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Probabilistic and Statistical Representations of Students When Teaching Quantum Physics in Academic Lyceums Formation on the Basis of Dynamic and Statistical Methods

Komil Rakhmatovich Sattarkulov

Lecturer, Gulistan State University, Uzbekistan

Email: komilsattarkulov@mail.ru

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Abstract

The article shows the content of the system of continuous education, raising the scientific level, constantly improving teaching methods, increasing the requirements for the quality of students' knowledge require physics teachers to constantly improve their knowledge and skills in the context of specialization, information technology and learning technologies, requirements for the quality of education and their requirements for advanced training, skills and methodological skills. Therefore, in this article, ideas are put forward for the formation of probabilistic-statistical concepts based on dynamic and statistical methods in teaching "Quantum Physics" in academic lyceums.

Keywords: *Probabilistic–Statistical; Dynamic Theory; Statistical Theory; Dynamics; Heat; Thermodynamic Equilibrium; Statistical Law; Probability; Events*

Introduction

All fundamental physical theories can be divided into two groups: dynamic and statistical theories. In dynamical theories, quantities obey unambiguous laws. Statistical theories are based on probabilistic–statistical laws.

In the middle of the 19th century, the question of the relationship between dynamic and statistical laws began to be raised in physics. Initially, dynamic laws have a certain superiority, the principle of the superiority of dynamic laws expresses the hidden presence of dynamic laws behind statistical laws and the objectivity of causal relationships in dynamic laws as a basis. For example, based on this principle, if it is possible to know exactly the initial state of all molecules in a gas and fully take into account the collisions of molecules, then it would be possible to determine the state of the gas without probabilistic assumptions, based on dynamic laws [1].

In this case, it would be possible to determine the gas laws for each gas molecule using the dynamic laws of classical mechanics, but the need to use statistical laws of a probabilistic nature is clearly demonstrated by the fact that the number of gas molecules is very large and it is impossible to dynamically determine the motion of each molecule. The laws of probability are relevant not only for physical systems consisting of a large number of particles, but also for individual atoms and molecules. The principle of the supremacy of dynamical laws dominated for a long time, since statistical physical theories were created much later than dynamical theories. In this case, it would be possible to determine the gas laws for each gas molecule using the dynamic laws of classical mechanics, but the need to use statistical laws of a probabilistic nature is clearly demonstrated by the fact that the number of gas molecules is very large and it is impossible to dynamically determine the motion of each molecule. The laws of probability are relevant not only for physical systems consisting of a large number of particles, but also for individual atoms and molecules. The principle of the supremacy of dynamical laws dominated for a long time, since statistical physical theories were created much later than dynamical theories.

Materials and Methods

Probabilistic–statistical ideas entered physics in the middle of the 19th century in the process of transforming molecular–kinetic ideas into consistent theories. The concept of probability was first used in physics in the 19th century, in 1859 by D. Maxwell.

Scientific works of such scientists as D. Maxwell, L. Boltzmann, R. Clausius, D. Gibbs, A. Einstein, M. Smoluchovsky are connected with problems related to the relationship of statistical and dynamic laws and physical properties of macroscopic bodies, laws of probability theory and mathematical statistics and is devoted to research based on structural models of substances.

At the beginning of the 20th century, the creation of statistical physics by D. Gibbs as an independent department of physics several times increased the importance of work in this direction. After the creation of the theory of Brownian motion (1905) by A. Einstein, M. Smoluchovsky, the statistical theory received full recognition, and using the example of Brownian motion, it was proved that statistical laws are applicable not only to a set of particles, but also to individual particles.

Statistical theories differ from dynamic ones in that they determine the content of the concept of the state of systems. In statistical theories, in contrast to dynamic theories, the state of the system is given not by the values of physical quantities, but by distribution laws. Distribution laws determine the probabilities of physical quantities taking on one or another value, and the quantities themselves are random variables that do not take specific values under given conditions.

Since the 20s of the 20th century, after the physical foundations of nonrelativistic quantum mechanics were created and quantum mechanics was formed as a science, the physics of microprocesses began to develop, quantum theories of a statistical nature and dynamical theories completely lost their original meaning [2].

Fundamental statistical theories, such as quantum electrodynamics, the theory of weak interaction, quantum chromodynamics, were created on the basis of quantum mechanics and are currently developing rapidly. Based on the above theories, a deeper insight into the essence of matter requires a transition from dynamical theories to statistical theories.

An analysis of the history of the creation of fundamental physical theories shows that dynamical theories correspond to the first stage of human cognition of nature, while statistical theories play a major role at later stages.

So, in conclusion, a comparison of probabilistic laws with dynamic laws shows that statistical laws are deeper, more fundamental laws.

Results and Discussion

Below we will dwell on the issues of penetration and development of probabilistic–statistical ideas into the quantum–physical branch of physics [3].

The first works in this direction were associated with the study of the properties of thermal radiation based on the statistical method, which expanded the boundaries of the application of statistical physics and thermodynamics and led to the introduction of new ideas in physics. In the works of M. Planck, thermal radiation was considered as a result of the emission and absorption of electromagnetic waves by these substances, the laws of classical electrodynamics and thermodynamics were applied to the study of thermal radiation. Working in this direction, M. Planck developed the ideas of S. Boltzmann and obtained the famous formula for the spectral density of radiant energy.

Based on the work of M. Planck, the concept of "Quantum of energy" is introduced as a discrete portion of energy, the concept of discreteness of energy is associated with the "Quantum of action" – (Planck's constant).

In the work of M. Planck, discreteness was studied as a property of matter, and in his study only the energy of oscillators was studied, and radiation was studied as a constant phenomenon in the form of an electromagnetic wave. In these works, the absorption of the energy field of the electromagnetic field in the form of small portions and main acts was not considered, although attention was paid to the issue of determining the spectral distribution of the equilibrium scattering energy [4].

A. Einstein (1905) introduces the idea of the discreteness of energy radiation or the "light quantum" hypothesis, which has two sides, namely, firstly, the idea of what constitutes a reflection from indivisible and scattered measurements, and secondly, the idea of discreteness of elementary processes based on this idea [6].

On the basis of this theory, A. Einstein discovered the corpuscular theory of light, later, as a result of the development of the quantum theory of light, put forward the theory of corpuscular–wave dualism of light. De Broylie applied and generalized the idea of wave–particle duality for microparticles, that is, matter. A. Einstein's analysis of the elementary processes of emission and absorption of radiation played an important role in the development of the quantum theory of atoms and molecules. An important stage in the creation of the theory of microscopic phenomena is associated with the work of N. Bohr on the application of quantum ideas, that is, ideas about the quantization of the energy of matter, the discreteness of radiation and absorption, to atoms (for the first time, the simplest atom, the hydrogen atom) and molecules, and in these works, stationary states, different from the frequency of motions in the system, new ideas about the frequencies of quantum transitions were introduced [7].

N. Bor used the atomic model proposed by E. Rutherford in 1911 to create a theory of the hydrogen atom. This model basically considers an atom to consist of a nucleus and electrons moving around it, since energy is lost to radiation due to the accelerated movement of electrons, this model cannot explain the stability of atoms based on classical laws. To solve this problem, N. Bohr introduces two of his postulates. Based on these two postulates of N. Bohr's theory, it is possible to explain a large amount of experimental material (the physical laws of spectra, the periodic law of chemical elements). Although this theory of N. Bohr was confirmed by experimental materials, it did not have a solid theoretical basis [8].

In N. Bohr's theory, quantum conditions are artificially imposed on the motion of electrons in stationary states according to classical laws.

A. Einstein's work on radiation problems used Bohr's theory for the hydrogen atom. Based on the problem of thermodynamic balance between the boron atom and radiation, he statistically proved Planck's formula for the spectral energy density of black body radiation, based on quantum concepts, and these works played a big role in the further development of quantum theory.

In Einstein's work on the theory of radiation, questions of spontaneous and stimulated emission and absorption were also considered, and it was proved that the probability of absorption is equal to the probability of stimulated emission.

Of great importance in the development of quantum images are also the works of De Broglie, in which the motion of a particle is compared with the motion of a wave moving with a certain phase velocity, and on the basis of wave images the conditions are determined, the quantization of the angular momentum in Bohr's theory is determined, and expressions are obtained for the condition for the quantization of circular orbits.

It is known that the concept of De Broglie waves is one of the most difficult concepts to master when studying quantum mechanics, since De Broglie waves are not like any of the electromagnetic, elastic and other types of waves known from classical physics, as they have a probabilistic nature. The physical content of De Broglie waves is based on the corpuscular-wave dualism of microparticles and probabilistic–statistical ideas and concepts. The physical, statistical content of the De Broglie wave is given by Born on the basis of probabilistic assumptions.

In M. Born's fundamental research on the theory of collisions, the question of the physical content of the wave function is considered and its probabilistic–statistical interpretation is given. The wave function proposed by N. Born is based on the idea of A. Einstein about the connection of light quanta with the wave field.

The coordinate and time–dependent wave function of all microparticles in the system was considered by Born as a solution to the Schrödinger equation or "Probability Wave". One of the most important relationships in the early development of quantum physics is the Heisenberg uncertainty relation. The corpuscular–wave dualism of the nature of microparticles, studied in quantum physics, shows that the spatial coordinates representing the state of microparticles and the corresponding momentum projections cannot take on exact values simultaneously. In this section, we have considered the introduction of quantum ideas into physics and the sequence of their historical development; on this basis, we will analyze the formation of probabilistic–statistical representations in quantum physics.

Quantum concepts, concepts of quantum theory, which have entered physics since the 20th century, have led to the emergence of new ideas and new methodologies. The formation of quantum physics as a science requires a comparison and evaluation of the role of dynamic and statistical laws, a change in the nature of physical models, and the rejection of concepts and ideas that have become common to many.

Conclusion

The description of quantum physics is not always easy to cover in one answer. Quantum physics is a theory that describes the properties of matter at the level of micro–phenomena and studies the laws of motion of micro–objects (molecules, atoms, elementary particles).

At the same time, quantum physics is considered the theoretical basis of knowledge about the properties and structure of matter and the field and studies the properties of matter at a deeper and more fundamental level than classical physics. When explaining to students in academic lyceums the field of studying quantum physics, the statement that classical physics is appropriate in the "Macroworld", and quantum physics in the "Microworld", leads to the formation of students' opinions about the existence of a separate "Macroworld" and a separate "Microworld" in nature. Rather, it is desirable to form an idea of the existence of macroobjects (macro–events), micro–objects (micro–events), since macro–objects consist of micro–objects. At present, the above ideas are not fully expressed in textbooks and teaching aids recommended for study in academic lyceums.

Thus, the amount of methodological literature aimed at improving the effectiveness of teaching aids for "Quantum Physics" academic lyceums is practically absent. It is desirable to radically improve the quality and efficiency of teaching the course of physics in general and quantum physics in particular in the educational course for academic lyceums, aimed at an in–depth study of physics.

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