wave model of visible light

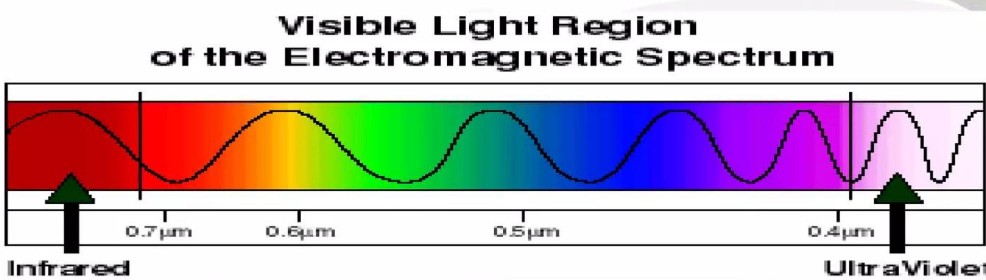
The wave model of visible light is a representation of light as an electromagnetic wave. This model describes light as a form of electromagnetic radiation, which includes a range of wavelengths that are visible to the human eye. Visible light is just a small portion of the electromagnetic spectrum, sandwiched between ultraviolet (shorter wavelengths) and infrared (longer wavelengths).
Light is the form of energy which makes object visible to our eyes. Light has dual nature particle as well wave nature. There were two theories proposed to discuss nature of light.

1) **Particle Theory:** This theory, sometimes referred to as the corpuscular theory, proposes that light is composed of tiny, discrete particles or "corpuscles." This view was championed by Sir Isaac Newton, who believed that light was made up of particles emitted by a light source. However, Newton's corpuscular theory faced challenges in explaining certain optical phenomena, such as interference and diffraction, which the wave theory could explain more effectively. This theory was unable to explain the interference ,diffraction , polarization phenomena which leads to the wave theory of light.

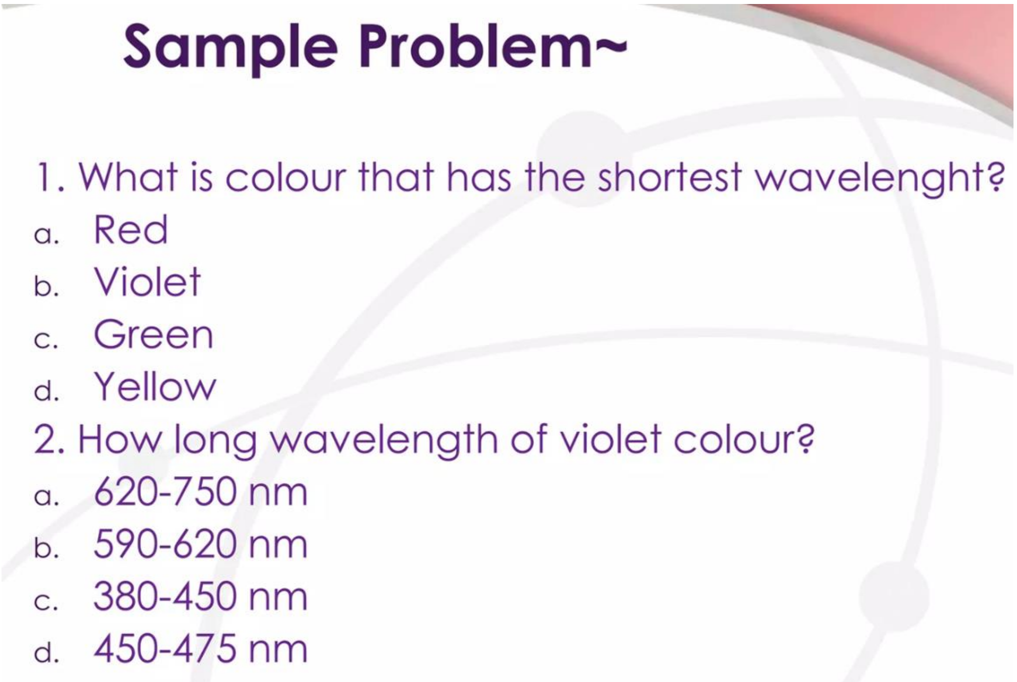
2) Wave Theory: This theory suggests that light behaves as a wave, similar to sound or water waves. According to this view, light propagates through space in the form of electromagnetic waves. This theory gained significant support with the work of scientists like Christian Huygens and later with the experiments of Thomas Young, who demonstrated interference patterns in light waves. The wave theory successfully explained various phenomena such as diffraction, interference, and polarization.
Later developments in physics, particularly with the advent of quantum mechanics in the early 20th century, led to the understanding that light exhibits both wave-like and particle-like properties. This duality is encapsulated in the concept of wave-particle duality, which asserts that

particles, such as photons (the quanta of light), can exhibit both wave-like and particle-like behavior depending on the experimental setup. This understanding reconciled many of the apparent contradictions between the wave and particle theories of light. The human eye has three types of light-sensitive cells that detect red, green, and blue light, respectively. Because of this, the colors red, green, and blue are known as primary colors.

Color Wavelength



Color	Frequency	Wavelength
violet	668–789 THz	380–450 nm
blue	631–668 THz	450–475 nm
cyan	606–630 THz	476–495 nm
green	526–606 THz	495–570 nm
yellow	508–526 THz	570–590 nm
orange	484–508 THz	590–620 nm
red	400–484 THz	620–750 nm



Particle Model: Quantum Theory

Quantum theory, a fundamental theory in physics, describes the behavior of matter and energy at the smallest scales, such as the atomic and subatomic levels. In this framework, matter and energy exhibit both particle-like and wave-like properties, challenging the classical Newtonian view of physics

Matter and Energy

The quantum theory of matter assumes that matter has two natures: a particle nature and a wave nature. The particle nature is described by classical physics (Newton's laws), and the wave nature is described by quantum physics. This is similar to light, which has both a wave and particle nature. The wave nature is described by the classical Maxwell's equations, whereas the particle nature is described by the quantum physics.

In the quantum theory, the concept of mass-energy equivalence, as described by Einstein's famous equation $E=mC^2$, still holds true.
Mass and energy are interchangeable, and particles can be created or annihilated in particle-antiparticle pairs as long as the total energy and other conserved quantities (like charge) are preserved.

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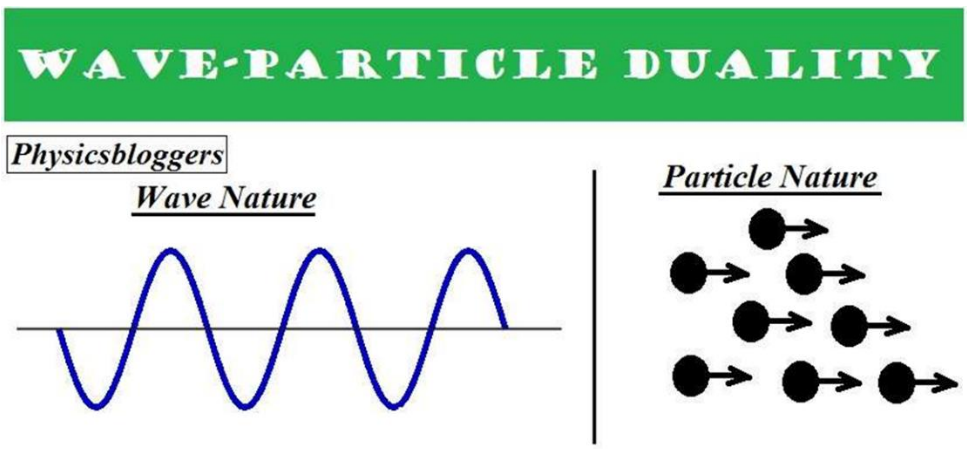


Waves are described by their wavelength l
and particles are described by their momentum, P

We can relate these two variables
by quantum theory
$E=h\nu=hc/\lambda$
$E=mc^2=pc$
$p=h/\lambda$

Interactions of photons with matter:

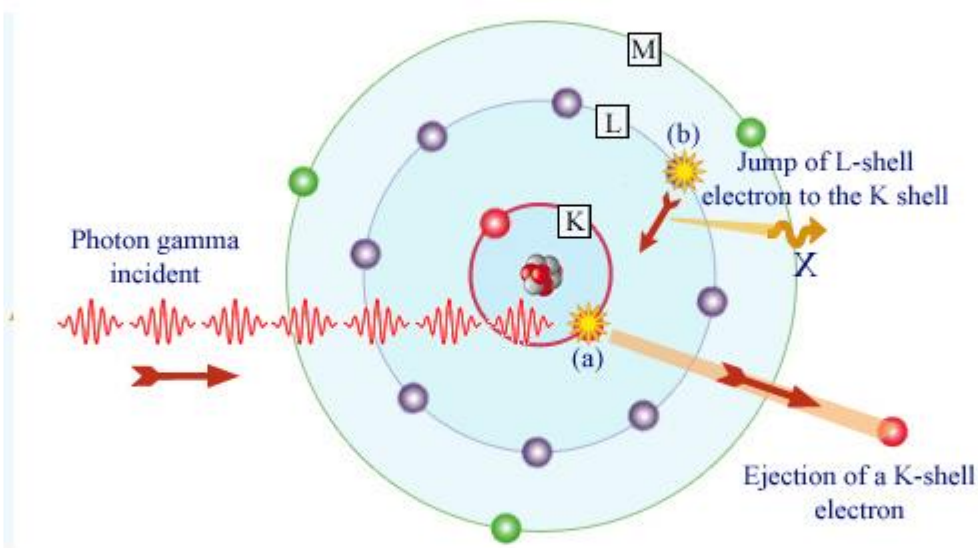
Photons are electromagnetic radiation with zero mass, zero charge, and a velocity that is always c, the speed of light. Because they are electrically neutral, they do not steadily lose energy via coulombic interactions with atomic electrons, as do charged particles.

Our main reason for doing this is to find out what happens to the radiation as it passes through matter and also to set ourselves up for considering how it interacts with living tissue and understand the chain of events leading to radiation injury. This knowledge also forms the bases of radiation therapy and diagnostic radiology. The main processes of interaction of photons with matter are the following: Photoelectric absorption, • Compton scattering, • Pair production,

Mechanisms of Energy Loss: Photoelectric Effect

Photoelectric effect: Occurs when an x-ray interacts with an electron in the matter. The photon is completely absorbed and its energy is transferred to an electron that is removed from the electron cloud. In photo electric effect K-shell electron is favored because of the high electron cloud density in the K-shell.

- Each photon has an energy E given by Planck's equation: $E=h\nu$, where h is Planck's constant (6.626×10^{-34} Js) and f is the frequency of the light.

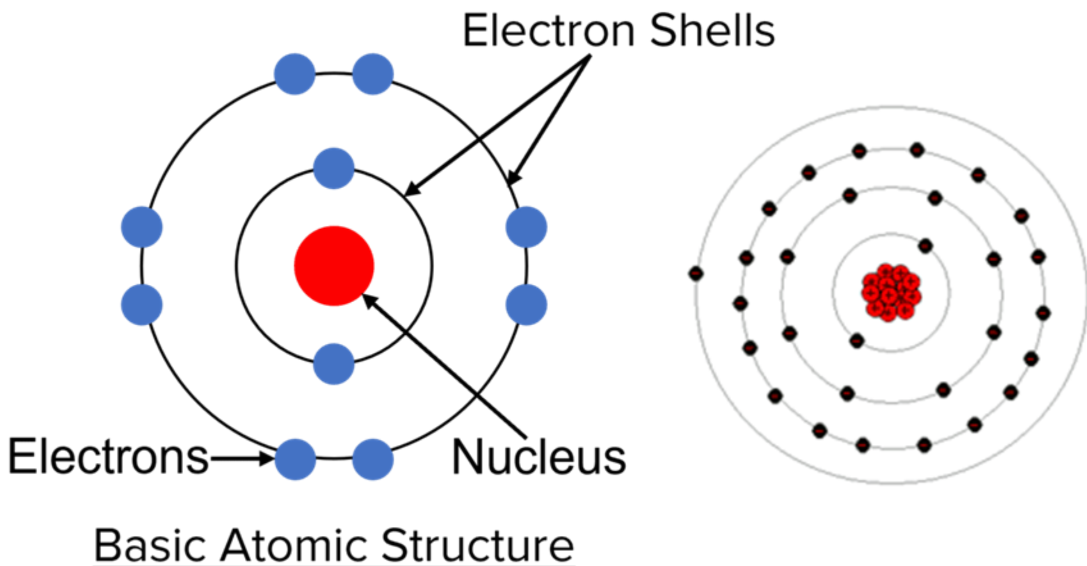


The relationship may also be written in the equivalent form $E = hc/\lambda$, where c is the speed of light and λ is its wavelength,

photoelectric equation $E_k = hf - \phi$, where E_k is the maximum kinetic energy of the ejected electron.

- For the photoelectric effect to occur, the energy of the photon must be greater than or equal to the work function (ϕ) of the material. The work function is the minimum energy needed to eject an electron from the material. If the photon's energy exceeds the work function, the excess energy is transferred to the electron as kinetic energy, causing it to be emitted from the material's surface.

Generally, low atomic number materials Z exhibit a weaker photoelectric effect compared to high atomic number materials.



Ex: A piece of metal has a work function (ϕ) of 2.5 eV. Light with a wavelength of 400 nm is shone on the metal. Determine whether photoelectric emission will occur and, if it does, calculate the maximum kinetic energy of the emitted electrons.

Determine the energy of the incident photons:

The energy (E) of a photon can be calculated using the equation:

$E = hc/\lambda$

where:

• h is Planck's constant (6.626×10^{-34} Js)

• c is the speed of light (3.0×10^{8} m/s)

$$E = \frac{6.626\times10^{-34} Js \times 3\times10^{8} m/s}{400\times10^{-9} m} = 4.97\times10^{-19} J$$

To convert from Joules(J) to electron volt(eV): divided $[J \div (1.6 \times \frac{10^{-19} J}{eV})]$

$$E = \frac{4.97\times10^{-19} J}{1.6\times10^{-19} J/eV} \approx 3.1 eV$$

1.Calculate the maximum kinetic energy (K.E.) of the emitted electrons: The maximum kinetic energy of the emitted electrons can be found using the photoelectric equation:

$$E_K = E_{Photon} - \phi = 3.1eV - 2.5eV = 0.6eV$$