# *Quantum Mechanics*

*Fourth Lecture*

# ***Wave Function***

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## 1. *what is wave?*

- A wave is a disturbance in a medium that carries energy without a net movement of particles. It may take the form of elastic deformation, a variation of pressure, electric or magnetic intensity, electric potential, or temperature.
- There are some basic descriptors of a wave. ***Properties of Waves***

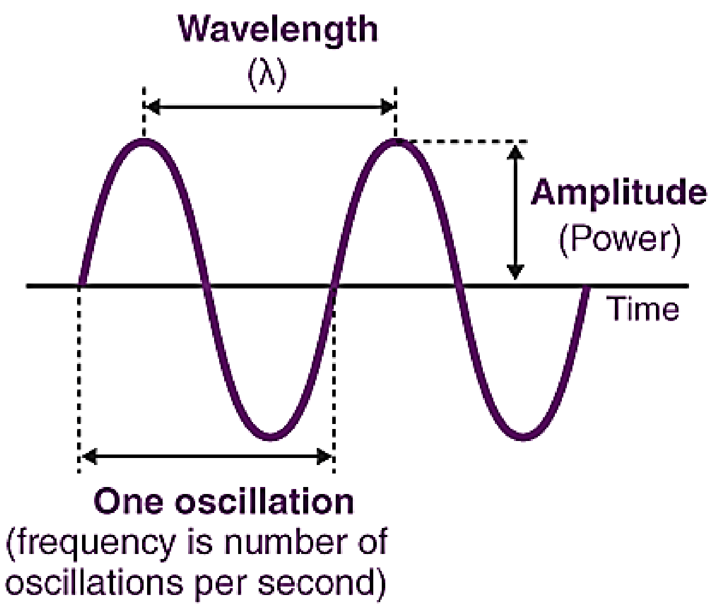
  ***1. Wavelength:*** is the distance between two successive identical parts of the wave.

  ***2. Amplitude:*** is the maximum displacement from the neutral position. This represents the energy of the wave. Greater amplitude carries greater energy.

  ***3. Displacement***: is the position of a particular point in the medium as it moves as the wave passes. Maximum displacement is the amplitude of the wave

  ***4. Frequency (f)***: is the number of repetitions per second in Hz, Period (T) is the time for one wavelength to pass a point.

  ***5. The velocity (v):*** of the wave is the speed at which a specific part of the wave passes a point. The speed of a light wave is c.



## 2. Types of Waves:

***a. Transverse Waves:*** Waves in which the medium moves at right angles to the direction of the wave.

**Examples of transverse waves:**

- Water waves (ripples of gravity waves, not sound through water)
- Light waves
- S-wave earthquake waves
- Stringed instruments
- Torsion wave

The high point of a transverse wave is a crest. The low part is a trough.

***b. Longitudinal Wave:*** A longitudinal wave has the movement of the particles in the medium in the same dimension as the direction of movement of the wave.

**Examples of longitudinal waves:**

- Sound waves
- P-type earthquake waves
- Compression wave

**Parts of longitudinal waves**:

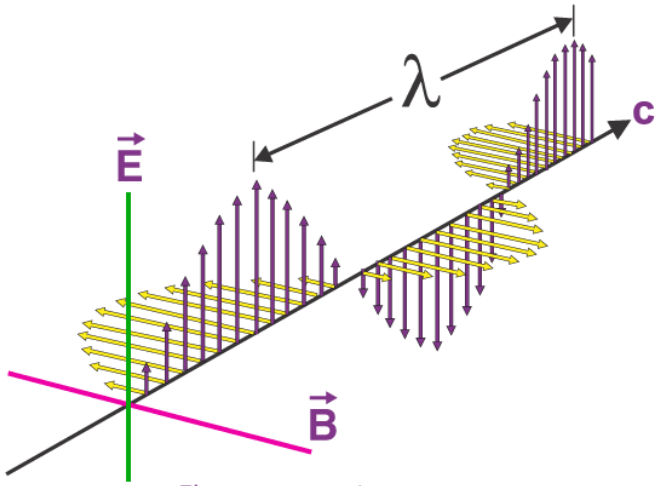
Compression: where the particles are close together.

Rarefaction: where the particles are spread apart.

***c. Mechanical waves:*** A wave which needs a medium in order to propagate itself. Sound waves, waves in a slinky, and water waves are all examples of this.

***d. Matter Waves:*** Any moving object can be described as a wave When a stone is dropped into a pond, the water is disturbed from its equilibrium positions as the wave passes; it returns to its equilibrium position after the wave has passed.

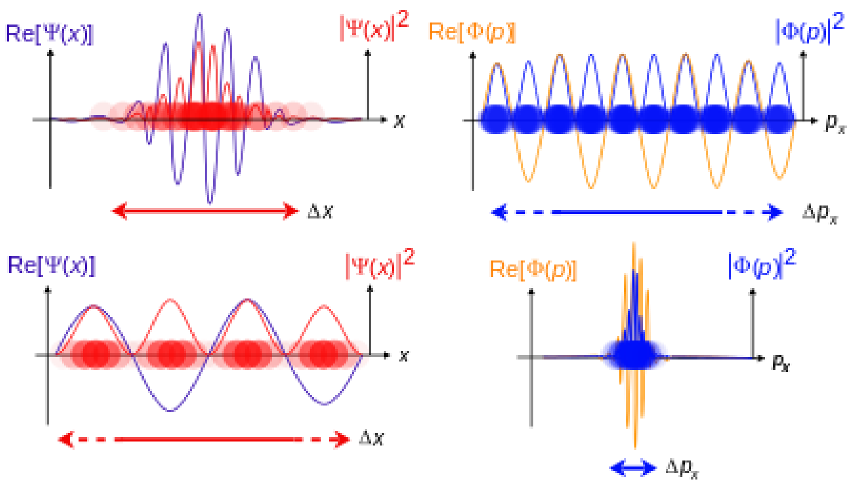
***e. Electromagnetic Waves:*** These waves are disturbance that does not need any object medium for propagation and can easily travel through the vacuum. They are produced due to various magnetic and electric fields. The periodic changes that take place in magnetic and electric fields and therefore known as electromagnetic Wave.



Electromagnetic wave

## 3. *Wave Function*

- A wave function, in quantum physics, refers to a mathematical description of a particle's quantum state as a function of spin, time, momentum, and position.
- Moreover, it is a function of the degrees of freedom that correspond to a maximal set of commuting observables. Furthermore, psi, **Ψ**, is the wave function symbol.



## The equation of Wave Function

$$\Psi(x, t) = A\, e^{i(kx-\omega t)}$$

## Properties of Wave Function

- All measurable information about the particle is available.
- Wave function should be continuous and single-valued.
- Using the Schrodinger equation, energy calculations becomes easy.
- Probability distribution in three dimensions is established using the wave function.
- The probability of finding a particle if it exists is 1.

***Q: Wave function should be***

- Continuous
- single-valued
- Non-continuous
- Option 1 and 2

***Q: A wave equation y = f(x-vt) represents a wave travelling in***

- +X axis
- +Y axis
- -X axis
- -Y axis

## 4. Probability Density of Wave Function

- The wave function represents the probability amplitude for finding a particle at a given point in space at a given time.
- The product of the wave function, Ψ(x, t), and its complex conjugate, Ψ∗ (x, t), is the probability density for the position of a particle in one dimension, i.e., $|\Psi(x, t)|^2\, dx$ yields the probability of finding a particle

described by the wave function, Ψ(x, t), in an infinitesimal element dx around x at a time t.

- More explicitly, this is the probability that when measurements of the position are made on independent, identically prepared particles each of which is described by the wave function Ψ(x, t), the result lies between x and x + dx.
- In three dimensions, the wave function Ψ(r, t) determines the probability density: $|\Psi(r, t)|^2$ dxdydz is the probability of finding a particle in an infinitesimal volume element dxdydz around r.

$$\Psi(x,t) = \text{single-valued probability amplitude at } (x,t)$$

$$\Psi^*(x,t)\Psi(x,t) = \text{probability of finding particle at } x \text{ at time } t \text{ provided the wavefunction is normalized.}$$

***Q: what is the difference between Ψ and $[\Psi]^2$?***

ψ is a wave function and refers to the amplitude of electron wave i.e. probability amplitude. It has got no physical significance. The wave function ψ may be positive, negative or imaginary.

$[\psi]^2$ is known as probability density and determines the probability of finding an electron at a point within the atom.