Government Engineering college, sheikhpura

MODULE 6: INTRODUCTION TO QUANTUM MECHANICS

WAVE NATURE OF PARTICLES

De-Broglie's hypothesis

From previous concept We know that the phenomenon such as interference, diffraction, polarisation etc. can be explained only with the help of wave theory of light. While phenomenon such as photoelectric effect, Compton effect, spectrum of blackbody radiation can be explained only with the help of Quantum theory of radiation. Thus radiation is assumed to exhibit dual nature.i.e., both particle and wave nature.

In 1924, **Louis de-Broglie** made a hypothesis, which can be stated as follows **"If radiation which is basically a wave can exhibit particle nature under certain circumstances, and since nature likes symmetry, then entities which exhibit particle nature ordinarily, should also exhibit wave nature under suitable circumstances."**

Thus according to De-Broglie's hypothesis, there is wave associated with the moving particle. Such waves are called **Matter waves** and wavelength of the wave associated with the particle is called **De-Broglie wavelength.**

Expression for De-Broglie wavelength (from analogy)

We know that radiation consists of stream of particles called Photon. Energy of each photon is given by

$$E = h\nu = \frac{hc}{\lambda}$$

Where h = Plancks constant, ν is the frequency and λ is wavelength of the radiation. But according to Einsteins relativistic formula for energy of a particle

$$E^2 = P^2c^2 + m_0^2\,c^4$$

Where p is momentum of the particle and

m_0 is rest mass of the particle. For photon rest mass $m_0 = 0$.

Therefore $E = pc = hc / \lambda$

$P = h$

is the momentum of the photon.

De-Broglie proposed that the same equation is applicable for matter waves also.

Therefore, wavelength of the waves associated with the moving particle of mass **m** moving with the velocity **v** is given by

$$\lambda = \frac{h}{mv}$$

where the momentum is given by $p = mv$ and λ is the de Broglie wavelength.

De-Broglie wavelength of an electron accelerated by a potential difference of V volts:

Consider an electron accelerated by a potential difference of V volts Kinetic energy gained by the electron is given by

$$E = eV = \frac{1}{2} mv^2$$

$$\Rightarrow V^2 = 2E/m$$

$$\Rightarrow V = \sqrt{2E/m}$$

$$\text{While } \lambda = \frac{h}{mv}$$

$$\therefore \lambda = h / m (\sqrt{2E/m})$$

$$\therefore \lambda = h/(\sqrt{2Em} = h/(\sqrt{2eVm})$$

substituting the value of *h, m,* and *e*

we get $\lambda = 1{:}226 / \sqrt{V}$

Properties of Matter waves

Following are some of the important properties of matter waves:

1. Matter waves are waves associated with the moving particle
2. They are not electro magnetic in nature
3. Wavelength of the matter wave is given by $\lambda = \frac{h}{mv}$
4. The amplitude of the matter wave at the given point determines the probability of finding the particle at that point at the given instant of time.
5. There is no meaning for Phase velocity in case of matter waves. Only group velocity has meaning.

Try Your self :

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1. State De-Broglie hypothesis and the conceptual reasoning on which it is based
2. What are matter waves? Show that the electron accelerated by a potential difference V volts has

$$\lambda = 1{:}226 / \sqrt{V}$$

3. Calculate the kinetic energy of an electron whose de-Broglie wavelength is equal to that of a 10*keV* photon.
4. Calculate the de-Broglie wavelength of an electron accelerated through a potential of 120 Volts.
5. Calculate the de-Broglie wavelength of a 0:3 kg cricket ball with a speed of 120*km/hr*.
6. A particle of mass $0{:}5 MeV/C2$ has kinetic energy $100eV$. Find its de-Broglie wavelength,where C is the velocity of light.
7. Calculate the de-Broglie wavelength associated with 400gm cricket ball with a speed of 90 Km/hr.
8. Compare the energy of a photon with that of an electron when both are associated with length of 0:2 nm