University Of Technology
Department of Biomedical Engineering

Biomedical Optics

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2023-2024

1-Introduction

Optics is a branch of physics that studies the behavior and properties of light, including its interactions with matter and the construction of instruments that use or detect it. It describes the behavior of visible, ultraviolet, and infrared light.

Optics has a long history and has been studied for centuries. It is also used in various fields such as medicine, engineering, and astronomy.

Optics has a wide range of modern research topics such as optical and quantum information processing. It also has various applications in daily life such as extending human vision, fiber optics communication, cameras, telescopes, microscopes, etc.

❖ The electromagnetic spectrum:

The electromagnetic spectrum is the range of all types of electromagnetic radiation, which includes energy that travels and spreads out as waves.

It spans a broad range of frequencies and wavelengths, from very long radio waves to very short Gamma rays.

The human eye can only detect a small portion of the electromagnetic spectrum, which is visible light. Other types of electromagnetic radiation include infrared radiation, ultraviolet radiation, X-rays, and microwaves. The known electromagnetic spectrum is diagramed in Fig. 1. and ranges from Gamma rays to radio waves.

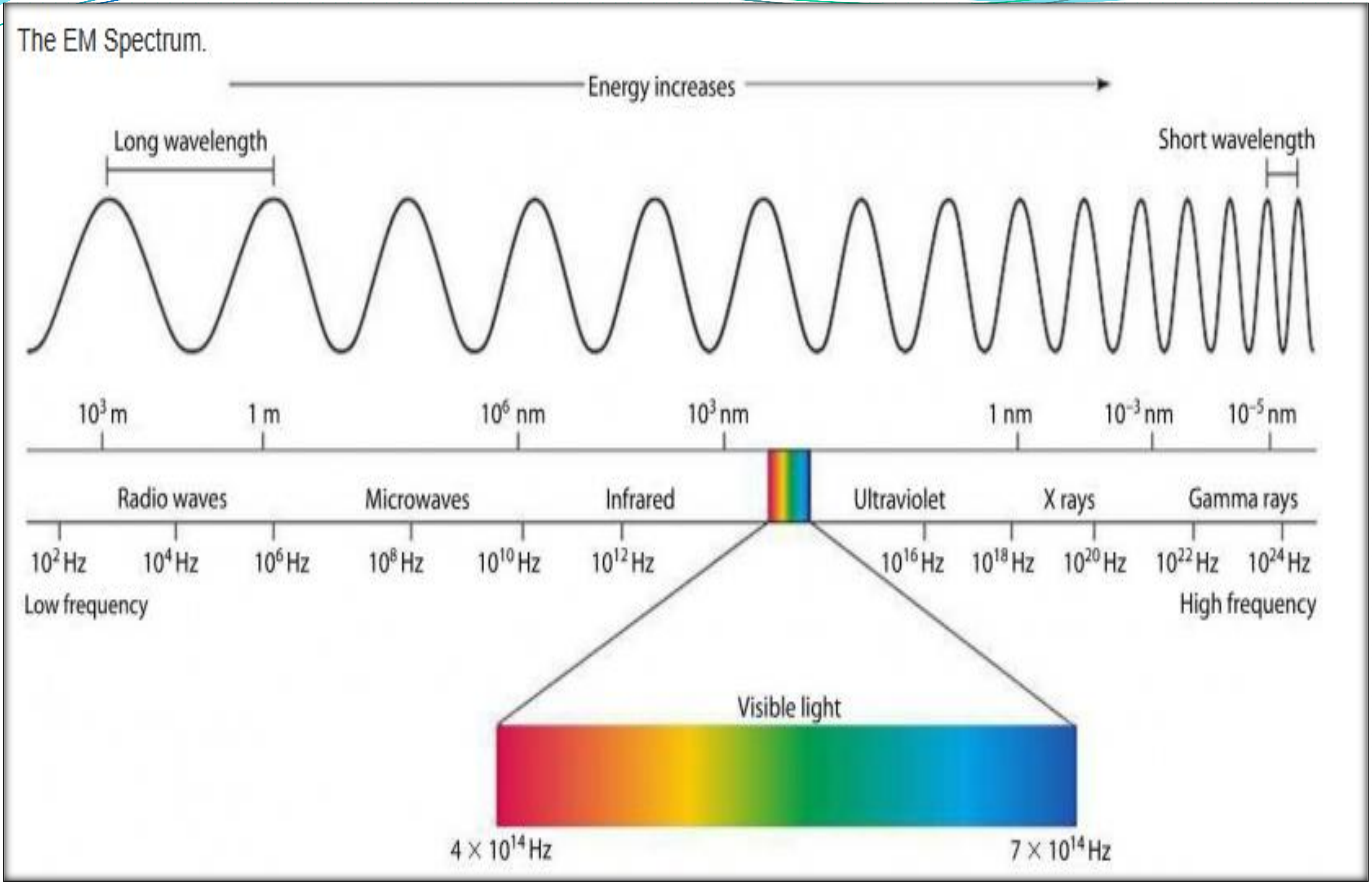

Figure 1: The electromagnetic spectrum.

The visible portion of the electromagnetic spectrum is the range of wavelengths that can be detected by the human eye as seen in (Fig. 2), typically from 380 to 700 nanometers. This range is commonly referred to as visible light and includes colors ranging from violet to red.

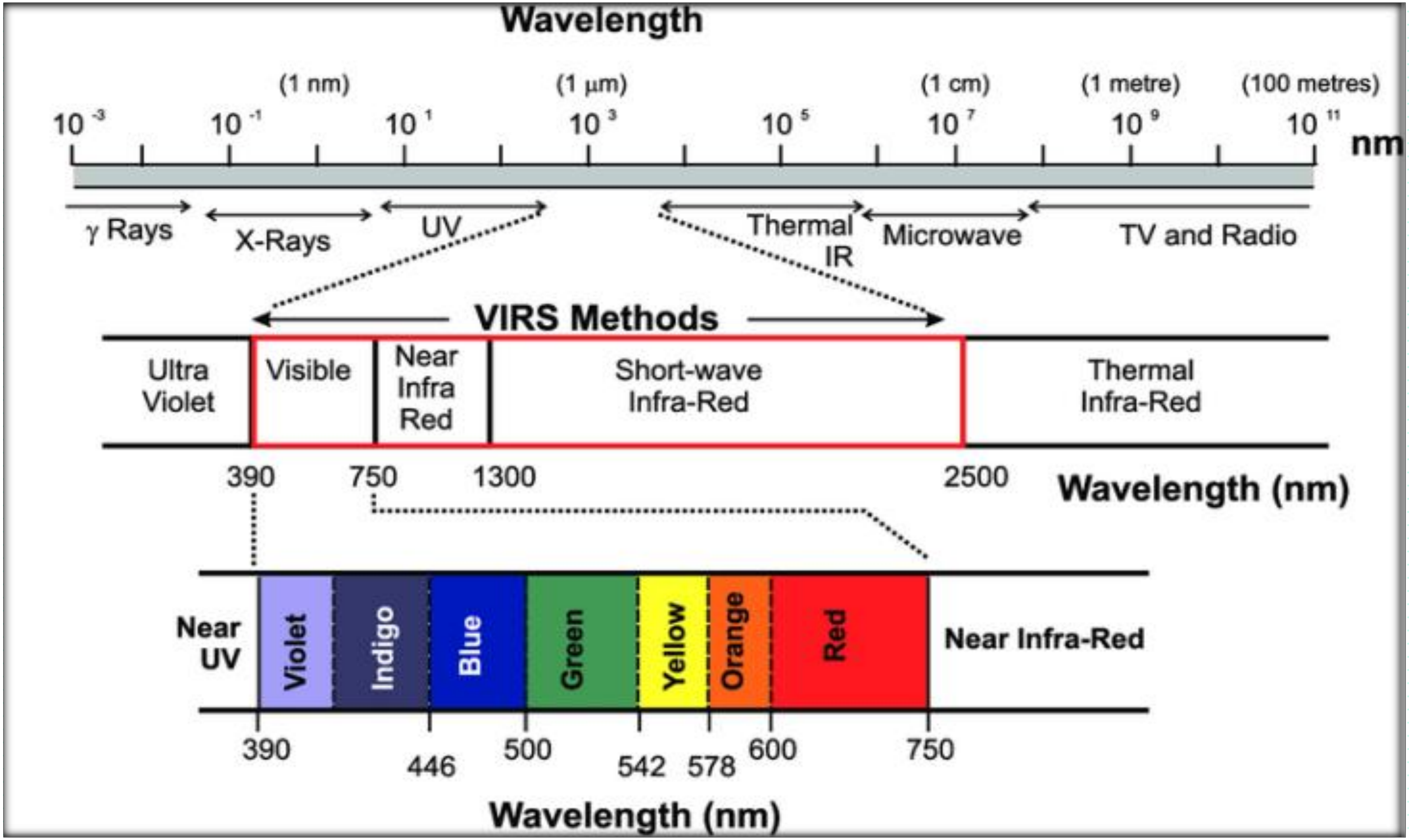

Figure 2: The visible portion of the electromagnetic spectrum.

The wavelengths associated with the colors seen by the eye are indicated in Fig. 2. The ordinary units of wavelength measure in the optical region are the angstrom (Å), where:

Angstrom (Å) (unit of length) = 10^{-10} m, or 0.1 nm.

2-Maxwell's equations:

Maxwell's equations, four equations that, together, form a complete description of the production and interrelation of electric and magnetic fields. The physicist James Clerk Maxwell, in the 19th century, based his description of electromagnetic fields on these four equations, which express experimental laws.

These equations are as follows:

1) Gauss's Law for Electricity (also known as Gauss's first law):

$$\nabla \cdot \mathbf{E} = \rho / \varepsilon_0$$

This equation states that the electric flux through any closed surface is equal to the total electric charge enclosed by that surface, where **E** represents the electric field, ρ is the charge density, and ε_0 is the vacuum permittivity.

2) Gauss's Law for Magnetism (also known as Gauss's second law):

$$\nabla \cdot \mathbf{B} = 0$$

This equation states that there are no magnetic monopoles; the total magnetic flux through any closed surface is zero, where **B** represents the magnetic field.

3) Faraday's Law of Electromagnetic Induction:

$$\nabla \times E = -\partial B/\partial t$$

This equation describes how a changing magnetic field produces an electric field, where **E** is the electric field and **B** is the magnetic field.

4) Ampère's Law with Maxwell's Addition:

$$\nabla \times \mathbf{B} = \boldsymbol{\mu}_0(\mathbf{J} + \boldsymbol{\varepsilon}_0\, \partial\mathbf{E}/\partial\mathbf{t})$$

This equation relates the circulation of the magnetic field around a closed loop to the electric current (**J**) and the rate of change of the electric field, where **B** is the magnetic field, $\boldsymbol{\mu}_0$ is the vacuum permeability, $\boldsymbol{\varepsilon}_0$ is the vacuum permittivity, **J** is the electric current density, and **E** is the electric field.

(free space) speed of light

$$c_0 = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = 3\times 10^8 \text{ m/s}$$

ε_0 = permittivity of free space

$$= \frac{1}{36\pi}\times 10^{-9} \text{ Farad/m} \qquad \text{(MKS)}$$

μ_0 = permeability of free space

$$= 4\pi\times 10^{-7} \text{ Henry/m} \qquad \text{(MKS)}$$

$$\varepsilon_0 \mu_0 {c_0}^2 = 1$$

3-Conservation law

A conservation law in physics is a fundamental principle that states that a certain physical quantity remains constant or is conserved over time in a closed system. These laws describe the behavior of various physical quantities and are fundamental to our understanding of how the physical world works.

Some of the most well-known conservation laws include:

1. **Conservation of Energy**
2. **Conservation of Linear Momentum**
3. **Conservation of Angular Momentum**
4. **Conservation of Electric Charge**
5. **Conservation of Mass:** In classical mechanics, this law states that the total mass of an isolated system remains constant. However, in modern physics, due to Einstein's theory of relativity, mass and energy are related by $\mathbf{E=mc^2}$, which means that mass can be converted into energy and vice versa, but the total mass-energy remains conserved.


Thank you