Light as a Wave
Chapter 10
Light as a Wave

Light is like an ocean wave. It travels through space.

- **Wavelength**: The distance traveled by light in one cycle.
- **Frequency**: The completed number of wave cycles each second.
- **Speed of light**: $3.00 \times 10^8 \text{ m/s}$.
Wavelength vs. Frequency

- The longer the wavelength of light, the lower the frequency.
- The shorter the wavelength of light, the higher the frequency.
Cont’d...Light as a Wave

Wavelength (\(\lambda\)):
- the **distance** between 2 similar points on a wave
- measured in meters or nanometers,
  \(1\text{nm} = 10^{-9} \text{m}\)

Frequency (\(\nu\)):
- # of peaks of a wave that pass a set point in 1 second
- Measured in peaks/s, \(\text{s}^{-1} = \text{Hz}\) (Hertz)
- Depends on:
  1) How far apart the peaks are \(\rightarrow \lambda\)
     \(\uparrow \lambda, \downarrow \nu\)
  2) How fast the wave is traveling \(\rightarrow c\)
     \(\uparrow c, \uparrow \nu\)
     \(c = \text{speed of light in a vacuum}; \text{constant}\)
     \(c = 3.00 \times 10^8 \text{m/s}\)

\[\nu = \frac{c}{\lambda} \Rightarrow c = \lambda \nu\]
Light as a Particle

Planck’s Quantum Theory:

Molecules and atoms emit and absorb energy ONLY in DEFINITE quantities.

Quantum = smallest amount of energy that can be emitted or absorbed in the form of electromagnetic radiation (EMR)

This energy is defined as:

\[ E = h\nu \]

\( h \) = Planck’s constant

\[ 6.626 \times 10^{-34} \text{ J} \cdot \text{s}, \]

\( \nu \) = frequency

a photon = A quantum of light energy
Problem:
What is the energy of a single photon of green light $(\lambda = 532\text{nm})$?
Visible Spectrum

• The radiant energy that is visible to the human eye is usually called light.

• This visible region has a range of wavelengths from 400 and 700 nm and called the visible spectrum.

• A human eye can not see the radiant energy that has a wavelength lower than 400 nm and greater than 700 nm.
The radiant energy spectrum includes most types of radiation, visible or invisible to the human eye.
Dual Nature of Light: Wave and Particle

In 1900, Max Planck: Proposes that radiant energy is not continuous, but is emitted in small bundles (quantum concept).

Radiant energy has both a wave nature and a particle nature.
The quantum concept states that energy is present in small, discrete bundles.

For example:

- A tennis ball that rolls down a ramp loses potential energy continuously.
- A tennis ball that rolls down a staircase loses potential energy in small bundles. The loss is quantized.
Bohr Model of the Atom

Bohr speculates that electrons orbit around the nucleus in fixed energy levels. Electrons can only exist in specific energy levels. The electron energy levels are quantized.
Cont’d…Bohr’s Atomic Model

Electrons exist in specific energy levels and can ONLY move from one level to another by gaining or losing a specific amount (quantum) of energy.

= electron

Energy emitted as an excited electron moves to lower energy levels

Energy absorbed as electron moves to higher energy levels - resulting in an excited state
Emission Line Spectra

- If electrical voltage passes through a gas in a sealed tube, you will see a series of narrow lines.

- These lines are called emission lines. The entire series of lines will be called as emission line spectrum.

- The emission line spectrum for hydrogen gas shows three lines: 434 nm, 486 nm, and 656 nm.
Evidence for Energy Levels

Bohr came up with an experimental evidence but still needed to prove his theory.

Electron gets temporarily excited to a higher orbit by the electric charge. When the electron drops back down, a photon is given off.

The red line shows the least energetic radiation and corresponds to an electron dropping from energy level 3 to 2.
Continuous Spectrum

Continuous spectrum: An uninterrupted band, complete radiant energy spectrum.
Atomic Fingerprints

Each element has a unique emission line spectrum, like a fingerprint.
Review

• Light has dual property: waves and particles.

• The particles of light are referred to as photons.

• The energy of photons is quantized.

• Electrons exist around the nucleus of atoms in discrete, quantized energy levels.

• Electrons can be excited to higher levels.

• Photons are emitted as electrons drop to lower levels.