Introduction

The past four decades witnessed major inventions in optics **(the branch of physics, which deals with the description of the phenomena and laws associated with the generation, and propagation of light and its interaction with matter)** which led to a silent revolution in communications and medical fields. It is often said that the near future belongs to Photonics, the technology based on the utilization of optical radiation **(the branch of technology concerned with the properties and transmission of photons, for example in fiber optics)**. A good knowledge of optics is essential for following the developments in Photonics.

We understand the world around us with the help of information reaching our five sense – organs, namely eyes, ears, nose, tongue and skin. The sense associated with the eyes is known as vision (or sight). Light is the agent which stimulates our sense of sight. The eyes convert the incoming light into electrical signals and convey them to the brain, which after processing the signals causes images or pictures to be created in our mind.

The source of light that we use most often to see with, comes from our local star, the Sun. Hot objects glow, and the Sun is the hottest natural object in our solar system. It gives off mostly yellow light, but also blue, green, red, orange, and additional colors. This light travels through space, penetrates our atmosphere, and illuminates our world. But there is much more to light than what we see, and there are many more uses to which it can be put. In addition to helping us to see, light is also used as a tool in lasers, fiber optics, and more.

Brief History

1- Development of Geometric Optics:

- The Greeks were aware of the rectilinear propagation of light. They knew that when light is reflected from a mirror, the angle of incidence is equal to the angle of reflection. They were also aware of refraction of light as it passes from one transparent medium to another. Further progress came to a halt with the fall of Roman Empire in 475 A.D.

- Study of light was again revived in Europe during the thirteen century. Francis Bacon (1215-1294) suggested the idea of using lenses to improve eyesight.
- In about 1280, Spectacle lenses came into use to correct faulty vision.
- In 1609 Galileo (1564-1642) devised a practical telescope.
- Van Leeuwenhoek (1632-1723) developed the first microscope.
- John Kepler discovered the phenomenon of total internal reflection.
- In 1621 Willebrod Snell (1591-1626) discovered the law of refraction.

2- Development of Wave Optics:

- In l678, Huygens, a contemporary of Newton, proposed wave theory of light. According to this theory, light energy is supposed to be transferred from one point to another in the form of waves. Huygens was able to prove the laws of reflection and refraction. He predicted that light should travel slower in a denser medium than in a rarer medium. He also explained the phenomenon of double refraction by assuming two types of waves. The wave theory was not accepted immediately. The chief reason was that a wave motion needs a medium; but light could travel to us from the sun through the vacuum of space.
- In 1803. Thomas Young (1773-1829) demonstrated for the first time the interference of light beams.

- In 1808, Malus (1775-1812) discovered the polarization of light.
- In 1815, Augustin Fresnel (1788-1827) further developed the wave theory and explained the rectilinear propagation of light which has been the chief obstacle in the way of accepting wave theory. He provided a satisfactory explanation of the diffraction phenomenon.
- Following Huygens, both Young and Fresnel assumed that ***light waves are longitudinal***. Young and Fresnel conceived of an elastic medium, which was assumed to exist pervading the entire universe, and it was named ***luminiferous ether***. The vibrations of the ether propagated as light, just as longitudinal vibrations in air propagate as sound. But the longitudinal wave theory of light could not explain polarization, a property exhibited by transverse waves but not by longitudinal waves.
- In 1850, Jean Foucault (1791-1868) established that light travels slower in liquids than in air.
- Finally, the wave model was accepted. The acceptance of the wave theory of light made it obvious that a supporting medium should exist. Subsequently, elastic ether theory was developed during the next ten years.

3- Nature of Light:

- Around 1836, Faraday (1791-1867) showed that a varying magnetic field induces an electromotive force and thus established the intimate connection between electricity and magnetism. Further, Faraday showed that the polarization of light was affected by a strong magnetic field, which was the first hint as to the electromagnetic nature of light.

- Clerk Maxwell (1831-1879) unified the empirical laws of electricity and magnetism into a coherent theory of electromagnetism.

- In 1873, Maxwell showed that the speed of electromagnetic waves equals the speed of light.
- In 1887, Hertz (1857-1894) confirmed Maxwell’s theoretical prediction by producing and detecting electromagnetic waves. The electromagnetic waves were initially supposed to be supported by the ether medium. Though electromagnetic theory is capable of explaining the phenomena connected with the propagation of light, it fails to explain the processes of emission and absorption.
- In 1887, Michelson-Morley performed the famous ether-drift experiment and found that light travels at the same speed irrespective of the position of the earth in its orbit. It led to the conclusion that ether does not exist.

4- Development of Quantum Optics:

- The theory that light moved in discrete bundles (i.e. photons) was presented in Max Planck's in 1900.
- In 1905, Einstein expanded on these principles in his explanation of the photoelectric effect to define the photon theory of light.
- Quantum physics developed through the first half of the twentieth century largely through work on our understanding of how photons and matter interact and inter-relate. This was viewed, however, as a study of the matter involved more than the light involved.
- In 1953, the maser was developed (which emitted coherent microwaves) and in 1960 the laser (which emitted coherent light). As the property of the light involved in these devices became more important, quantum optics began being used as the term for this specialized field of study.

The phenomena of interference, diffraction, polarization and propagation of light in space is adequately explained by classical electromagnetic wave theory, whereas the experiments involving interaction of light with matter, such as photoelectric effect are best explained by assuming that light is a particle.

The Most Important Theories

Various theories have been put forward about the nature of light.

1. **The Corpuscular Theory**: According to this theory, a luminous body continuously emits tiny, light particles called corpuscles in all directions. These particles or corpuscles are so small that they can readily travel through matter with the velocity of light and they possess the property of reflection from polished surface or transmission through a transparent medium. When these particles fall on the retina of the eye, they produce the sensation of vision.
2. **The Wave Theory**: Huygens proposed the wave theory of light. According to this, a luminous body is a source of disturbance in hypothetical medium called ether. This medium pervades all space. The disturbance from the source is propagated in the form of waves through space and the energy is distributed equally, in all directions. When these waves carrying energy and incident on the eye, the optic nerves are excited and the sensation of vision is produced.
3. **The Electromagnetic Theory**: Maxwell ingeniously synthesized electricity and magnetism and developed equations which combine the important theories. He showed that electromagnetic waves travel with the speed of light and hence drawn the most important conclusion that light wave itself is an electromagnetic wave.

Light appears to be a continuous electromagnetic wave of frequency (f) and on the other hand it appears to be a collection of photons having energy (E). It has been found that neither of the models can separately explain all the experimental facts. A particle is precisely localized in space whereas a continuous wave cannot be attributed to a particular location in space. **Thus, the corpuscular nature and wave nature appear to be mutually exclusive. Therefore, the light exhibits dual nature**. When light propagates through space or any medium the electromagnetic wave description is used, and whenever light interacts with matter the photon description is used.

The Source of Light:

The sun, the stars, lamps give off light. They are called luminous bodies. Other objects moon, mountains, trees etc. are non-luminous. They are visible only when they receive light from some luminous source and they send the light to our eyes. Whether a body is luminous or non-luminous depends on the conditions as well as on the material of which it is made. By changing the conditions, we can make substances luminous or non-luminous. For example, the filament inside the electric bulb is non- luminous unless it is heated by an electric current.

Bodies emit light at the expense of various kinds of energy. The most common is thermal radiation. When bodies are heated, to a temperature of 300° C they emit electromagnetic radiation, which lies in infrared region. They emit light as result of thermal motion of their molecules that is at the expense of their internal energy.

At a temperature of 800° C, bodies emit visible radiant energy and appear red hot; a larger part of the energy still lies in IR region. At around 3000° C they appear white hot. Such heated materials are known as incandescent bodies. Not all sources are incandescent.

Some bodies can emit light, which is not due to transfer of thermal energy into the energy of electromagnetic waves. Emission of light due to supply of energy through processes other than heat is called luminescence.

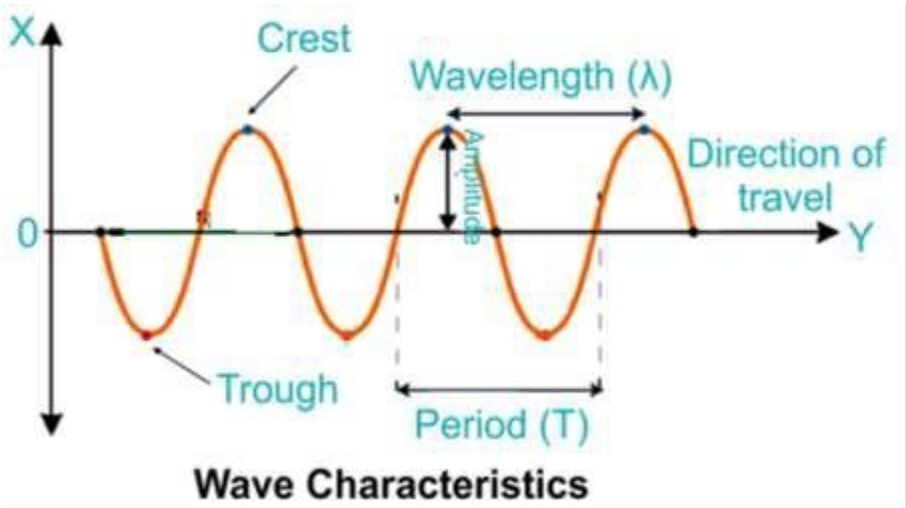
Wave of Light

According to the dictionary, a wave is a disturbance that moves through space over time. Light is a wave and it can travel through **medium** (air, water, glass), and it can also travel through the **vacuum**, which is empty space.

Ordinary waves need a **medium**, a substance that waves pass through. Water waves cannot exist without water, Sound does not exist in empty space, and sound waves need air or water or something that allows them to travel from one place to another. A wave traveling through a rope needs the rope, otherwise it wouldn't exist.

Fundamentals of Waves: Frequency, Amplitude, and Wavelength

Waves are made up of different parts, and each one has its own term. The high parts of the wave are called the **crests (peaks)** and the low parts are called the **troughs (valleys).** The distance between two peaks is called the **wavelength**. All waves are built the same way. They all have crests, troughs, and wavelengths, and of these features, the most important part of a wave is usually its wavelength. **Amplitude** is the term used to describe how tall waves are. The given distance that the wave rises above the reference line is called the amplitude, which can be looked at as a measure of the strength of the wave.



Imagine that your wave moves, so that the crests and troughs travel toward the right side of the page. The **phase** of a wave can tell you the location of the crests and troughs at any given time in relation to where they started. At the beginning, the waves will be exactly where you drew them; a moment later, the crests and troughs will be shifted a little to the right.

Each type of wave moves at a given speed. So, waves can be described in terms of the speed at which they move. And by knowing the wavelength and the speed, it's also possible to calculate the number of wave crests (or troughs) that move past a certain point every second—this is called the **frequency**.

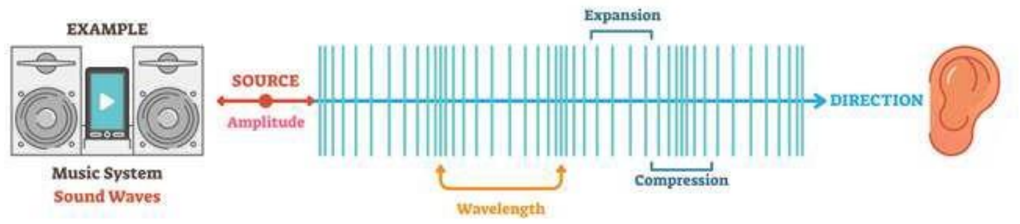
$$f = \upsilon/\lambda$$

In this equation, f is the frequency (in hertz), υ is the speed of the wave, and λ is the wavelength.

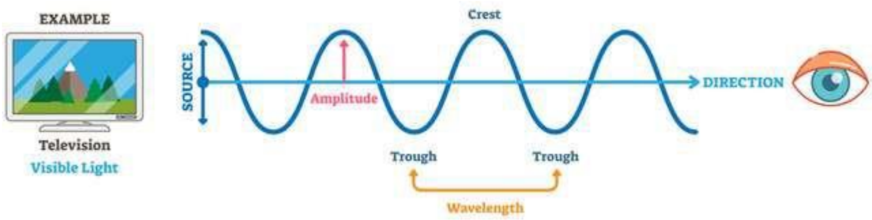
For light wave, **c** equals the speed of light (186,282 miles per second [299,792,458 m/s ≈ **$3*10^8$ m/s**] in a vacuum [empty space]; a little bit slower as it travels through any non-empty space, such as air, water, or glass).

Types of Waves

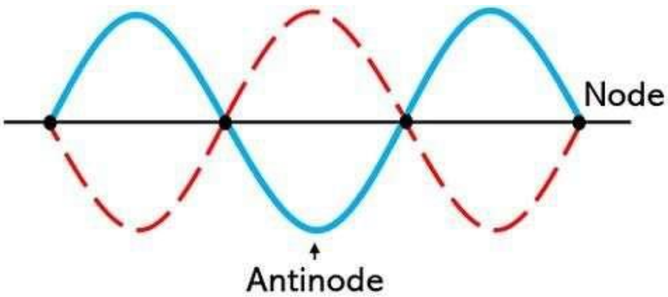
1. **Longitudinal wave** the wave moves in the exact same direction that's parallel to the back-and-forth vibrations of the air molecules.



2. **Transverse wave** the wave moves in a direction perpendicular to the up-and-down motion of the wave's crests and troughs.



3. **Standing wave** the wave stands in place, forming a series of crests and troughs that just vibrate up and down at the same location.



Electromagnetic Wave

Electromagnetic waves are waves which can travel through the vacuum of outer space. Electromagnetic waves are created by the vibration of an electric charge. This vibration creates a wave which has both an electric and a magnetic component. The electromagnetic behaving as waves and also as particles called photons which travel through space with the speed of light 3 x 10^8 m/s carrying radiant energy.

MEDICAL OPTICS