(U1)Lecture 1: Introduction of Quantum Mechanics, Debroglie concept of Matter waves

The optical phenomenon, such as interference, diffraction and polarization of light could be explained by wave theory of light; whereas photoelectric effect or Compton Effect of light could only be explained if we consider the light as particle. Hence light shows itself wave nature at one end while particle nature on the other hand.

This nature of light is known as dual nature and the property is known as wave particle duality.

In 1924 Louis de-Broglie proposed that the matter also possess dual character like light. His concept about the dual nature of matter was based on the following facts:

(i) Matter and light both are forms of energy and each of them can be transformed into the other.

(ii) Both are governed by the space time symmetries of the theory of the relativity.

According to Louis de-Broglie, a moving particle is surrounded by a wave whose wavelength depends upon the mass of the particle and its velocity. These waves associated with the matter particles are known as matter waves or de-Broglie waves.

De-Broglie provided a connection between, the wavelength of matter waves and momentum of the particle i.e. $\lambda = \frac{h}{p}$ (1)

Concept of matter waves

Louis de Broglie made the suggestion that particles of matter, like electrons, might possess wave properties and hence exhibit dual nature. His hypothesis was based on the following arguments:

The Planck's theory of radiation suggests that energy is quantized and is given by

$$E = h\nu \qquad (1)$$

where ν is the frequency associated with the radiation.

Einstein's mass-energy relation states that

$$E = mc^2 \qquad (2)$$

Combining the two equations, it can be written as

$$E = h\nu = mc^2$$

Hence, the momentum associated with the photon is given by

$$P = mc = h\nu/c = h/\lambda$$

Extending this to particles, he suggested that any particle having a momentum p is associated with a wave of wavelength given by

$$\lambda = h/p \qquad (3)$$

This is called **de Broglie's hypothesis** of matter waves and λ is called the de Broglie wavelength.

Properties of Matter-waves

1. Matter waves are associated with any moving body and their wavelength is given by $\lambda - \frac{h}{mv}$
2. The wavelength of matter-waves is inversely proportional to the velocity of the body. Hence, a body at rest has an infinite wavelength whereas the one traveling with a high velocity has a lower wavelength.
3. Wavelength of matter-waves depends on the mass of the body and decreases with increase in mass. Because of this, the wave-like behavior of heavier objects is not very evident whereas the wave nature of subatomic particles can be observed experimentally.
4. Amplitude of the matter-waves at a particular space and time depends on the probability of finding the particle at that space and time.
5. Unlike other waves, there is no physical quantity that varies periodically in the case of matter waves.
6. Matter waves are represented by a wave packet made up of a group of waves of slightly differing wavelengths. Hence, we talk of group velocity of matter waves rather than the phase velocity.
7. Matter-waves show similar properties as other waves such as interference and diffraction.