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Single nature of matter: No wave is associated with material particle

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ABSTRACT

According to de-Broglie, a moving material particle can be associated with a wave. In other word, a wave can guide the motion of a particle. He derived the wavelength of moving particle as $\lambda = \frac{h}{mv}$, by considering $E = h\nu = \hbar\omega = mc^2$. But mc^2 is the total energy of particle and $h\nu$ only denotes kinetic energy of particle. So how can we equate total mass energy with kinetic energy. The relation $E = h\nu = \hbar\omega = mc^2$ works only for photon, as the rest mass of photon is zero, but not for material particle. So the relation $\lambda = \frac{h}{mv}$ is not correct. According to Arthur Beiser, shobhit Mahajani the wave associated with particles are mathematical constructs. It does not describe the space time variation of any measurable quantity like displacement or any characteristic present in a medium. Wave picture given by Schrödinger equation represent the curve of probabilities of the entities to be at various phases away from the most probable phases of different point of time. The waves are here represented by a kind of graphical picture of probabilities for the entities to be in certain phases. They do not represent the real wave picture of moving electrons or photon.

Keyword: Wavelength; Frequency; Rest mass; energy; Photon.

1. INTRODUCTION

De-Broglie Waves

A moving body behaves in certain ways as though it has a wave nature.

According to Planck and Einstein, if E is the energy associated with the photon and ν the frequency associated with it, they are related as

$$E = h\nu$$

On the particle character energy is given

$$E^2 = p^2c^2 + m_0^2c^4$$

As the rest mass of Photon is zero, so from above equation

$$E = pc$$

$$p = \frac{E}{c} = \frac{h\nu}{c}$$

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

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

This is the wavelength of photon.

Louis de-Broglie argued that the wave character is also associated with all particles in motion and the wave length and frequency associated with them are given by

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

$$\& \ \nu = \frac{E}{h} = \frac{mc^2}{h}$$

De-Broglie phase velocity:-

$$u = \lambda\nu = \frac{mc^2}{h} \times \frac{h}{mv} = \frac{c^2}{v}$$

Because the particle velocity v must be less than the velocity of light c, the de-Broglie waves always travel faster than light. The de Broglie wave group associated with a moving body travels with the same velocity as the body. So the above unexpected result has been resolved.

Proof of De-Broglie wave length

Let us consider a particle say electron moving with velocity v has energy

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

$$\hbar\omega = (p^2c^2 + m_0^2c^4)^{\frac{1}{2}}$$

$$\hbar\frac{d\omega}{dk} = \frac{1}{2}(p^2c^2 + m_0^2c^4)^{\frac{-1}{2}}(2pc^2\frac{dp}{dk})$$

$$\hbar\frac{d\omega}{dk} = \frac{pc^2}{mc^2}\frac{dp}{dk} = \frac{p}{m}\frac{dp}{dk}$$

Hence $\hbar dk = dp$,

integrating we get,

$$p = \hbar k = \frac{h}{2\pi}k = \frac{h}{\lambda}$$

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

This is the expression of de-Broglie wavelength.

2. NO WAVES IS ASSOCIATED WITH A MATERIAL PARTICLE

According to Planck and Einstein, if E is the energy associated with the photon and ν the frequency associated with it, they are related as

$$E = h\nu$$

On particle character alone energy E is given by

$E^2 = p^2c^2 + m_0^2c^4$

As the rest mass of photon is zero

$$E = pc$$
$$p = \frac{h\nu}{c}$$
$$p = \frac{h}{\lambda}$$
$$\lambda = \frac{h}{p}$$

But rest mass of electron is not zero, so for electron we never write E = pc = mvc, so for electron

$$p \neq \frac{h\nu}{c}$$
$$\text{Again} \frac{\nu}{c} \neq \frac{1}{\lambda}$$

As ν is the assumed frequency of electron and c is the velocity of light.

2.1. Why $E = h\nu \neq mc^2$ for particle?

The relation E = hν can only be used when the vibration kinetic energy of body is converted into energy of photon, in other cases we cannot use this relation. We can only use $E = h\nu = mc^2$ for photon or as equivalence relation for particle.

For example:

a) If proton and electron vibrate with same frequency, then their kinetic energy will be same (velocity of electron will more than proton). According to Planck they emit photon of same energy. So hν is independent of mass, it only depends on vibration kinetic energy of particle. We cannot compare hν with total mass energy. Proton and electron vibrate with same frequency cannot be equated with total energy. If for logic we consider

$$h\nu_e = m_e c^2$$
$$h\nu_p = m_p c^2$$

Since the frequency of electron and proton are same, according to de- Broglie, their total energies will also be same.

Then, $m_{oe}c^2 + p_e{}^2c^2 = m_{op}c^2 + p_p{}^2c^2$

Since kinetic energy of proton and electron are same and $p^2 = 2mE_k$

So p^2 is directly proportional to mass. Since the mass of proton is more than electron, so in this case

$$m_p c^2 > m_e c^2$$

So we cannot equate hν with mc^2. But de- Broglie has considered, ν_e not as frequency of electron, but frequency of electron wave and equated Planck's energy with total mass energy. But Planck's energy cannot be equated with total mass-energy as per Planck's, this will only possible if total mass will converted into energy.

If we write $E = h\nu = mc^2$ for electron, then for equivalence it is ok, but here ν is not the frequency of electron, when the mass-energy of electron will completely converted into photon, then the energy of photon will be hν and ν will be considered as frequency of photon. If we consider ν as frequency of electron wave, then $\nu = \frac{mc^2}{h}$. For vibrating with this frequency it requires energy equal to mc^2, so particle character of electron will not exist after one second.

b) In de-Broglie hypothesis, we are taking frequency in terms of energy, not in the terms of oscillation of waves per second, but taking wavelength as distance between two consecutive crests or troughs. In the relation E = hν, ν is not the frequency of vibration of photon, it is the frequency of oscillator which when vibrates with frequency ν, emits a photon of energy E = hν. Actually photon frequency and light frequency are not same. In case of hydrogen atom of first orbit, de- Broglie has considered 2πr = λ, which is circumference of circle. Again u = λν, which he considered as phase velocity is numerically equal to electron velocity (v) in Bohr's first orbit. Since $v = \frac{2\pi r}{T}$ which is also numerically = λν. Here there are no unexpected results (u = v) on considering Broglie's hypothesis also. So if we consider frequency in terms of energy then only unexpected results arise. So in the relation E = hν, ν is not the frequency of particle wave, it is only the energy term of the particle.

c) According to waves optics, the velocity of light wave decreases due to decrease in wavelength when enters in denser medium. If this is true then according to Quantum Mechanics ($\lambda = \frac{h}{p} = \frac{h}{mv}$), velocity of electromagnetic particle (photon) in the denser medium will increase, that is v > c. But this is not true because the velocity of photon inside denser medium is c. So $\lambda = \frac{h}{p} = \frac{h}{mv}$ is not correct relation. In the denser medium photon takes longer time to move through the medium because they are being absorbed and re-emitted. In other words, the energy of each photon is always E = hν = $\frac{hc}{\lambda}$ for a given wavelength.

d) When the electron revolves in stationary orbit, then also total energy of electron cannot be equated with hν because in this case electron not radiates energy. When electron jumps or vibrate from higher energy level to lower energy level, then it emits a photon of energy E = hν. If ν is not the Planck's frequency of electron in stationary orbit, then how $\lambda = \frac{h}{p} = \frac{h}{mv}$ will be the wavelength of electron in stationary orbit. Whether we can compare revolving electron as standing wave system?

e) If we write E = hν = mc^2, then we have to think that whether there is a relation between mass and frequency, since h and c are constant? Frequency is independent of mass, when mass will completely converted into energy, and then only we can write mass and energy are dependent. When electron moves in free space then it is not converted into photon and again back to electron.

f) What Planck's showed that, when oscillator vibrates with frequency ν it emits a photon of energy hν. In that case hν can be never equated with E = mc^2. Planck's showed that only a part of energy of oscillators is converted into energy of photon which is equal to hν.

g) In case of cyclotron, keeping the frequency of charge particle constant, we can gradually increases the energy of charge particle up to a maximum value. So in this case we cannot use the relation E = hν or hν ≠ energy of charge particle in cyclotron. There is no relation between frequency and energy of charge particle in cyclotron.

h) If ν is the frequency of electron wave and electron wave has energy E = hν = mc^2 then what is the energy of electron. Total energy of electron wave system will be equal to hν + mc^2. Since electron will be always inside the wave packet.

i) According to David J. Griffiths, a wave is a disturbance of a continuous medium that propagates with fixed shape at constant velocity. Neither the velocity of electron wave is continuous nor does it have definite shape. What is electron wave made up of? What is it that varies in case of matter waves? According to Arthur Beiser, shobhit Mahajani the wave associated with particles are mathematical constructs. It does not describe the space time variation of any measurable quantity like displacement or any characteristic present in a medium. Rather the waves relates to the probabilities of observing the particles at different space location as a function of time.

2.2. Planck's quantum hypothesis-

An oscillator absorbs energy from the radiation field and delivers it back to the field in quanta of 0, E 2E........, where E is a quantum of energy proportional to frequency of oscillator. So E = nhν

Here hν appears due to kinetic energy of oscillator. So kinetic energy of oscillator is hν. So when a oscillator oscillates with frequency ν, it emit a photon of energy hν. Here ν is only the frequency of the oscillator, when it oscillates between excited and ground state, ν is also not the frequency of emitted quanta.

Again Planck's constant has the dimension of angular momentum. So it represents only motion.

h = $\frac{C_2 k}{c}$ = 6.6×10^{-34}Js

C_2 = Wien's constant

K = Boltzmann constant

C = speed of light in vacuum

All constant represent motion. C_2 and k are used to represent heat and we know that heat is the energy in transit.

2.3. Bohr's Theory:- When electron jumps from higher excited orbit to lower orbit then it emit energy in the form of packet, which is equal to difference of energy of two orbit i.e. $E_2 - E_1 = h\nu$

Here also hν denotes photon energy as well as change in kinetic energy of an electron when it jumps from one orbit to another.

Further from the relativistic relation of total energy of particle, we have

$E^2 = p^2c^2 + m_0^2c^4$

$m^2c^4 = p^2c^2 + m_0^2c^4$

$p^2c^2 = (m^2 - m_0^2)\, c^4$

$p^2c^2 = (m - m_0)\, c^2 \times (m + m_0)\, c^2$

$p^2c^2 = \Delta mc^2 \times \Delta m_1c^2$

Since, Δmc^2 = kinetic energy

$\Delta mc^2 = \frac{p^2c^2}{\Delta m_1 c^2} = \frac{p^2}{\Delta m_1}$

So for electron $E \neq pc \neq h\nu$,

But $\Delta mc^2 = h\nu$

So $\Delta mc^2 \neq pc$,

If we assume $\Delta mc^2 = pc$,

Then $h\nu = pc$

$p = \frac{h\nu}{c}$

$\frac{c}{\nu} = \frac{h}{mv}$,

But $\frac{c}{\nu} \neq \lambda$

So $\lambda \neq \frac{h}{mv}$

3. NO SYMMETRY AT ALL

Bohr explained for the 1st time how light is emitted from a light source.

An atom starts emitting a light waves as it leaves the excited state and ceases emission as soon as it reaches the lower energy state. Thus an emission event produces a light burst or a photon or wave packet. Each light burst occurs over a period of about 10^{-8} s only each is a wave train containing only a certain limited number of wave oscillations in it, so the light emitted by an ordinary light source is not an infinite long, simple harmonic wave but it is a jumble of finite wave trains.

If a wave train last for a time interval Δt , the length of wave train in vacuum is

$l = (x_2 - x_1) = c\,\Delta t$, where c is the speed of light in vacuum. If we take $\Delta t = 10^{-8}$s

Then $l = 3\times 10^8 \mathrm{ms}^{-1} \times 10^{-8}\mathrm{s} = 3\mathrm{m}$

The no. of oscillation present in the wave train is $N = \frac{l}{\lambda}$

Where λ is the wave length of emitted light.

Assuming that $\lambda = 5000Å = 5\times10^{-7}$ m

$$N = \frac{3\mathrm{m}}{5\times10^{-7}} = 6\times10^6$$

Thus a wave train contains about a million wave oscillations. This oscillation takes place inside photon. Since photon has particle character and wave exist inside photon according to wave theory.

But in de Broglie hypothesis it has been assumed that 'A moving body behaves in certain way as though it has a wave nature'. So a moving body or particle behaves as wave. According de- Broglie the wavelength of electron in Bohr's stationary orbit is a multiple of n. So wave not exist inside electron. So there is no symmetry at all.

4. FROM PARALLELISM BETWEEN MECHANICS AND GEOMETRICAL OPTICS

According to principle of least action of Hamilton,

$$\delta \int_{p_1}^{p_2} (mv)\, ds = 0$$

$$\text{And } \delta \int_{p_1}^{p_2} (\mu)\, ds = 0$$

According to Cauchy formula, we can say $\mu \, \alpha \, \frac{1}{\lambda^2}$,

Or $\frac{1}{\lambda^2} \, \alpha \, mv$

Or $\lambda^2 \, \alpha \, \frac{1}{mv}$

If we take h as constant of proportionality, then $\lambda^2 = \frac{h}{mv}$, which is not de-Broglie equation. So parallelism theory of Broglie fails here.

5. DE-BROGLIE WAVELENGTH CANNOT BE DERIVED FROM BOHR'S THEORY

According to de-Broglie the only phenomena involving integers in physics were those of interference and modes of vibration of stretched string, both implying a wave motion, so the electrons in the privileged orbit could not simply be regarded as material particle. But Planck's hypothesis also involved integer E = nhν and Bohr theory is also based on Planck's hypothesis. Further quantization of charge q = + ne also represent integers both implying particle character.

Let us calculate so called wave length of electron and its frequency (ν) from Bohr's theory.

Bohr quantization condition is, $mvr = \frac{nh}{2\pi}$

For first orbit n = 1, $mvr = \frac{h}{2\pi}$

$2\pi r = \frac{h}{mv}$

De-Broglie has assumed that, for the first orbit

$\lambda = 2\pi r$

If it is true, then the frequency of electron should be equal to frequency of revolution.

So $\nu = \frac{v}{2\pi r}$.

Then its phase velocity $u = \lambda\nu = 2\pi r \times \frac{v}{2\pi r}$

So $u = v = v_g$. So the so called phase velocity is equal to particle velocity or group velocity, there is no unexpected result. According to wave theory phase velocity must be greater than group velocity; here there is no difference, so we can say that there is no wave associated with moving electron.

6. CALCULATION OF VALUE OF PLANCK'S CONSTANT FROM DE-BROGLIE HYPOTHESIS

According to de-Broglie, hν = kinetic energy + potential energy

In Bohr's Theory, total energy of electron in first orbit is -13.6 eV

According to de-Broglie, this should be equal to hν,

So $h\nu = -13.6 \times 1.6 \times 10^{-19}$ J

$h = \frac{-13.6 \times 1.6 \times 10-19\, J}{\nu} = \frac{-21.76 \times 10^{-19}}{0.70 \times 10^{16}} = -3.1 \times 10^{-34}$ Js

This is not the true value of Planck's constant and h is a positive constant. So hν is only vibration kinetic energy of electron during its jumping between two orbits. The revolution kinetic energy of electron in Bohr's orbit is $\frac{1}{2}$ hν. Again $\frac{1}{2}$ hν is not the zero point energy of harmonic oscillator at absolute zero.

Alternative proof:-

In the alternative proof of de-Broglie hypothesis using the equation of Relativity, there are many mistakes.

a) If for logic we consider wave is associated with moving particle, then standing wave will only form in motion in stationary orbit not during the case of rest. So at rest when v = 0, ν = 0.

b) $\nu = \frac{\nu_0}{(1-\frac{v^2}{c^2})^{\frac{1}{2}}}$ is not the correct expression, in place of it we have to use, $\nu = \frac{\nu_0 - \frac{v}{\lambda}}{(1-\frac{v^2}{c^2})^{\frac{1}{2}}}$ if ν_0 exist.

c) Again we have compared relativistic equation of electron with non relativistic equation of wave. So the relation $\lambda = \frac{h}{mv}$ is also wrong.

7. CONCLUSION

Since the relation E = hν = mc^2 is not correct. So the relation $\lambda = \frac{h}{mv}$ is also wrong for material particle. We can say that, no wave is associated with material particle.

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