
University Of Technology
Department of Biomedical Engineering


# *Biomedical Optics*

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**2023-2024**

# 1-Introduction

Light is a type of waves that carries energy from one place to another. Light waves are made of a mixture of electricity and magnetism, so they are called electromagnetic waves.

Light waves have crests and troughs, and the distance between one crest and the next, which is the same as the distance between one trough and the next, is called **the wavelength**.

- **Light's dual nature as both a wave and a particle can be expressed mathematically through two fundamental equations:**

1) **Wave Equation (Wave Nature):**

$$c = \lambda f$$

**This equation relates the speed of light to its wavelength and frequency, demonstrating the wave-like nature of light.**

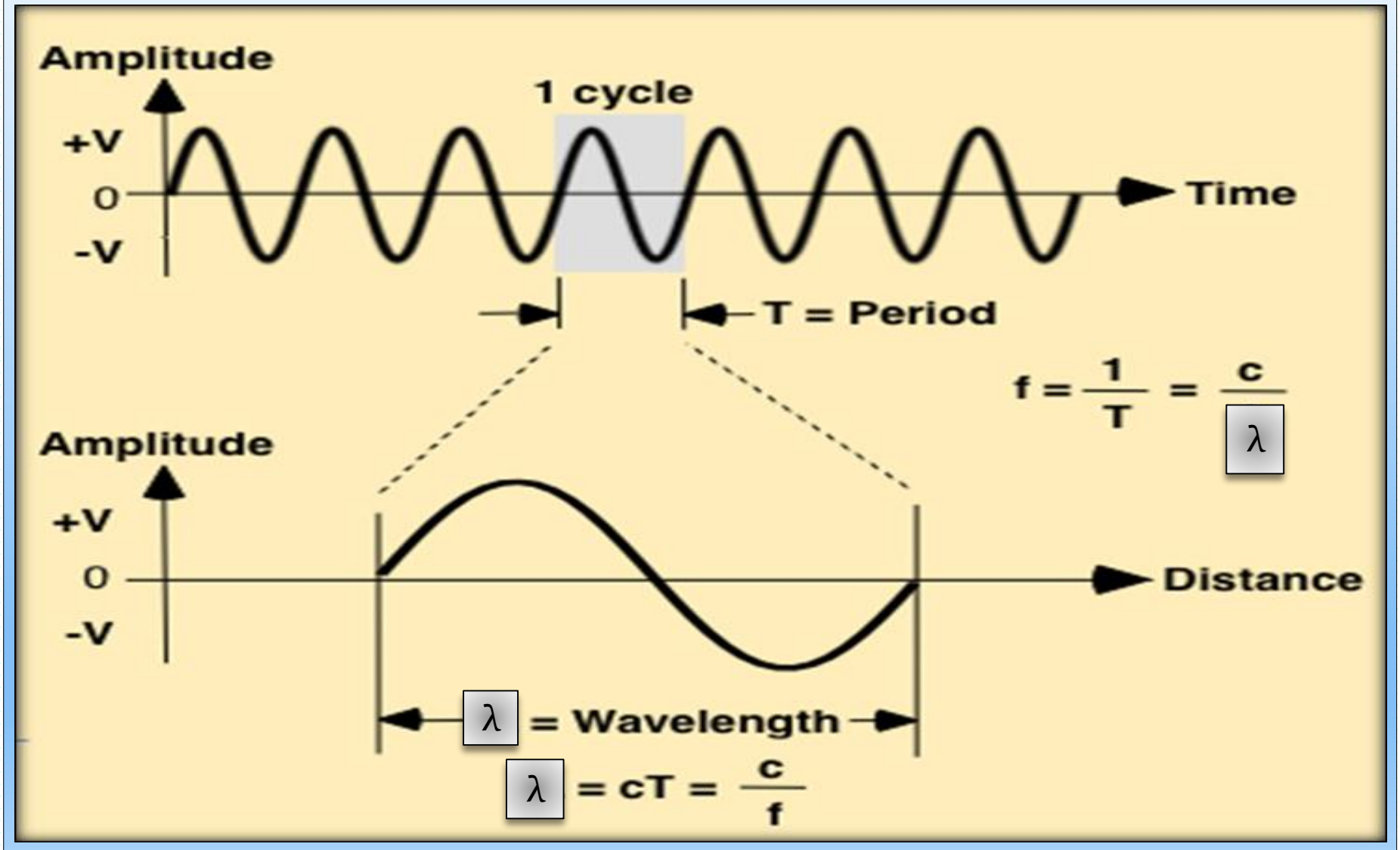
2) **Photon Energy Equation (Particle Nature):**

$$E = h f$$

- **E is the energy of a single photon.**
- **h is Planck's constant is (6.626 × 10^-34 J s).**
- **f is the frequency of the light wave associated with the photon.**

**This equation quantifies the energy associated with a single photon of light and is a fundamental concept in understanding the particle-like interactions of light, such as the photoelectric effect.**

# Electromagnetic Wave Parameters:



*Where:*

**T** = period (time to complete 1 cycle)

**c** = speed of light

f = frequency

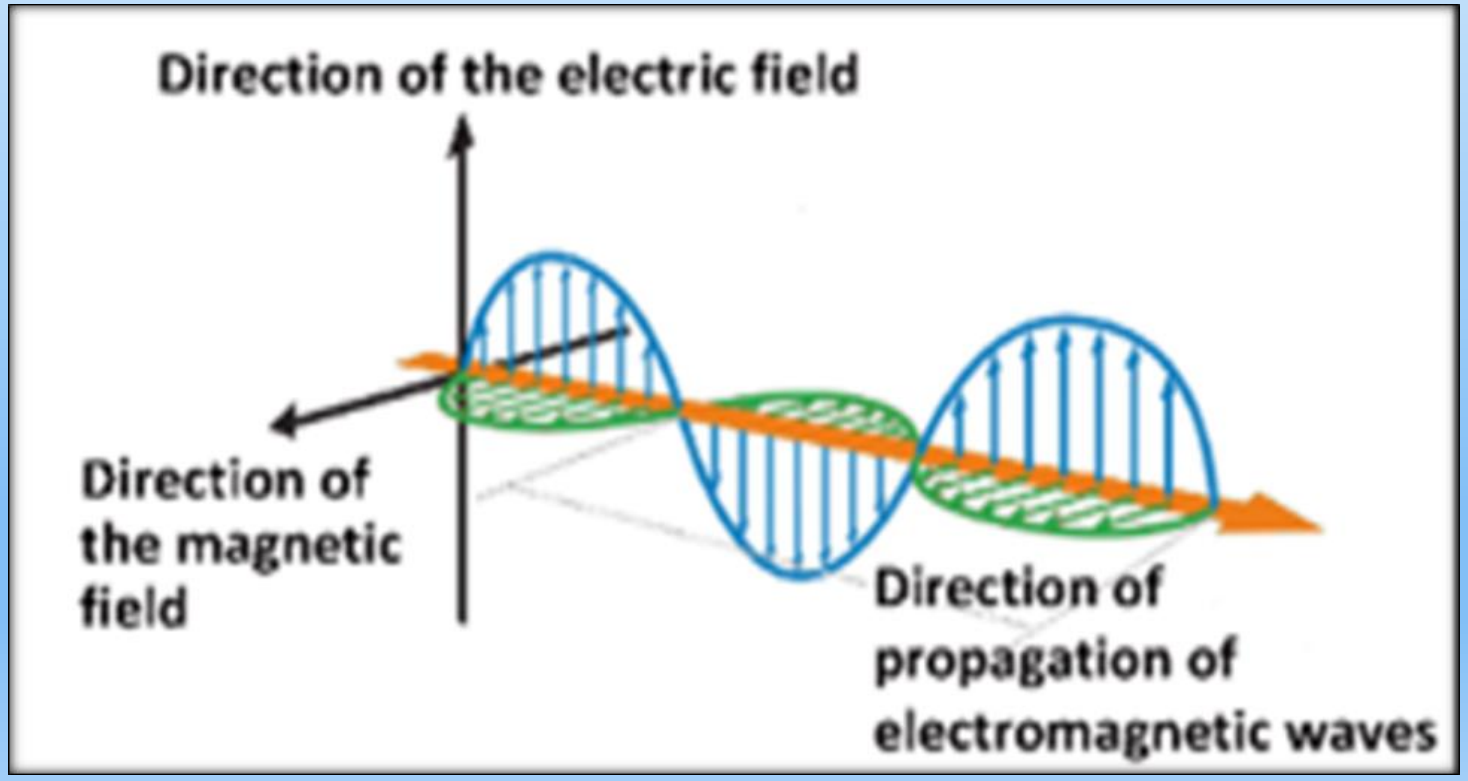
λ = Wavelength

- There are seven types of light waves, including radio waves, microwaves, infrared radiation, visible light, ultraviolet rays, X-rays, and gamma rays. Each type of light wave has a different wavelength and frequency.

- **Polarization of light** refers to the orientation of the oscillations of the electric field vector in a light wave. Light is an electromagnetic wave, and its electric field oscillates in a specific direction perpendicular to the direction of the wave's propagation. When these oscillations occur in a specific plane, the light is said to be polarized.
- Polarization is an important parameter in areas of science dealing with transverse waves, such as **optics, seismology, radio waves, microwaves and Remote Sensing**.

- **The phase of light** refers to the position of the electric field of a light wave in an oscillation cycle. It is particularly important in the context of interference and diffraction effects.
    - Electromagnetic waves consist of two perpendicular fields: an electric field and a magnetic field. These fields are intertwined and support each other as the wave moves through space.

- The shorter the wavelength is (the higher the frequency is), the higher the energy of an electromagnetic wave.
- The energy of radiation is expressed in electron volts (eV). (1 eV = 1.6 x 10^-19 Joule).



# 2-Vector and scalar wave equations:

**The wave equation is a fundamental equation in physics that describes the behavior of waves: -**

**a) The scalar wave equation** describes waves that have only one component, such as sound waves or electromagnetic waves with only one polarization. (That is, it is used to represent a physical quantity which is independent of direction, for example, say the temperature at a point on a surface is 30 degree centigrade. No notion of direction is required to describe the temperature at a point).

b) **The vector wave equation** describes waves that have multiple components, such as electromagnetic waves with both electric and magnetic fields (that is, used to represent a physical quantity which is dependent on the direction).

**For example**, when one says the acceleration of a body is 20 m/s^2, the representation is physically incomplete without specifying the direction with respect to a basis (fixed/moving).

One has to say, the body is accelerating towards the +ve X-direction from a fixed point at 20 m/s^2.

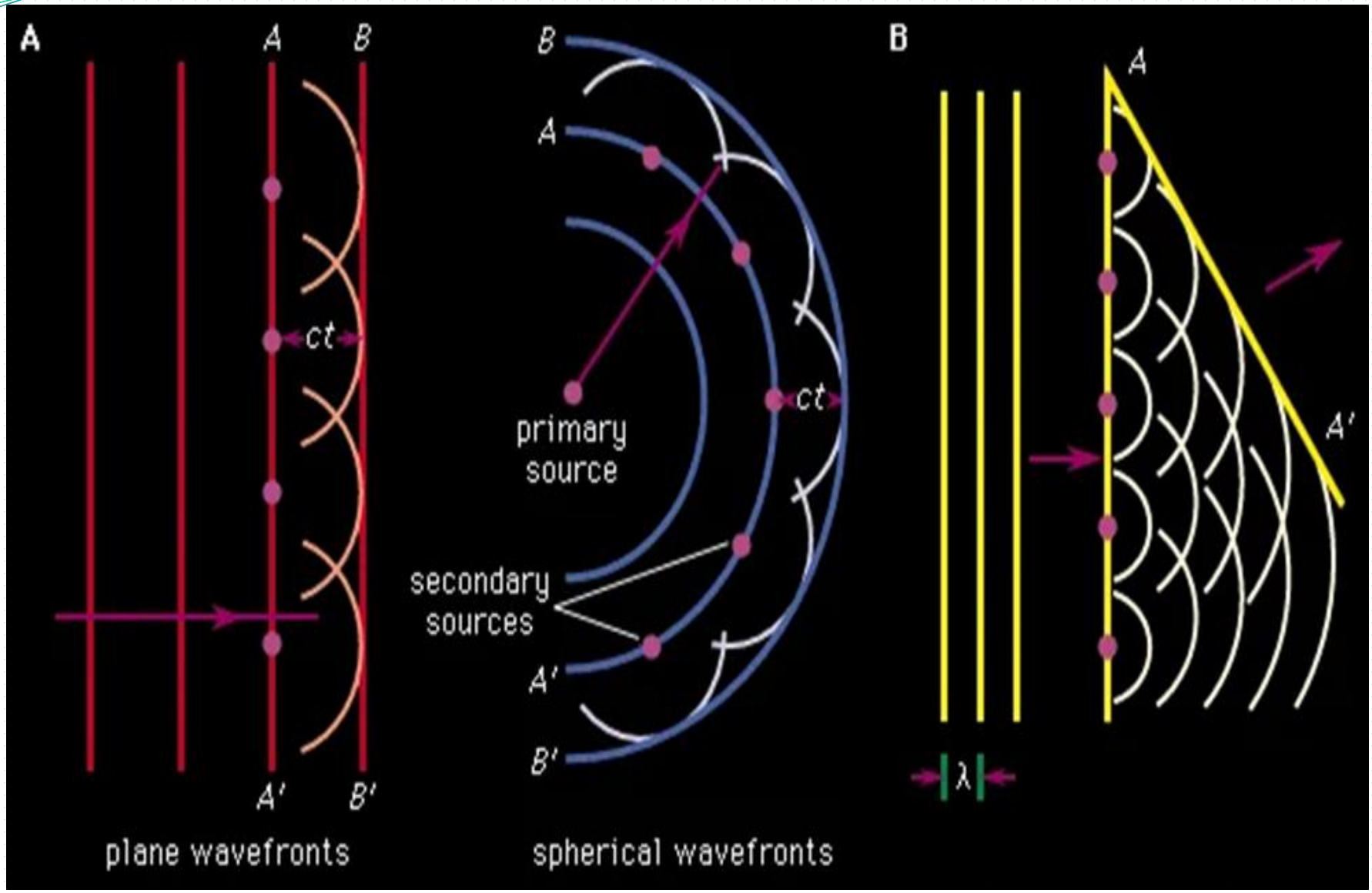
**Mathematically represented as:**

$$a=20i+0j+0k$$

(where i, j and k are the unit vectors in X, Y and Z directions), or [20,0,0]. Acceleration, in this scenario doesn't have components in the Y and Z directions.

# 3- Huygen's principle

Huygen's principle is a theory in optics that every point on a wave front of sound in a transmitting medium or of light in a vacuum or transparent medium, can be considered as a source of tiny secondary wavelets that spread out in all directions. The sum of these secondary wavelets determines the position and shape of the wave front at a later time. This principle was proposed by Dutch physicist Christiaan Huygens in the 17th century and is still used today to explain the behavior of light waves and other types of waves in physics. The diagram below is a graphical representation of Huygens' principle.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Thank you