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Some Methodological Methods Of Solving Issues From Quantum Physics

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Annotation: In this article, some aspects of the methodology for teaching the course “quantum mechanics” for theoretical training of students studying in the field of physics will be considered. In the study of”quantum mechanics", methods of adaptation of lecture materials, which are difficult to understand, in practical exercises, the application of quantum operators to the study of quantum systems, and the approach to probability are studied.

Keywords: physical and Mathematical Sciences, quantum mechanics, quantum states, wave function, mean values and operators of physical quantities.

The course "theoretical physics" is a fundamental component of the theoretical preparation of a physical teacher, knowledge plays a key role, and without it, in the future, the activity of a physical teacher can not be successful. Theoretical physics is given priority in the formation of the natural-scientific worldview and the unified physical landscape of the universe, students– future teachers in the development of scientific thinking [1,5]. In the study of”quantum mechanics", attention is paid to the methods of adaptation of lecture materials, which are difficult to understand. Assignments aimed at clarifying the basic theoretical concepts and strengthening the knowledge gained in the lectures are offered for analysis in practical classes. To study the quantum system, the application of quantum operators and the probability approach are studied.

In the study of the general course of physics, a classical (Newton) approach is used to describe laws that will be familiar and obvious to the student as well as physical phenomena, since it works with intuitively clear concepts of macroolam. Accuracy is lost when moving to the concepts of quantum mechanics. If the use of the theory of probabilities in classical physics is associated with incomplete information about the system (in the future it is possible to supplement this information, - the assumption says), then in quantum mechanics such an opportunity is excluded in principle. Instead of the usual coordinates and impulses, operators who can not have accurate values at the same time, do not correspond to any measured physical quantity, give complete information about the system, if it is incomprehensible to the student, and mavhum be given through the wave function, make it difficult to understand the Basic Rules of science.

Quantum mechanics has a principled probability approach in describing the physical landscape of the universe and requires greater attention to its interpretation than classical mechanics. According to one of the concessions developed by Nils Bor at the end of the 1920-ies, quantum mechanics characterizes the properties of micro-objects, and not their own, but their manifestation in the process, by observing their interaction with classical measuring instruments. In fact, none of the interpretations is accepted as a general theory. Although the future teacher of physics can not perform complex calculations with the help of quantum mechanics math apparati, but it is necessary to master the physico-philosophical aspect of this science at the level of its capabilities.

Usually, lecture materials are presented in a compact way and lead to the formation of a large number of gaps in the student's perception. Therefore, practical lessons are designed not only to help the student master the skills of applying quantum mechanics methods to specific problems, but also to expand the boundaries of understanding existence, the formation of real quantum ideas. A lot of work is devoted to the teaching of quantum mechanics, where the methods of solving the issues of studying quantum mechanics are briefly studied. Our goal is to clarify and systematize the theoretical knowledge gained by the students in the lectures.

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As an example, we will consider one of the first practical lessons (during the course). It implies the tasks of applying the wave function, finding the average values of physical quantities, including the understanding of the concepts used. The lesson also includes the knowledge of quantum operators of physical dimensions, their ability to use them in solving specific problems and the skills of using mathematical hardware. The lesson begins with a review of the mandatory theoretical questions necessary to solve the intended questions.

1. The concept of the wave function of the state of a quantum object (particle) is introduced: - wave function (State vektori) the complex function of coordinates and time (-a set of generalized coordinates) describes the state of the quantum mechanical system. It should be noted that knowing the wave function, in principle, allows you to get the most complete information about the system available in the microwave. Although the wave function itself does not have any physical meaning, it can be used to calculate all measured dynamic dimensions of the system, to find the density of the probability of finding a particle in a given V volume of space and its position in subsequent time Moments [2]:

$$W = \int_V dW = \int_V |\Psi|^2 dV \qquad (1).$$

2. Since the nature of the behavior of the microsphere is determined by the laws of probability, and the wave function is considered as an amplitude of probability, the density of probability (- Komplex joint) is a real quantity. Since the probability of detecting a particle with a given wave function in an infinite space as a whole (or in another given region) is equal together, we can enter the condition of normalizing the wave function and determine the normalization time [2]:

$$\int d\omega = \left[\int |\psi|^2 dV\right] = 1 \qquad (2)$$

3. In the series of the same experiments in quantum mechanics, the results of measuring the physical quantity can be different, in contrast to the classical one. Therefore, the approach to the results of measuring physical quantities in quantum mechanics has a probability, statistical feature. It is not possible to give a specific value to a dynamic variable, but can always be put to suit a specific probability. If several measurements of any dynamic variables of a system in a situation with a certain wave function are carried out, then based on the results of these measurements it is possible to determine the average value.

A certain number of microbes Ψ - the mathematically expected average value of the size of the G-physicist in the quantum state is calculated using the operator G, which corresponds to it (integralization is carried out throughout the entire area of determination of the function):

$$\langle G \rangle = \int \Psi^* \hat{G} \Psi dV \qquad (3).$$

In the imagination of coordinates, the rules for performing algebraic operations on operators and operators of basic physical sizes are defined: for example, the coordinate operator $\hat{\vec{r}} = \vec{r}$; impulse operator $\hat{\vec{p}} = -i\hbar\vec{\nabla}$ ($\hbar$ - Plank always, $\vec{\nabla}$ - Operator of Laplas).

4. Geysenberg is defined as the attitude of uncertainty. According to this relationship, unlike classical mechanics, it is not possible to accurately measure the value of the corresponding coordinateatasi and impulse of the particle at the same time (canonical joint parameters). With an increase in the accuracy of measuring the coordinate, the accuracy of measuring the impulse decreases, and vice versa.

Students are offered to complete a series of practical assignments using the above concepts. Consider a particle of mass m moving in a one-dimensional potential orbit with a width whose walls are infinitely high (See Photo). The solution of the Shredinger equation leads to the quantization of particle energy:

$$E = \frac{\hbar^2 \pi^2 n^2}{2 m_0 a^2}, \quad n = 1,2,3,\ldots\ldots\ldots \qquad (4)$$

Energy levels are schematically shown in the figure. (4) - wave functions corresponding to the energy spectrum have the following appearance [3,4]:

$$\Psi(x) = C \sin\left(\frac{n\pi x}{a}\right), \quad n = 1,2,3,\ldots\ldots \qquad (5)$$

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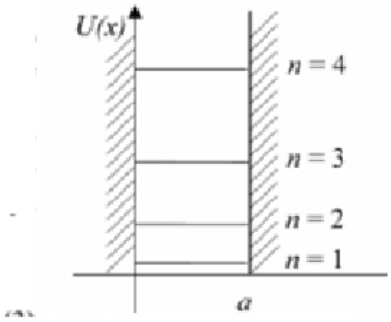
1-Assignment $0 \le x \le a$ in the range (5) normalization constant for a particle in a situation described by the function of the visible wave Define C.

Solution: the particle moves in a limited area of space. Therefore, from the condition that we normalize (2) $0 \le x \le a$ we use the range (for one-dimensional coordinate) :



Potensial o'ra

$$\int_0^a |\Psi|^2 dx = C^2 \int_0^a \sin^2\left(\frac{n\pi x}{a}\right) dx = \frac{C^2}{2}\int_0^a \left(1-\cos\left(\frac{2n\pi x}{a}\right)\right) dx = C^2\frac{a}{2} = 1 \Rightarrow C = \sqrt{\frac{2}{a}}.$$

$$\Psi(x) = \sqrt{\frac{2}{a}}\sin\left(\frac{n\pi x}{a}\right). \qquad (6)$$

2-Assignment. Potential relay n-the coordinate of the particle, which is characterized by the function of the wave in the stationary State (6) $\langle x \rangle$- average value and $\Delta x = \langle x^2 \rangle - \langle x \rangle^2$ find the dispersion (see photo).

Solution. Particle $0 \le x \le a$ moves in one dimension in the range. (3) using the mean value of the physical dimension, for the coordinate operator, we get the following expressions:

$$\langle x \rangle = \int_0^a \Psi^* \hat{x} \Psi dx = \frac{2}{a}\int_0^a x\sin^2\left(\frac{n\pi x}{a}\right) dx = \frac{1}{a}\int_0^a \left(1-\cos\left(\frac{2n\pi x}{a}\right)\right) x\ dx =$$

$$= \frac{a}{2} - \frac{a}{2n\pi}\left(x\sin\left(\frac{2n\pi x}{a}\right)\Big|_0^a - \int_0^a \sin\left(\frac{2n\pi x}{a}\right) dx \right) = \frac{a}{2} \qquad (7)$$

We see that the probability of being a particle is greater near the middle of the range. This result corresponds to the average value of the classical particle coordinate. dispersion of coordinate $\Delta x = \langle x^2 \rangle - \langle x \rangle^2$ determined by the formula. Since it is like above, we leave the calculation details and (6) calculate the average value of the square of the coordinate in the case:

$$\langle x^2 \rangle = \frac{2}{a}\int_0^a x^2 \sin^2\left(\frac{n\pi x}{a}\right) dx = a^2\left(\frac{1}{3} - \frac{1}{2(\pi n)^2}\right). \qquad (8)$$

In the classical case -the average value of a continuous random quantity $0 \le x \le a$ in the range

$$\langle x^2 \rangle = \int_0^a x^2 f(x) dx\ ; \qquad f(x) = \frac{1}{a+0}; \qquad (9)$$

taking into account the definition of the expression (in this $f(x) -$ distribution function),

$$\langle x^2 \rangle = \int_0^a x^2 f(x)\, dx = \int_0^a x^2 \frac{1}{a} dx = \frac{1}{a}\int_0^a x^2 dx = \frac{1}{a}\cdot\frac{a^3}{3} = \frac{a^2}{3} \qquad (10)$$

we draw attention to the fact that it is [3]. This value is determined by the principle of compatibility of boron (8) striving for the infinity of quantum numbers in expressiontirib ($n \to \infty$,that is, the transition to a continuous spectrum in large quantum numbers) can get. Using (7) and (8), we find the

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dispersion: $\langle\Delta x\rangle^2 = \langle x^2\rangle - \langle x\rangle^2 = a^2\left(\frac{1}{3}-\frac{1}{2(\pi n)^2}\right)-\frac{a^2}{4}=\frac{4a^2}{12}-\frac{6a^2}{12\pi^2 n^2}-\frac{3a^2}{12}=\frac{a^2}{12}\left(1-\frac{6}{(\pi n)^2}\right).$ (11) In this expression, too, strive for the infinity of quantum numbers according to the principle of compatibility of Discordant $(n\to\infty)$,in the classical case, it is possible to see the definition with the first had. In the classical case -continuous random quantity $0\le x\le a$ dispersion in the range.

$$D(x)=\int_0^a x^2\ f(x)\ dx-\left[M(x)\right]^2;\quad f(x)=\frac{1}{a-0};\quad M(x)=\frac{0+a}{2} \qquad (12)$$ i

considering the identification with the foda,

$$D(x)=\int_0^a x^2 f(x)dx-[M(x)]^2=\int_0^a x^2\frac{1}{a-0}dx-\left[\frac{0+a}{2}\right]^2=\frac{1}{a}\int_0^a x^2dx-\left[\frac{a}{2}\right]^2=\frac{a^2}{3}-\frac{a^2}{4}=\frac{a^2}{12} \qquad (13)$$ we

pay attention to the fact that [3].

3-Assignment. (6) the potential relay characterized by the wave function is the impulse of a particle of mass m in the N-stationary position $\langle p_x\rangle$- average value and impulse $(\Delta p)^2=\langle p^2\rangle-\langle p\rangle^2$- find the dispersion (see photo).

Solution. Like the previous one, we find the average value of the impulse:

$$\langle p_x\rangle=\int_0^a\Psi^*\hat{p}\Psi dx=\frac{2}{a}\int_0^a\sin\left(\frac{n\pi x}{a}\right)(-i\hbar)\frac{d}{dx}\sin\left(\frac{n\pi x}{a}\right)dx=-i\hbar\frac{1}{a}\sin\left(\frac{\pi n x}{a}\right)\Bigg|_0^a=0 \qquad (10)$$

It turned out that the average value of the impulse projection is zero. Based on the classical imagination, we get that even the impulse projection is zero. From the general principles it can be proved that in a case when a particle has a certain energy, its impulse will not have a definite value. In other words, in any stationary state of the discrete spectrum, the average value of the impulse is zero.

We calculate the average value of the impulse Square and the dispersion:

$$(\Delta p)^2=\langle p_x^{\ 2}\rangle=\int_0^a\Psi^*\hat{p}_x^{\ 2}\Psi dx=\frac{2}{a}\int_0^a\sin\left(\frac{n\pi x}{a}\right)(-i\hbar)^2\left(\frac{d}{dx}\right)^2\sin\left(\frac{n\pi x}{a}\right)dx=$$

$$\frac{2}{a}\hbar^2\left(\frac{\pi n}{a}\right)^2\int_0^a\sin^2\left(\frac{n\pi x}{a}\right)dx=\left(\frac{n\pi\hbar}{a}\right)=2mE. \qquad (11)$$

Here E - (4) performance. N according to classical imagination.The same result, according to the principle of compatibility of boron, namely $2mE$ gives expression, but energy $E=p^2/2m$ is understood as.

4-Assignment. The potential relay is a multiplicity of the uncertainty of the coordinateatasi and corresponding impulse projection of the particle, characterized by the wave function (6), located in the N-stationary position $\Delta x\cdot\Delta p_x\ge\hbar/2$ indicate that it is subject to inequality (see photo).

Solution. For the dispersion of the coordinate and impulse, we use (9) and (11) formulas:

$$(\Delta x)^2\cdot(\Delta p_x)^2=\frac{a^2}{12}\left(1-\frac{6}{(\pi n)^2}\right)\cdot\left(\frac{n\pi\hbar}{a}\right)=\frac{\hbar^2}{4}\left(\frac{(\pi n)^2}{3}-2\right)\Rightarrow\Delta x\cdot\Delta p_x\ge\frac{\hbar}{2}. \qquad (12)$$

even, n = 1 even when the expression in brackets is not negative and n = 2, 3, 4, and for the values will be even greater. For the particle of the potential field, too, it was proved that Geizenberg's attitude to uncertainty is appropriate [2,4].

In solving tasks, the student gets acquainted with the exact content and new concepts of the formalism of quantum mechanics, which has not yet been mastered. From classical concepts to quantum concepts " "builds a bridge". Although it is rare, solving problems that support the wave function will help the reader to get visual results, get used to new objects and update mathematical skills.

As an example, the practical issues that will be considered will allow to systematize the amount of knowledge received in the lectures. "Mavhum" quantum objects parameters and probability approaches allow you to see and determine whether they correspond to experimental results and empirical data, to study the algorithm of solving practical tasks. Explaining the basic concepts of theoretical material to undergraduate students makes it easier for them to adapt to the concept that is new to them. At the initial stage of the study of quantum mechanics mavhum it is possible to achieve certain physical results from formulas. In the future, these knowledge and skills will enable students to learn more complex problems such as learning basic quantum models.

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