COMPARATIVE ANALYSIS OF CLASSICAL AND QUANTUM REPRESENTATIONS IN TEACHING PHYSICS

J.M.Abdullaev
Senior teacher, Navoi State Pedagogical Institute
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Abstract. *The article provides a comparative analysis of classical and quantum statistics. The general properties and differences between the statistics of Maxwell and the statistics of Bose-Einstein, Fermi-Dirac from the methodological point of view are revealed.*
Keywords: *classical and quantum statistics, continuity, competence, correspondence principle, Maxwell statistics, fermions, bosons.*

The development of modern engineering and technology poses urgent tasks of teaching physics in the preparation of future specialists in the national economy. One of these tasks is the advanced teaching of physics, which requires a detailed analysis of each topic and the physical phenomena associated with it. In the implementation of this task, the use of improved teaching methods is important. These methods include interdisciplinary communication, integration with production, scientific substantiation of the phenomenon under study, which lead to an increase in the competence of future specialists. One of the ways to improve the competence of future specialists is to analyze the continuity between theory and experiment, between the stages of training in the system of continuous education, as well as between old and new theories.

This paper analyzes the continuity in the formation of statistical concepts at various stages of lifelong education.

Statistical physics in its present form is quite complex and therefore difficult to access for pupils and students. Therefore, to study the foundations of statistical physics, it is necessary to form the ideas of statistical physics at the early stages of education [2, p.22]. The initial concepts of statistical physics are formed during laboratory classes in mechanics, where we deal with measurements of certain quantities and conduct numerous experiments to evaluate measurement errors. At the same time, students are confronted with the concepts of absolute and relative error, average value, probability. It is at this stage that students realize that the average value is the value of the greatest probability and that the average value of the measured value is often taken as the true value, and that with an increase in the number of measurements, measurement errors can be reduced.

Further development of the formation of statistical ideas is associated with the study of molecular physics and thermodynamics. in this section we are dealing with a multitude of atoms and molecules, all phenomena under study obey statistical laws. The physical parameters characterizing these phenomena often have a statistical character and are an integral characteristic. The formation of statistical ideas and concepts in the study of various branches of physics and their different features are shown in Table 1.

Table 1. Formation of statistical ideas in the study of various branches of physics.

General physics course				
Mechanics	Molecular physics	Electromagnetism	Optics	Atomic and nuclear physics

Evaluation of the results of physical measurements, introduction of the concept of average value	Introduction of the concept of average speed. Statistical interpretation of the main thermodynamic parameters	Chaotic motion of charged particles. The principle of superposition of electro-magnetic fields	Corpuscular-yarno wave dualism of light. Interference and diffraction of light	Movement electrons and nucleons. Radioactivity

It is necessary to state the role of studying the laws of probability theory in the formation of statistical ideas in the study of physics. It is the theory of probability that serves as the mathematical basis for studying the regularities of physical processes. The main task of the probability theory is to determine the distribution function of the process under study, which can be the distribution of energies, velocities, etc.

When teaching physics in the next stages, it is necessary to point out the difference between classical and quantum statistics. Similarities and common properties, as well as differences between classical and statistical physics can be indicated in the Venn diagram (Fig. 1).

Fig.1. Comparative Venn diagram of classical and quantum statistics.

As can be seen from the diagram, there is also a correspondence principle between the classical and quantum theories, which means the coincidence of the results obtained from these theories in the boundary states.

Quantum statistics, in turn, is divided into Bose-Einstein and Fermi-Dirac statistics, which describe the behavior of elementary particles with integer and half-integer spins, respectively. The classical and quantum distributions can be expressed in a general way by the expression:

$$n_i = \frac{1}{e^{\frac{W_i-\mu}{kT}}+\delta}$$

Where $W_i -$ is the energy of the system; μ- chemical potential; k- Boltzmann constant; T is the temperature of the system; $\delta = \pm 1 -$ depending on the kind of statistics.

From this generalized statistical distribution formula, by changing the values of μ and δ, one can obtain the functions of a specific distribution, which are indicated in Table 2.

Table 2. Comparison of expressions for the classical and quantum distribution functions.

General function	Maxwell-Boltzmann statistics ($\mu = 0, \delta = 0$)	Bose-Einstein statistics ($\mu < 0, \delta = -1$)	Fermi-Dirac statistics ($\mu > 0, \delta = +1$)
$n_i = \frac{1}{e^{\frac{W_i-\mu}{kT}} + \delta}$	$n_i = \frac{1}{e^{\frac{W_i}{kT}}}$	$n_i = \frac{1}{e^{\frac{W_i-\mu}{kT}} - 1}$	$n_i = \frac{1}{e^{\frac{W_i-\mu}{kT}} + 1}$

A comparison of the behavior of the above energy distribution functions for a fixed temperature is shown in the graph in Fig. 2[3, p.379].

With Maxwell's staistics, the individuality of particles is preserved. Bose-Einstein and Fermi-Dirac statistics are based on the principle of particle identity. In addition, the Fermi-Dirac statistics also obeys the Pauli principle.

From the chemical potential expression $\mu = \theta \ln \frac{n\hbar}{(2\pi m\theta)^{3/2}}$ It can be seen that at sufficiently high temperatures$\frac{n\hbar}{(2\pi m\theta)^{3/2}} \ll 11$ and the Bose-Einstein and Fermi-Dirac distributions go over to the Maxwell-Boltzmann statistics. At low temperatures, the classical and quantum distributions differ sharply. As can be seen from Fig.1. all distribution curves converge exponentially to the x-axis.

At absolutely zero temperature, the distribution curves are strongly deformed: the Bose-Einstein distribution curve is completely attracted to the y-axis; the Fermi-Dirac curve takes a quadrangular shape with coordinates (1; μ) which means that the particles are in the lowest states at zero temperature, taking into account the Pauli principle.

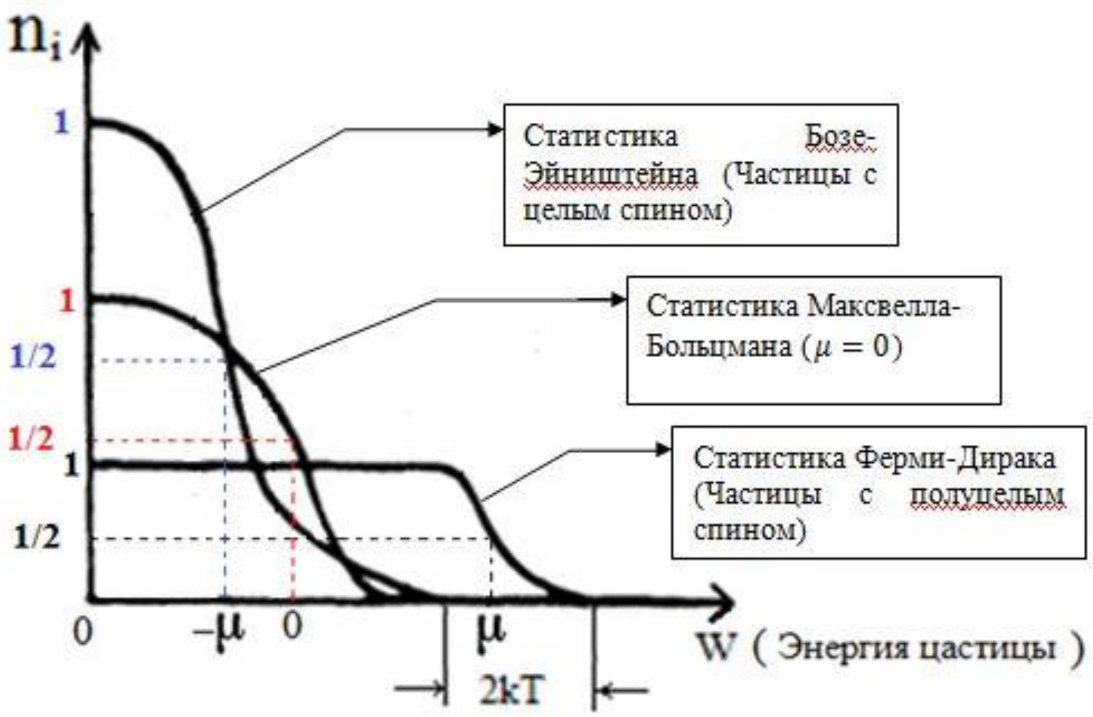

Fig. 2. Generalized graph of classical and quantum distributions.

The formation of statistical representations is carried out on the basis of the principle of continuity even in high school and academic lyceums when studying various sections of the physics course: in mechanics - when processing experimental results of laboratory classes, when assessing measurement errors; in molecular physics, when studying the distribution of molecules in terms of velocities (Stern’s experiments, Maxwell's distribution); in the course of electromagnetism - in the study of the process of current flow in metals, the distribution of electric charges; in atomic and nuclear physics - in the study of the phenomenon of radioactivity, the uncertainty principle, etc.

A comparative analysis of the regularities of classical and quantum statistics serves as the basis for the formation of knowledge on the fundamental laws of nature by in-depth study of statistical distributions in the preparation of future physics teachers in pedagogical universities.

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