Wave Mechanics- De Broglie's Equation

The matter is a particle and also a wave. In 1920, a young physicist named Louis de Broglie made a radical suggestion that since light has both a particle and wave nature then matter has a wave nature too. Now, that's something very difficult to wrap your head around. In this article, we will learn about the wave nature of the matter.

Table of Contents

Wave Nature of Matter

The wave nature of matter is one of the most counter-intuitive concepts in Physics. You have seen examples of both the particle nature of light and the wave nature of light. You know about the Photoelectric effect due to Albert Einstein's courtesy.
In the photoelectric effect, the electrons and photons exhibit the properties of a particle, just like a billiard ball. But you surely remember the Diffraction experiment and the Interference Rings.
Just like how two ripples on the surface of a pond interact. We see the wave nature of light in these cases. It's an amazing mystery. It even involves our sight! The gathering and focusing mechanism of light by the eye-lens conform to the wave nature of light. But its absorption by the rods and cones of the retina conforms to the particle nature of light! While we were still struggling to understand this mystery, along came Louis de Broglie to make it even more complicated with his de Broglie Relation.

De Broglie's Equation

De Broglie's hypothesis stated that there is symmetry in nature and that if light and radiation behave as both particles and waves, matter too will have both the particle and wave nature. Through de Broglie's relationship, we now had a wave theory of matter. The 'Lambda (λ)' here represents the wavelength of the particle and 'p' represents the momentum of the particle. Here h is Planck's constant, m is the mass and v is the velocity of the particle. The significance of the de Broglie relationship is that it proved mathematically that matter can behave as a wave. In layman's terms, the de Broglie equation says that every moving particle – microscopic or macroscopic –has its own wavelength.
For microscopic objects, the wave nature of matter is observable.
For larger objects, the wavelength gets smaller with the increasing size of the object, quickly becoming so small as to become unnoticeable which is why macroscopic objects in real life

don’t show wave-like properties. Even the cricket ball you throw has a wavelength that is too small for you to observe. The wavelength and the momentum in the equation are connected by the Planck’s constant.

Heisenberg’s Uncertainty

The Davisson-Germer experiment proved beyond doubt the wave nature of matter by diffracting electrons through a crystal. In 1929, de Broglie was awarded the Nobel Prize for his matter wave theory and for opening up a whole new field of Quantum Physics. The matter-wave theory was gracefully incorporated by Heisenberg’s Uncertainty Principle. The Uncertainty Principle states that for an electron or any other particle, both the momentum and position cannot be known accurately at the same time. There is always some uncertainty with either the position ‘delta x’ or with the momentum, ‘delta p’.

Heisenberg’s Uncertainty Equation:

Say you measure the momentum of the particle accurately so that ‘delta p (Δp)’ is zero. To satisfy the equation above, the uncertainty in the position of the particle, ‘delta x (Δx)’ has to be infinite. From de Broglie’s equation, we know that a particle with a definite momentum has a definite wavelength ‘Lambda’. A definite wavelength extends all over space all the way to infinity. By Born’s Probability Interpretation this means that the particle is not localized in space and therefore the uncertainty of position becomes infinite.

In real life though, the wavelengths have a finite boundary and are not infinite and thus both the position and momentum uncertainties have a finite value. De Broglie’s equation and Heisenberg’s Uncertainty Principle are apples of the same tree.

Frequently Asked Questions – FAQs

Q1

What is de Broglie Equation?

De Broglie Equation is used to define the wave properties of matter. De Broglie Equation defines the wave nature of the electron..

Q2

What is the formula to find the de Broglie wavelength?

The de Broglie Wavelength formula is given by:

Q3

Give the Heisenberg’s Uncertainty Equation.

Heisenberg’s Uncertainty Equation is given by
Q4

State true or false: de Broglie was awarded the Nobel Prize for his matter wave theory.

True.
Q5

Does microscopic particle-like electrons possess dual nature property.?

Yes, microscopic particle-like electrons possess dual nature property.