Research Article

Methods Of Studying Louis De Broglie Wave And Corpuscular-Wave Dualism In The Course Of Physics In Academic Lyceums

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Article History: Received: 10 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 16 April 2021

Abstract. The analysis of the textbooks of the physics course of academic lyceums shows that the content of the teaching materials in the department of quantum physics is sufficiently complex that it is briefly, vaguely described by the authors of the textbooks. Despite the fact that in recent years in the Russian Federation and Uzbekistan in this area have defended several dissertations, published textbooks and suggestions for improving teaching methods, the content of textbooks remains very shallow. Quantum physics is the basis of modern physics, a great contribution to the development of physics and technology. adds. It is well known that microcosm phenomena are subject to statistical laws, macrocosm, or physical phenomena studied on the basis of classical physics are mainly subject to dynamic laws, but systems consisting of many particles studied on the basis of classical physics, such as gaseous and liquid properties, are also subject to statistical laws.

The phenomena of the microworld are studied on the basis of quantum physics, in contrast to the phenomena of the macroworld, the state of each particle in the microworld has a statistical character. Thus, the phenomena studied on the basis of quantum physics are based on probabilistic-statistical laws [3.4,5]. In the physics course of lyceums the basic ideas of teaching methods of the department of quantum physics with the correct formulation of the content of teaching materials and the application of probabilistic-statistical laws are presented. Currently, in the physics textbooks of secondary schools and academic lyceums in the Republic and the Russian Federation, the department of quantum physics is mainly limited to a detailed study of the photoelectric effect and Compton effect, a brief description of the corpuscular-wave dualism. [10,11,12] For this reason, students' perceptions of quantum physics remain shallow.

The authors teach the experimental foundations of quantum physics, ie the laws of radiation of an absolutely black body, the concept of quantum, photoeffect, Compton effect, De Broglie waves and its probabilistic-statistical interpretation, wave function, are invited to add topics. [9,20]

Pedagogical experiments were conducted on the proposed content of quantum physics in the areas of in-depth study of physics in academic lyceums, resulting in a sharp increase in students' interest in learning the basics of modern physics [7,9,14]. The presented article is devoted to the study of De Broglie waves and their possible statistical interpretation topics.

Keywords: Quantum physics. Microparticles, De Broglie ideas, De Broglie wave, probability-statistical imagination, dynamic laws, statistical laws, probability, quantum, quantization, wave, wave phase, wavelength, energy, momentum, Planck's constant, De Broglie wavelength, photon, electron, wave function.

INTRODUCTION

The methodology of teaching quantum physics in the course of physics in academic lyceums is one of the fastest growing and developing scientific and methodological areas. Russian scientists A.V. Tarasov and VV Multanovsky, VM Yavorsky, VG Razumovsky have done a lot to introduce modern physics, ie the elements of quantum physics, in the curricula and textbooks of physics in general secondary schools and academic lyceums with in-depth study of physics. [1 , 2,4,7,12,18].

In the section of quantum physics of physics textbooks for academic lyceums in the Republic of Uzbekistan, only the topics of photoelectric effect and corpuscular-wave dualism are given, but almost no attention is paid to the content of these phenomena, ie the statistical significance [8,11].

Although the Department of Quantum Physics is not fully disclosed in the textbooks of general secondary schools and lyceums of the Russian Federation, attempts have been made to shed more light on probabilistic statistical concepts on the topics of De Broglie ideas and De Broglie waves [5,6,10].

Object of research and methods used

The object of research in the article is the department of quantum physics in the physics course of academic lyceums and the basic concepts in it.

The article focuses on the content of the materials included in the section of quantum physics, focusing on students' full understanding of the subject and the specific features of De Broglie waves and their differences from conventional waves, and the probabilistic-statistical nature of the physical and mathematical base of academic lyceum students [9]. In addition, in the physics textbooks of academic lyceums, recommendations are given for a broader coverage of this topic, and perhaps for a deeper inculcation of statistical ideas in the minds of students. In our opinion, the following should be given more attention when covering the topic of De Broglie wave [3,7,9,13]

1. De Broglie's ideas and the De Broglie wave. As an example, the problem of quantization of circular orbits is a proof of N. Bor's conditions based on the above ideas.

2. Application of corpuscular-wave dualism to microparticles.

3. Correlation of pulse, frequency and wavelength.

De Broglie's ideas and his work on the De Broglie wave are important milestones in the development of quantum imagery, which can be used to simply prove Bohr's conditions for the quantization of circular orbits based on De Broglie wave imaginings.

A microparticle of mass m and energy E (momentum p) corresponds to a flat, monochromatic wave of frequency (i) and wavelength (l), and the idea that the momentum of a microparticle is expressed in terms of $p = \frac{2\pi \;\; \hbar}{\lambda}$ through wavelength l promoted by De Broglie. [9]

First, the relationship between impulse and wavelength obtained by De Broglie argues that this idea can be applied to microparticles as well as to the explanation of corpuscular-wave dualism.

Second, the wave properties are important at what values of the microparticle (body) pulse, and also at what values of the microparticle pulse it can be ignored.

Third, the expression $p = \frac{2\pi \;\; \hbar}{\lambda}$ allows us to determine whether the quantization condition $m\upsilon r = n\hbar$ used by Bohr for the hydrogen atom is valid, i.e., n De Broglie waves can be placed in the n-orbit.

According to Planck's idea, if a light wave is characterized by a frequency w and a wave vector k, each of the photons that make up the wave must have energy e and momentum p:

$$\varepsilon = \hbar\omega \quad (1.1)$$

$$\vec{p} = \hbar\vec{\kappa} \quad (1.2)$$

It can be seen from formulas (1.1) and (1.2) above that in the energy and momentum expressions of a photon, the magnitudes w, k - representing the wave, and e, p representing the corpuscle (particle) are interrelated.

The wave characteristics of a photon indicate that it has the ability to interference and diffract, while the corpuscular characteristics indicate that it can be viewed as a particle. Hence the Planck constant h is the quantity that interconnects these two different characteristics.

In short, De Broglie argues that based on the existing symmetry in nature, if light (photons) exhibits corpuscular properties in addition to wave properties, microparticles must also have wave properties in addition to corpuscular properties. [3.9 , 14]

N. Bohr introduced the condition of quantization of the momentum in the theory of the hydrogen atom, but it was known that it was not substantiated, and ten years later the above quantization condition was substantiated on the basis of de Broglie's ideas [9].

According to De Broglie, every electron in an atom corresponds to a stationary wave of a certain wavelength. Since Bohr theory considers the motion of electrons in circular orbits, de Broglie easily proved that the electrons in an atom correspond to circular stationary waves that bind to each other.

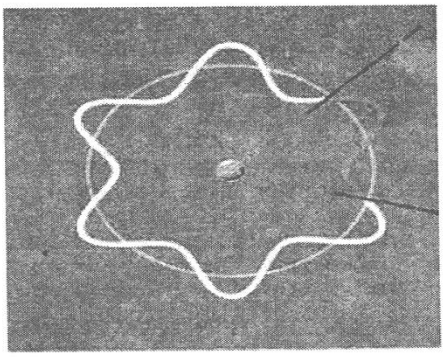

Figure 1. Describe the state of an electron in an atom in the form of a stationary wave.

Based on this assertion, the quantization conditions of Bohr and the results derived from them are fully substantiated. Let us proceed to the mathematical substantiation of the above points.

Thus, de Broglie states that an electron with a p-pulse must be associated with a wavelength l_e:

$$\lambda_в = \frac{2\pi\hbar}{p}$$

With the motion of a free-moving electron with energy E and momentum p, the de Broglie plane wave is connected as follows, where, - r - radius corresponding to an arbitrary point in space, t -vector, time:

$$\psi(r,t) = C\exp[\imath(\omega t - kr)] = C\exp\left[\imath\left(\frac{\mathrm{E}t}{\hbar} - \frac{\vec{p}\,\vec{r}}{\hbar}\right)\right] \quad (1.4)$$

$\vec{\kappa} = \frac{\vec{p}}{\hbar} = \frac{1}{\lambda}$ - wave vector.

The relationship between the wave and corpuscular characteristics of particles is also represented by equations that are appropriate for a photon, i.e.

$$\mathrm{E} = \hbar\omega \quad (1.5)$$

$$\vec{p} = \hbar\vec{\kappa} \quad (1.6)$$

Equations (1.5), (1.6) are called de Broglie's basic equations. If we determine w and k from these equations and put them into equation (1.4), de Broglie wave expression is generated.

$$\psi(r,t) = C\exp\left[\frac{i}{\hbar}(Et - \vec{p}\vec{r})\right] \quad (1.7)$$

At first glance, it is difficult to determine the relationship between the motion of a wave and the mechanical motion of particles from expression (1.7). In the study of whether this connection is more pronounced, it is assumed that by selecting a single, OX axis direction, this direction corresponds to the direction of motion of the wave. In this case, instead of (1.7) the following expression is formed:

$$\Psi(x,t) = Ce^{i(\omega t - kx)} \quad (1.8)$$

In (1.8) the magnitude in the exponent exponent (wt-kx) represents the wave phase. Let the wave phase at any point x have a definite value a = const, the corresponding coordinate is determined as follows.

$$\alpha = \omega t - kx \quad (1.9)$$

The value of the wave phase shifts rapidly in space over time, in order to determine the velocity u, equation (1.9) is differentiated over time, and the expression for the phase velocity u is determined.

$$u = \frac{\omega}{\kappa} \quad (1.10)$$

From the dependence of the u-phase velocity on $\lambda = \frac{2\pi}{\kappa}$, it appears that it also depends on the wavelength (5), such a connection represents the wave dispersion. De Broglie waves, unlike electromagnetic waves, also have the property of dispersion in free space (vacuum), which indicates that De Broglie waves differ from electromagnetic waves. [9,14,17,18]

In the fields where Newtonian mechanics is relevant in the theory of relativity, that is, when the condition v << c is satisfied, the energy of a free-moving particle is determined as follows.

$$\mathrm{E} = +\sqrt{m_0^2c^4 + p^2c^2} = m_0c^2 + \frac{p^2}{2m_0} + \ldots\ldots. \quad (1.11)$$

Here, m_0 is the rest mass of the microparticle. Using the appropriate formulas, we generate the expression for w

$$\omega = \frac{m_0c^2}{\hbar} + \frac{\hbar\kappa^2}{2m_0} + \ldots\ldots.. \quad (1.12)$$

and, given that $\vec{p} = \hbar\vec{\kappa}$, we come to the following conclusion.

$$\omega = \frac{m_0 c^2}{\hbar} + \frac{p^2}{2m_0\hbar} + ... \quad (1.13)$$

Hence, the dependence of the momentum on the velocity is from p = mv, based on (1.13) it is determined that the velocity v is a function of the wave vector k, which also proves the existence of variance.

To determine the relationship between wave motion and microparticle motion, we consider a strictly non-monochromatic wave with a certain frequency w (l = wavelength), and such waves are called “wave packets” or “wave groups”.

A wave group (wave packet) is a superposition of waves that differ very little from each other in the direction of propagation and the size of the wavelength (Δl is small enough).

The coordinate of the center of the wave group is determined from the following equation.

$$\alpha(x,t) = \left[x - \left(\frac{d\omega}{dk}\right)t\right]\Delta k = 0 \quad (1.14)$$

Hence, 555 follows from (1.14) when x = x0. It can be seen that the center of the packet moves at a constant speed along the x-axis. The velocity of the center of the wave packet is debated by the group velocity and is determined from the following formula.

$$\upsilon_{гр} = \frac{\hbar k}{m_0} \quad (1.15)$$

We calculate the dependence of the De Broglie wavelengths on the kinetic energy of the microparticle for three boundary states.

1. At low velocities, i.e., where the condition is appropriate, we obtain the following formula, which relates the De Broglie wavelength to the kinetic energy of the particle.

$$\lambda = \frac{2\pi\hbar}{\sqrt{2m_0 \mathrm{E}_k}} \quad (1.16)$$

2. At relativistic velocities, the De Broglie wavelength is correlated with the kinetic energy of the microparticle as follows.

$$\lambda = \frac{2\pi\hbar c}{\sqrt{\mathrm{E}_k\left(\mathrm{E}_k + 2m_0c^2\right)}} \quad (1.17)$$

3. When the condition is satisfied, i.e. at ultrarelativistic velocities, the De Broglie wavelength is related to the kinetic energy of the particle as follows.

$$\lambda = \frac{2\pi\hbar c}{\mathrm{E}_k} \quad (1.18)$$

Hence, if the mass and energy of the particle are known, the wavelength of the particle can be calculated using the above formulas. De Broglie's idea was quickly confirmed by experience. Interference and diffraction phenomena were observed, as in experiments with light or X-rays for particles. In 1927, Davisson and Djermer were the first to experiment with the diffraction of electrons in crystals.

The concept of de Broglie waves is one of the most difficult to understand and comprehend because this wave does not resemble waves (electromagnetic, elastic, or other waves) known from classical physics [28,53].

To understand the physical nature of the de Broglie wave, we need to consider the corpuscular-wave dualism and probabilistic-statistical representation of microparticles.

Students need a comprehensive in-depth explanation of how a microparticle or microobject can be described and imagined. Naturally, the characteristics of a microparticle or microobject, such as its mass and electric charge at rest, indicate that they should also be considered "corpuscles", and the meaning and essence of the term microparticle or elementary particle is also a particle (corpuscle). [4,6, 13,15,18,19]

The fact that the motion of a microparticle or microobject is not represented by a trajectory such as the motion of a classical corpuscle, the self-destructive nature of a microparticle or microobject, the specificity of its movement through potential barriers (obstacles) show that they are radically different from classical corpuscles.

A classical particle is a physical object that has a mass and exists in a certain part of space, with precise coordinates, depending on a point in space (locally), obeying the laws of dynamics, with a trajectory of motion.

According to the classical notion, a wave is the propagation of vibrations in an elastic medium, and the motion of the wave represents the motion of that medium, i.e., it is assumed that there is a wave where the medium exists. [16,17,18].

In short, in classical physics, wave propagation and corpuscular motion are radically different phenomena.

Hence, in classical physics, wave and corpuscular motion exist independently as two types of motion.

The task of a physics teacher is to inculcate in students the concepts of classical particle, classical wave (mechanical waves, electromagnetic waves) based on concrete examples, but in preparing students for a radical change in the study of microcosm phenomena, he must explain to them the essence of the new imagination of course, this requires great methodological skill from the teacher.

In the particles of the microcosm, however, these two properties are manifested in a dialectical combination in a single object.

The parameters that characterize the wave property of a microparticle, the frequency wavelength (number of waves), and the energy and momentum physical quantities that characterize the corpuscular nature of a microparticle are interconnected by the Planck constant in the De Broglie equations.

If a microobject cannot be thought of as a corpuscle (particle) in the classical sense, a wave in the classical sense, we ask whether it can be imagined as a “symbiosis” of a corpuscle and a wave. [9.13.]

One attempt to imagine micro-objects in this way is to model a micro-object in the form of a wave packet, and another is to model a micro-object as a corpuscular “core” and a “combination” of some wave that controls the motion of that “core”. [4]

Such attempts are based on superficial notions of corpuscular-wave dualism, and the micro-object can never be imagined in the form of corpuscular-wave symbiosis.

In general, when studying the essence of corpuscular-wave dualism, the question arises as to how a microobject or microparticle can be imagined?

Just as it is inappropriate to introduce the concept of corpuscles into the microcosm in classical physics, so it is inappropriate to introduce the concept of waves into the macrocosm. In the history of the development of physics, since the study of the motion of matter began with macrocosm phenomena, the terms corpuscle and wave correspond to macrocosm phenomena, and applying them directly to microcosm phenomena does not yield the expected result.

When using these terms in the microcosm as well, it is necessary to apply them not as retaining their meaning in classical physics, but as considering them as one of the specific features of the microobject. The uniqueness of this topic can be explained to the students as well, if the physics teacher fully imagines it.

When the motion of an electromagnetic field quantum photon is studied, its wave property is more pronounced, and when the process of interaction of photons with other particles (objects) is studied, the corpuscular property is more pronounced. and one feature complements the other. [4]

Nowadays, corpuscular-wave dualism is understood as a potential opportunity for a microobject (microparticle) to express its various properties depending on one or another external condition. It follows that the creation of a visual model of a microobject (microparticle) is in principle impossible.

The peculiarity of determining the state of a micro-object is, in fact, due to the simultaneous manifestation of elements of a necessity and randomness.

Laplace's determinism, which plays a key role in classical physics, holds that there are no elements of randomness in determining the state of a particular object, i.e., necessity plays a key role in classical physics. Therefore, the laws of classical mechanics are only dynamic laws, not statistical laws.

Elements of randomness (statistical laws) are manifested in classical physics in the process of studying the physical properties of a set (collective) of objects.

In quantum physics, the study of the state of each microobject (microparticle) in the phenomena associated with the motion of microparticles shows the simultaneous presence and manifestation of the elements of necessity and randomness.

For example, in the process of spontaneous (spontaneous) return of an atom to its ground state without external influences, spontaneous transitions of electrons from one level to another occur.

In this phenomenon, it is impossible to predict when the excited atom will return to the ground state and to what level it will pass, because the acts of transition from the ground state to another level occur as a random process.

Any change in the state of a microobject is associated with the random and simultaneous manifestation of elements of necessity.

One of the most famous physicists, Fock, acknowledged that the concept of probability is primary in quantum physics and that it plays a fundamental role. [4,17,19]

The condition of a particular micro-object is random, and the probability of the condition is necessary. Although a microobject (microparticle) is free from dynamic effects, it is under the influence of random forces that produce quantum fluctuations due to uncertainty, but in quantum physics (quantum mechanics) such a particle can be considered a free particle.

In fact, the basic laws in nature are not dynamic laws, but statistical laws. The probable form of causation is the basic form, while classical determinism is only a boundary case. [4,9,16.20]
The statistical content of the De Broglie wave was discovered by M. Born, and on this basis the statistical content of the wave function is also explained.
According to statistical interpretation, the intensity of the De Broglie wave at a point in space is proportional to the probability that a microparticle will be present at that point. The de Broglie wave intensity indicates the probability density of a microparticle in a sufficiently small volume element of space. In general, we express the state of a microparticle (a system of microparticles) with a $\psi = \psi(x, y, z, t)$ wave function, which is a complex function of time, x y z coordinates.
We write a De Broglie wave and a statistical interpretation of the wave function through the probability of the presence of a volume element around the x y z coordinate point at the time moment of the microparticle.

$$dW = |\psi(x, y, z, t)|^2 dV \qquad (3.2.36)$$

From this expression we write the expression for the probability density

$$\omega(x, y, z, t) = \frac{dW}{dV} = |\psi(x, y, z, t)|^2 \qquad (3.2.37)$$

The wave function represents a potential (information) field, not a physical field.

CONCLUSION
Of course, these concepts of quantum physics are complex concepts, the correct formation of these concepts in the minds of students, deepens their physical worldview. It is also important to study these topics more broadly in elective classes.
According to the classical concept, the probabilistic distribution is formed due to the large number of events and their irregularity. In quantum physics, the probability of individual, elementary phenomena is also discussed. Even the passage of a single electron from a single crystal is governed by the laws of probability.

In explaining the physical nature of the Born wave function, he relates the square of the modulus of the wave function to the probability density of the particle being present in a volume element around a certain coordinate point.
In short, the state of microparticles is determined on the basis of complete probabilistic laws, in addition to the fact that the most probable state of stationary states in atoms, the interaction (scattering) of particles of a certain velocity is also governed by probabilistic laws.

References

1. Personalized State education standarts and curriculum. T. 2010, 34 p.
2. Curriculum of physics in academic lyceums.- T .: 2020. 26 p.
3. Jo'raev M. Statistical ideas in physics teaching. Methodical manual. T. “Teacher”, 1996, 104 p.
4. L.V. Tarasov Modern physics in high school. - M .: "Education", 1990, 288 p.
5. Myakishev G.Ya. Dynamic and statistical laws in physics. - M .: "Science", 1973, 5-205 p.
6. Yavorskiy BM Basic questions of the modern school course of physics - M. Pedagogika. 1976.
7. Djoraev M. Methods of teaching physics. Study guide. T. 2015 256 b.
8. Ganiev A.G., Avliyokulov A.K., Alimardonova G.A. Physics. Textbook for AL and KHK. Part 2. Tashkent. “Teacher” NMIU, 2009, 178 p.
9. Djoraev M., Samatov G.B., Khodjanov E.B. Improving the teaching of physics in the system of continuing education on the basis of statistical methods, textbook, Tashkent, "Abu Press-Consult" 2017, 288 p.
10. G.Ya. Myakishev, B.B. B.B. Bukhovtsev, V.M. Charushek Physics, Classical course, M, - Education, 2019, 426 p.
11. Olmasova M.R., Physics. Optics, Atomic and Nuclear Physics (Book 3), AL. Textbook, Tashkent, "Cholpon", 2010, 383 p.
12. Jilko V.V., Markovich L.G. Physics, UP., Minsk, 2014,282 p.
13. Djoraev M. Probabilistic and statistical ideas in teaching physics. Monograph. - T .: Fan, 1992, 124 p.
14. Djoraev M., Samatov G.B., Khodjanov E.B. Probability-statistical bases of quantum and atomic physics departments of physics lyceums of academic lyceums.- Gulistan. “University”, 2016, 100 p.
15. Umarovs Sh.A., Improvement of methods of teaching quantum physics on the basis of computer technology in a secondary school, Abstract, Tashkent, 2008, 24 p.
16. Petrova D.V. Study of the fundamental provisions of quantum physics at different levels of education, dissertation abstract, St. Petersburg, 2015, 26 p.

17. Tarasov L.V. The world built on probability - M.: Education, 1984.
18. Razumovsky V.G. Development of creative abilities of students in the process of teaching physics, M.: Enlightenment, 1985
19. Multanovsky V.V. Physical interactions and the picture of the world in the school course. - M.: Enlightenment, 1983
20. Samatov GB, "Methods of introducing probabilistic statistical ideas in the teaching of" De Broglie waves "in the course of quantum mechanics in universities, -" Actual problems of improving the teaching of physics in continuing education ", Republican scientific-practical conference (April 29, 2017) Collection of materials (part 1) - Gulistan .: 2017, 25-29