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Frequency of Matter Waves

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Abstract

hydrogen spectrum, among many other things. At ultra-relativistic velocities wavelengths according to existing and revised theories differ widely. What is needed is that some experimentalist should take the readings without any prejudice; and that is very difficult. Because, theory guides the experimental results, or more correctly, theory dictates the experimental results. As it is well known that phenomenon of wave particle duality was experimentally observed by some scientists much before the discovery of wave particle duality by Louis de Broglie. But there was no theory to guide those results and hence they were ignored. Results of Davisson and Germer were not ignored because they came after Louis de Broglie proposed the theory of wave particle duality. Now Louis de Brogile's theory is established so firmly that no experimentalist has courage to defy it.

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Introduction

In this article, we will discuss the relationship between group velocity and phase velocity of matter waves. These velocities are directly linked with frequencies of matter waves as follows:

$v_{phase}=\lambda\nu_{phase}$

$v_{group}=\lambda\nu_{phase}$

Where:

V_{phase}=phase velocity of matter waves,

V_{group}=group velocity of matter waves,

ν_{phase}=phase frequency of matter waves,

ν_{group}=group frequency of matter waves,

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λ=wavelength of matter waves.

You must have noticed that unlike velocity and frequency, the wavelength doesn't come in two flavors [1]. It is same in both cases (*i.e.*, phase and group). The relationship between phase velocity and group velocity of matter waves at non-relativistic velocities in some text-books on quantum mechanics (e.g., Quantum mechanics by David Griffiths, Pearson, 2/e, chapter 2, section 2.4, page 67, Ref 1) is given by:

$V_{phase}=(1/2)\ V_{group}$ (1)

Literature Review

Not all scientists would support this equation [2]. Notice that this topic lies almost in the domain of "Foundations of Quantum Mechanics" and the world has seen a great debate between groups of scientists headed by Einstein and Bohr, on this subject. However, some scientists believe in the correctness eqn (1) and some authors have also included this equation in their books on quantum mechanics. In this article we will tinker with this equation [3].

In case of photons, the relation between phase velocity and group velocity is given by:

$V_{phase}=V_{group}$ (2)

Unlike eqn (1), eqn (2) is universally accepted by all scientists.

Now, when we accept eqn (1) and eqn (2) as valid equations, then we are also required to provide a third equation which is nothing but a generic relation between phase velocity and group velocity [4]. Let this be eqn (3) something like shown below:

$V_{phase}=p \times V_{group}$ (3)

Where:

p=Some expression

In eqn (3) if we make the following substitutions (which are meant for non relativistic particles): $v << c$ and m=m0

then eqn (3) should reduce to eqn (1).

Here:

v=Speed of particle,

c=Speed of light,

m=Relativistic mass of particle,

m_0=Rest mass of particle.

Also, in eqn (3) if we make the following substitutions (which are meant for photons): v=c and m_0=0

then eqn (3) should reduce to eqn (2).

Here:

v=c=speed of photons,

m_0=rest mass of photons=0.

So what is a suitable expression for the p used in eqn (3) given above? After tinkering with various quantities, we find that the prospective equation for p is as follows:

$V_{phase}=((mc^2-m_0c^2)/(mv^2)) \times V_{group}$ (4)

Now let us check whether it reduces to eqn (1) and eqn (2) or not, under appropriate conditions. Firstly, consider the case of non-relativistic particles. In case of these particles, we have:

$v << c$ and $m=m_0$ Also,

$mc^2-m_0c^2=(1/2)\ m_0v^2$ and $mv^2=m_0v^2$

Notice that $mc^2-m_0c^2$=relativistic kinetic energy of particle and $(1/2)\ m_0v^2$=non-relativistic kinetic energy of particle.

Make these substitutions in the parenthesized expression in eqn (4) and we get:

$((mc^2-m_0c^2)/(mv^2))=(1/2)\ m_0v^2/(m_0v^2)=1/2$

$((mc^2-m_0c^2)/(mv^2))=1/2$

Put this value in eqn (4) and we get:

$V_{phase}=(1/2) \times V_{group}$

Which is nothing but eqn (1), as expected.

So far so good. Now consider the case of photons. In case of photons, we have: $v=c$ and $m_0=0$

Make these substitutions in the parenthesized expression in eqn (4) and we get:

$((mc^2-m_0c^2)/(mv^2))=((mc^2-0 \times c^2)/(mc^2))=(mc^2)/(mc^2)=1$

$((mc^2-m_0c^2)/(mv^2))=1$

Put this value in eqn (4) and we get:

$V_{phase}=(1) \times V_{group}$

$V_{phase}=V_{group}$

Which is nothing but eqn (2), as expected. Nice.

Thus our eqn (4) works well as a generic expression between phase velocity and group velocity.

But eqn (4) looks horrible. The physical interpretation of parenthesized quantity is also a headache issue. Nature loves simplicity but complicated looking eqn (4) goes against this notion. And that is why I am tempted to provide another set of equations that does not force the nature to behave in a complicated manner [5]. Another set of equations-with some relevant information-is given below. For details of this theory, please refer the references given at the end of this article. The following quotation by Richard Feynman had prompted (more correctly, ordered) me to develop this set of equations [6]. A modification of a basic physical principle is interesting if it is consistent with everything known previously.

Nature and microscopic world

In this theory the generic expression that gives relation between phase velocity and group velocity is very simple and it is given below:

$V_{phase}=V_{group}$ (5)

Compare the simple looking eqn (5) with the complicated eqn (4) and you will realize that there must be an element of truth that has given such a simple and beautiful equation, compared to very complicated equation (4).

According to Louis de Broglie, when a micro-particle (or object in our macro world) moves, it is accompanied by probability waves. The probability waves decide the destination of particle. In case of macro-objects, the role of probability waves is insignificant, but in case of micro-particles, you cannot ignore the role of probability waves. The wavelength of probability waves is given by the equation:

$\lambda=h/p$ (6)

Where:

λ=wavelength of probability waves,

h=Planck's constant,

p=Momentum of particle.

de Broglie also assumed that following equation holds true for a moving particle:

$m'c^2 = h$ (7)

Where:

m'=Relativistic mass of particle,

c=Velocity of light,

h=Planck's constant,

h=Frequency of probability waves.

Equation (7) also provides relation between classical energy and quantum energy of a particle. LHS of equation (7) represents the classical energy of a particle and RHS of equation (7) represents the quantum energy of a particle. Equation (6) is verified for all particles. Equation (7) is verified for photons only.

An enigmatic equality

An enigmatic equality is observed in case of an electron in the ground state of hydrogen atom, which can be stated as follows:

$(1/2).m.v^2=(1/2).h.\nu$ (8)

Where:

m=Rest mass of electron,

h=Planck's constant,

v=Velocity of electron in the ground state of hydrogen atom,

ν=Orbital frequency of electron in the ground state of hydrogen atom.

LHS of equation (8) represents the kinetic energy of electron, and RHS of equation (8), however, represents an enigmatic term. Equation (8) can be proved easily using existing theories, but it cannot be interpreted using existing theories [7].

Discussion

But why should we try to interpret this equality? Because history of science tells us so. In science whenever such equality exists, there is always some physical principle lying behind it rather than that equality being a mere coincidence. For example, since the times of Newton it was believed that equality between inertial mass and gravitational mass of a matter is a mere coincidence, but Einstein interpreted that equality using his famous "principle of equivalence." Notice one more example from other discipline. The salinity of our blood is almost the same as that of seawater. This is, however, not a coincidence. Millions of years ago ancestors of human beings were sea-animals, and their body fluids were derived from the seawater; and that's why the said equality. Revised theory of matter waves offers satisfactory explanation to the enigmatic equality stated in equation [8-10].

Revised theory offers solution

According to revised theory the classical energy of an elementary particle is related to its quantum energy by the following expression:

$m'c^2\text{-}mc^2=s.h.\nu$ (9)

Where:

m'=Relativistic mass of an elementary particle,

m=Rest mass of an elementary particle,

c=Velocity of light,

s=Spin number of an elementary particle,

h=Planck's constant,

ν=Phase frequency of probability waves. Combining equation (9) with the standard wave equation v =ν.λ, we get the following expression for λ (the wavelength of probability waves):

$\lambda=s.h.v/(m'c^2\text{-}mc^2)$ (10)

Where v is the phase velocity of probability waves. In revised theory, the phase velocity of probability waves is equal to the group velocity of probability waves, which in turn is equal to the particle velocity; therefore, hereafter we identify the "v" with the particle velocity. In case of photons, putting s=1, m=0, and v=c, equation (10) yields the familiar relation, as follows:

$\lambda=1.h.c/(m'c^2\text{-}0)=h/(m'c)=h/p$

Where:

p=Momentum of photon.

Equation (9) also yields the familiar relation, as follows:

$m'c^2\text{-}0=1.h.\nu$

therefore, $m'c^2= h\nu$

In case of non-relativistic electrons, using the substitutions: s=1/2 and $m'c^2\text{-}mc^2 = (1/2).m.v^2$, equation (10) yields the familiar relation, as follows:

$\lambda=(1/2).h.v/(1/2).m.v^2 = h/mv=h/p$

Where, p=momentum of non-relativistic electrons; and equation (9), however, yields the relation which is not familiar but certainly a welcome, as follows:

$(1/2).m.v^2 = (1/2).h.\nu$ (11)

In equation (11), ν is the phase frequency of the probability waves associated with an electron. For first orbit of hydrogen atom, circumference of orbit=wavelength of probability waves, therefore, orbital frequency of electron=phase frequency of probability waves. And this completes the physical interpretation of otherwise enigmatic equality stated in equation (8). Equations (9) and (10) are stated for elementary particles, but also hold good for composite particles. However, in case of composite particles the "s" stands for the common spin numberof constituent particles (and not the total spin number of the composite particle). As all matterin the universe is composed of spin (1/2) quarks and spin (1/2) leptons, the behavior of composite particles is essentially same as electron. See the references given below for details [11-13].

Bell's cautious reaction

As expected, revised theory instantly came under the charge of blasphemy, and despite the sound and consistent theoretical framework, scientists strongly resented it with religious zeal. Theoretical Physicist John Bell (Bell's inequality fame) wrote to author in a personal communication. It takes a great courage to start all over again at this stage. Does your theory like that of Dirac give the correct hydrogen spectrum?

Conclusion

The trouble is that predictions of revised theory hardly differ from the predictions of established theories, and hence, it gives correct hydrogen spectrum, among many other things. At ultra-relativistic velocities wavelengths according to existing and revised theories differ widely. What is needed is that some experimentalist should take the readings without any prejudice; and that is very difficult. Because, theory guides the experimental results, or more correctly, theory dictates the experimental results. As it is well known that phenomenon of wave particle duality was experimentally observed by some scientists much before the discovery of wave particle duality by Louis de Broglie. But there was no theory to guide those results and hence they were ignored. Results of davisson and germer were ignored because they came after louis de broglie proposed the theory of wave particle duality. Now Louis de Brogile's theory is established so firmly that no experimentalist has courage to defy it.

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