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Concepts and methods in quantum theory

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Quantum theory: concepts and methods
by A Peres (Dordrecht–Boston–London: Kluwer Academic Publishers, 1993)
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Russian readers have always had a good choice of books on quantum mechanics. *Wave mechanics* by Ya I Frenkel' was one of the first such detailed books on the subject in the world literature. After that the books *Course on quantum mechanics* by V A Fock, *Quantum mechanics* by D I Blokhintsev, and *Quantum mechanics* by L D Landau and E M Lifshitz, the third volume of the series "Theoretical physics", were added to this list. Translations of good foreign books have also been published. All the editions of *Fundaments of quantum mechanics* by P A M Dirac and, for example, a very popular monograph by L I Shiff were translated into Russian. The distinctive feature of most of these books and especially of Landau and Lifshitz' course is their 'practical' orientation. The exposition is such as to prepare the reader to solve numerous quantum-mechanical problems used in very different fields of pure and applied physics. That is why the aforementioned books of soviet authors have also been widely recognized abroad too.

It is essential, however, that the notion of 'practical orientation' changes with time. Dramatic progress in experimental physics, primarily in quantum optics, made it possible to realize the experiments that have been considered for a long time, for example those discussed by Einstein – Podolsky – Rosen and Bohr. Works by Bell and his adherents stimulated experiments with 'non-traditional' settings. At last, the technical applications of the 'finest' features of quantum mechanics having no classical analogs have recently become actual. Here we speak about the construction of quantum computers, the quantum transfer of information, and message encoding. All these have strengthened the interest in those fields of quantum theory that are not sufficiently studied in the aforementioned monographs. The reader must turn to other books.

One of the new books that treat quantum mechanics 'differently' and give much attention to the novel questions and problems is the recently published *Quantum theory: concepts and methods* written by A Peres, an expert in the fundaments of quantum mechanics and in quantum informatics.

The author begins with a detailed and original presentation of the theory of quantum measurements. Then the mathematical apparatus of the theory in its abstract representation is presented. The reader used to the conventional presentation of quantum mechanics will of course find it strange that the Schrödinger equation first appears on page 239, according to the subject index. (In fact it is already used in the exercise on page 81.) The presentation however is fully consecutive and specifically attractive. After that the theory of quantum correlations is given.

Two small chapters are devoted to Bell's theorem and related problems. These chapters are the central part of the book. The corresponding difficult problems are presented clearly and in detail. Here the author describes the sophisticated experiments that proved that Bell's inequalities and the analogous inequalities of Clauser – Horne – Shimoni – Holt, which follow from admitting the existence of the hidden parameters, are reliably excluded by direct measurements. This also excludes the possibility of explaining quantum randomness by a more refined stochastic dynamics of a subquantum world, i.e. on the basis of hypothetical equations of hidden parameters dynamics. From the practical point of view this means the final confirmation of the Copenhagen school interpretations, as well as the nonlocality of quantum theory (considered together with quantum correlations during measurements).

Part III, which represents almost half the book, is called "Quantum dynamics and information". In the book, quantum dynamics is first of all related to symmetry properties and is presented as a theory of the corresponding unitary transformations.

Then the author considers the relation of quantum dynamics to statistical mechanics and the information theory and introduces the notion of entropy. In the same chapter the author speaks of the intriguing problems of quantum cryptography and of 'teleportation', i.e. of the transmission of information on the quantum state. In particular, here a proof of the impossibility of copying an arbitrary state of a quantum system is given. Of special interest is the section about the impossibility of measurements of non-orthogonal states — otherwise a contradiction of the second law of thermodynamics would arise. Unfortunately, these questions are comparatively briefly discussed.

The chapter on quasi-classical methods is very interesting. Here the reader can find many useful things, for example, information on the properties of Wigner's distribution function.

Then the author discusses chaotic motion in classical and quantum mechanics. In order to read this chapter one needs a sufficient knowledge of classical chaos theory, but the presentation here is specific and clear.

The last chapter is devoted to a detailed theory of measurements. This is a very subtle question and the reader will find many interesting things here. The author's point of view does not always coincide with the classical point of view of von Neuman. But the author emphasizes "this book considers only the standard quantum theory that physicists actually use to predict and analyze experimental results". As is well known, the problem of measurements in quantum theory is one of the most difficult from the logical point of view. The ultimate theory of measurements has not yet been constructed.

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The book by Peres clarifies this point but does not create a feeling of its final solution. Therefore many physicists who hold, according to the author's terminology, to the position of 'naive realism', will prefer to wait for the appearance of a fuller and more detailed theory of measurements.

This book can hardly be recommended for a first acquaintance with quantum mechanics. But the book is very useful for those who want to make their knowledge of the subject deeper. In addition, a vast quantity of problems, mostly not very difficult, considerably facilitates an autonomous study of the text. Reading the text one always feels that the book is written by a specialist who knows the material very well and on whose opinion one can rely. It would be worthwhile, if possible, translating the book into Russian, especially in view of the high price of the original English edition.

The book on the nature of the ball lightning

V D Shafranov

On the physical nature of the ball lightning. I P Stakhanov (Moscow: Nauchnyj Mir, 1996) p. 264
PACS numbers: **52.80.–s**, **52.90.+z**

The Russian Fund for Basic Research made a very big and useful affair by having supported a new post-mortem edition of the book by I P Stakhanov *On the physical nature of the ball lightning* (project 96-02-30084). All the content of the 1985 edition, which became a bibliographic rarity, is conserved in the new edition and some additions are included. First of all, these are materials of studies made by I P Stakhanov himself which have not been included into the previous edition and were partially published in the periodicals and partially unpublished at all and restored by I G Stakhanova using the author's archive. The afterword is written by O A Sinkevich and reviews the current status of the problem.

The book provides a serious analysis of the eyewitness descriptions of rarely observed, mostly during lightstorms, luminous phenomena with a high energy storage that is called ball lightning. The statistical analysis of the results of an unprecedentedly broad poll of the eyewitnesses made by the author through the monthly *Nauka i zhizn'* (Science and Life) by the initiative of S L Lopatnikov and I P Stakhanov and the comparison of these studies with the material collected in other countries allows the sufficiently definite conclusion about the most probable external characteristics of the phenomenon, including the duration of the existence (up to tens of seconds), the diameter of the ball lightning (10 – 15 cm), its color (mostly orange or white), and others. The statistics of these data together with the analysis of the ball lightning behavior make little probable the point of view of the sceptics that this is an apparent phenomenon connected with a peculiarity of the physiology of the eye vision, and the reader, after the author, becomes completely sure that this phenomenon really exists. The secondary information deduced from the descriptions with taking into account physical laws concerning the density, temperature, energy, surface tension, electromagnetic radiation in different bands and other appearances of the electromagnetic properties of the ball lightning, allows the author to formulate main criteria the hypotheses on its nature suggested at different time must meet, and to criticise the hypotheses contradicting the estimates of the aforementioned physical parameters.

The book also describes the cluster hypothesis suggested by I P Stakhanov himself in 1973 – 1975, which appears to me the most natural and argumented in comparison with other hypotheses. According to I P Stakhanov's idea, the ball lightning consists of an unusual plasma — a mixture of positive and negative ions surrounded by neutral molecules with a large dipole momentum (for example, molecules of water). According to the idea, the molecular coating impedes the recombination of the ions, which explains the prolonged existence of the plasma in a metastable state. The estimates given by the author, which can be traced by the reader with a sufficient background in physics, self-consistently explain many peculiarities of the ball lightning behavior under minimal assumptions about still unknown properties of the cluster plasma. A review of work done in the last 10 years that appeared already after the death of I P Stakhanov confirms these estimates (see the afterwords).

The main part of the book is available for the broad reader. Written with enthusiasm by a live language, the book is read with a great interest. The critical author's discussion of the existing information on the properties of the ball lightning teaches the reader and possible future observers the scientific approach to the consideration of similar phenomena. And the increase in the cultural level of the eyewitnesses, as the author correctly notes at the beginning of the book, should impact the quality of the information reported. It in this way that one should expect the progress in solving the mystery of a phenomenon, at least until it cannot be reproduced in the laboratory conditions. However, as follows from the book, the present level of understanding of the problem makes no doubts in the necessity to stimulate the laboratory researches. It is not excluded that the demystification of the ball lightning could lead to the construction of novel means of the energy storage.

The first editions of I P Stakhanov's book received positive estimations in the literature in reviews by prof. A A Rukhadze [*Usp. Fiz. Nauk* **131** (1) 75 (1980)], by Dr. V I Kogan [*Priroda* (8) 124 (1980)], etc.

I completely join these estimations and believe that the book represents a really significant contribution to studies in the long-known but rare natural phenomenon. Its value is not only in acquainting the reader with this phenomenon and its possible explanations, but primarily in that in fact it teaches the correct methodological approach in studying the problems similar to those discussed in the book.

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