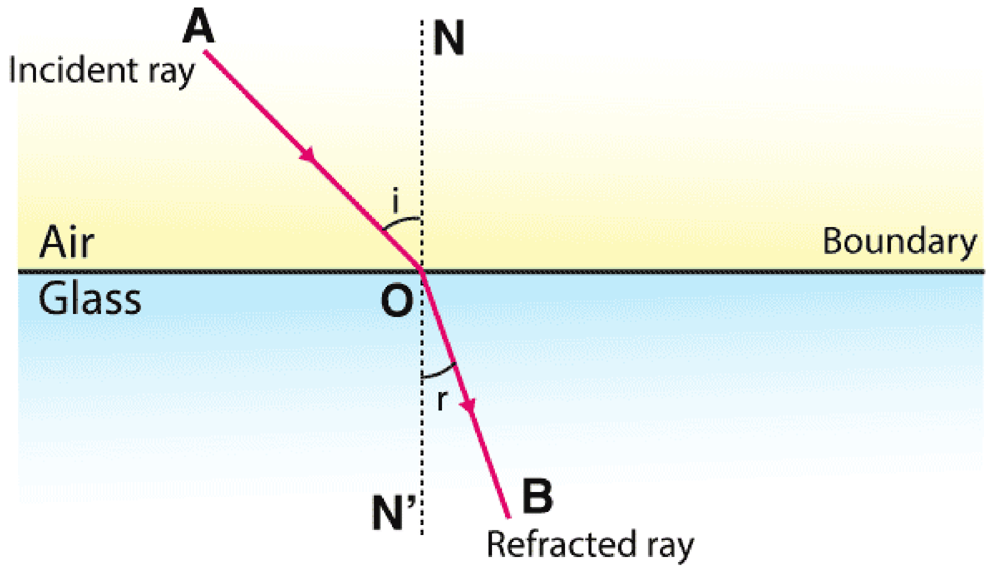
  2- The angle of refraction is the angle between the refracted ray and the normal.

  Refraction is responsible for many optical phenomena, such as the formation of images by lenses, the dispersion of light by prisms, and the appearance of rainbows.

- **Causes of Refraction**

Change of Speed Results in Change in Direction: A light ray refracts whenever it travels at an angle into a medium of different refractive indices. This change in speed results in a change in direction. As an example, consider air travelling into water. The speed of light decreases as it continues to travel at a different angle.



The refraction of light in glass is shown in the figure above. When light travels from air into glass, the light slows down and changes direction slightly. When light travels from a less dense substance to a denser substance, the refracted light bends more towards the normal line. If the light wave approaches the boundary in a perpendicular direction, the light ray doesn't refract despite the change in speed.

Laws of Refraction of Light

Laws of refraction state that:

1- The incident ray refracted ray, and the normal to the interface of two media at the point of incidence all lie on the same plane.

2- The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant.

- This is also known as Snell's law of refraction.

$$n_i \sin \theta_i = n_r \sin \theta_r$$

Where n_i and n_r are the refractive indices of the first and second medium, and θ_i and θ_r are the angles of incidence and refraction, respectively.

Index of refraction of light

The index of refraction (n) is an essential parameter in optics that determines the speed by which light travels through a medium other than a vacuum. A vacuum, like is present in outer space, is the only medium in which electromagnetic waves experience no dispersion and travel at the speed of light c. Traveling through all other media slows the sine propagation wave of light.

Refractive index is defined as:

The ratio of the speed of light in a vacuum to its speed in a specific medium.

Refractive Index Formula

The refractive index is dimensionless. It is a number that indicates the number of times slower than a light wave would be in the material than it is in a vacuum. The refractive index, represented by symbol n, is the velocity of light in vacuum divided by the velocity of light in a medium. The formula of the refractive index is as follows: $n = \frac{c}{v}$

Where:

n= is the refractive index of the material.

c= is the speed of light in vacuum or air, which is approximately (3×10^8 m/sec).

v= is the speed of light in the material.

Key Points:

1. Velocity of Light: Light travels at different velocities in different materials. It slows down when it enters a denser medium.

2. Dependence on Medium: The refractive index depends on the material through which light is passing. Different materials have different refractive indices.

3. Wavelength Dependence: The refractive index generally varies with the wavelength of light. This phenomenon is called dispersion. For example, glass has different refractive indices for different colors of light, which causes the separation of colors in a prism.

4. Directional Dependence: In anisotropic materials (like crystals), the refractive index can vary with the direction of propagation of light. This phenomenon is known as birefringence.

5. Important in Optics: The refractive index is crucial in understanding various optical phenomena like reflection, refraction, and total internal reflection.

6. Snell's Law: The refractive index plays a central role in Snell's Law, which describes how light bends when passing from one medium to another with different refractive indices.

7. Applications: Refractive index measurements are used in various fields such as optics, materials science, chemistry, and biology. They are utilized in designing lenses, prisms, fiber optics, and in characterizing materials.

Example:

A light ray falling on a flat surface separating two transparent media with an index of refraction (n_1 = 1.6, n_2 = 1.4), and the angle of incidence of the ray was (30 degrees). Calculate the angle of refraction.

Solution:

$$n_i \sin\theta_i = n_r \sin\theta_r$$

$$\sin\theta_r = \frac{n_i}{n_r} \sin\theta_i$$

$$\sin\theta_r = \frac{1.6}{1.4} \sin 30 \rightarrow \sin\theta_r = 0.57$$

$$\theta = \sin^{-1} 0.57 = 35°$$

Example: What is the speed of light in a glass (refractive index of glass is 1.5).

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

$$v = \frac{c}{n} = \frac{3 \times 10^8}{1.5} = 2 \times 10^8 \, m/s$$