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CALCULATIONS AND NON-NEGATIVE DISTRIBUTIONS IN APPLIED MECHANICS

Dr. Z. Abdul Rahim
Associate Professor, Department of Civil Engineering,
Maulana Azad National Urdu University, Hyderabad
Email id: dr.zabdulrahim@gmail.com

Abstract: Problems with the measurement device's interface with the micro system are still unsolved. The focus shifted from the device's effect on the system's state at the start of quantum mechanics to the inverse problem, which is fundamentally more traditional: how micro-objects affect the macro-system's state. Multiple interconnected links make up measuring equipment. The first two cascades can be quantum, according to quantum theory of measurements, but the third and final one must be classical, or, to use modern language, an analyzer and a detector. Incorporating such a method of measuring devices into the quantum mechanical framework is the subject of this research. In fact, the measurement process and measuring devices can and should be linked to test functions in quantum mechanics with nonnegative distribution functions (QDF in quantum mechanics Kuryshkin-Wodkevich). We argue that these operations should be associated with the measuring device and explain how it communicates with the rest of the system. The fact that the Hamiltonians in QDF are not Hermitian conveys this link, as it turns out. Consequently, the QDF is gradually coming together as a quantum theory of measurements, after a long time of being portrayed as an alternate and exotic quantum theory. The significance of this formalization in the context of quantum measurement theory was recently elaborated in our publications. Within the context of studying quantum entanglement, the comparisons between wave functions in the examples of D. Blokhintsev's measuring instruments and auxiliary functions in QDF theory are encouraging. These areas of research have the potential to greatly advance quantum cryptography. In this regard, this work ought to serve as a watershed moment in the QDF's transition to new uses.

Keywords: Quantum mechanics, non-negative quantum distribution function, quantum measurements

I. INTRODUCTION

Quantum computing based on the correct processing of quantum information is a promising branch of research. Re- search leads to the conclusion that progress here is impossible without revising the foundations of quantum theory in terms of information theory [1]. On the other hand, there is an enrichment of the quantum theory from the developing theory of communications and information processing. Experimental research is largely focused on the study of quantum cryptography [1]– [9]. In 1984, Bennett and Brassard presented an idea of using quantum mechanics for cryptography, called quantum key distribution (QKD) [7]. The question was posed as follows: how to ensure the safety of information transmission, by complicating coding algorithms or by using quantum laws? The second option was preferred [8]. Clearly, such advantages of QKD over conventional coding methods have stimulated active research [5]. Although quantum cryptography and QKD seems fascinating field of research, it needs collaborative efforts from diverse fields of physics [4], including first of all theory of quantum measurements, since information (bits) is written, transformed and read by manipulating and measuring the quantum states of photons [5]. Thus, the need arises to involve the entire spectrum of approaches, including alternative ones, for studying quantum measurements as applied to cryptography. Quantum mechanics with non-negative distribution function (QDF) is an alternative physical theory with a developed theoretical formalism [10]– [13]. However, until now, there have been practically no calculations of real systems based on this formalism. The reason is that the mathematical formalism of QDF is much more complex than that of conventional quantum mechanics. In particular, the formalism includes the calculation of com- plex multidimensional integrals. As a consequence, analytical calculations, in particular of spectra, are problematic. In such cases, it is of interest to combine analytical and numerical methods implemented in a single software package. Then, if with the help of QDF results for specific systems are obtained, numerically close to those obtained by conventional quantum mechanics, this will serve as a weighty basis for the statistical and measurement interpretation of quantum mechanics of communications and information processing. Experimen tal research is largely focused on the study of quantum cryptography [1]–[9]. In 1984, Bennett and Brassard presented an idea of using quantum mechanics for cryptography, called quantum key distribution (QKD) [7]. The question was posed as follows: how to ensure the safety of information transmission, by complicating coding algorithms or by using quantum laws? The second option was preferred [8]. Clearly, such advantages of QKD over conventional coding methods have stimulated active research [5]. Although quantum cryptography and QKD seems fascinating field of research, it needs collaborative efforts from diverse fields of physics [4], including first of all theory of quantum measurements, since information (bits) is written, transformed and read by manipulating and measuring the quantum states of photons [5]. Thus, the need arises to involve the entire spectrum of approaches, including alternative ones, for studying quantum measurements as applied to cryptography. Quantum mechanics with non-negative distribution function (QDF) is an alternative physical theory with a developed theoretical formalism [10]. However, until now, there have been practically no calculations of real systems based on this formalism. The reason is that the mathematical formalism of QDF is much more complex than that of conventional quantum mechanics. In particular, the formalism includes the calculation of com- plex multidimensional integrals. As a consequence, analytical calculations, in particular of spectra, are problematic. In such cases, it is of interest to combine analytical and numerical methods implemented in a single software package. Then, if with the help of QDF results for specific systems are obtained, numerically close to those obtained by conventional quantum mechanics, this will serve as a weighty basis for the statistical and measurement interpretation of quantum mechanics.

II. IMPLEMNATION AND RESULTS

The program is written up in the language MAPLE according to the algorithm described in [15]–[17] and in references therein. The Fig. 1 above presents the general scheme of the program. It consists of nine stages. In the first block, the initial required functions are calculated (Spherical harmonics, Clebsh-Gordan coefficients etc). In the second block, expressions for the potential energy operators are calculated (according to the rules of the QDF theory). The third block calculates the corresponding kinetic energy operators. In the fourth block, the elements of the Ritz matrices are calculated. The fifth block generates the program code of the Ritz matrices for possible subsequent use elsewhere. In the sixth block, the spectrum of the Hamilton operator in a hydrogen-like atom is calculated. The seventh block is devoted to the optimization of model parameters for hydrogen. Similarly, in the eighth block, the parameters are optimized for alkali metals. Finally, in the ninth block, the transition probabilities are calculated, which are intended for comparison with the experimental values.

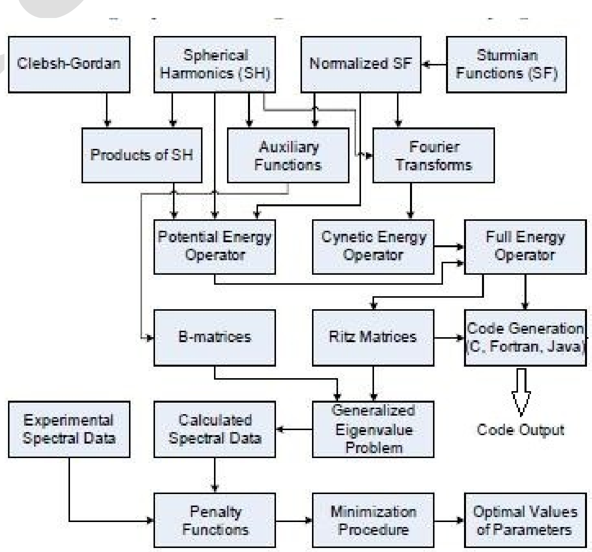

Fig. 1. The global structure of the program.

Matrix elements of Ritz matrices are computed and written to external files. As is known, the method consists in finding the eigenvalues of the Ritz matrices, which represent the spectrum, i.e. energy levels. The algorithm consists in solving the generalized eigenvalues problem $M\vec{x} = \lambda B\vec{x}$ where M is a Ritz matrix and B is the matrix of pair-to-pair scalar products of coordinate functions. In general, the program can build and process Ritz matrices of any dimension. However, for large matrices, computational and performance limitations come into play. Currently, calculations with dimensions 55 and 91 are available. The parameter E_0 is adjustable. For example, Figs. 2 and 3 show the dependence of the residuals on E_0 for the first levels of lithium and sodiumatoms.

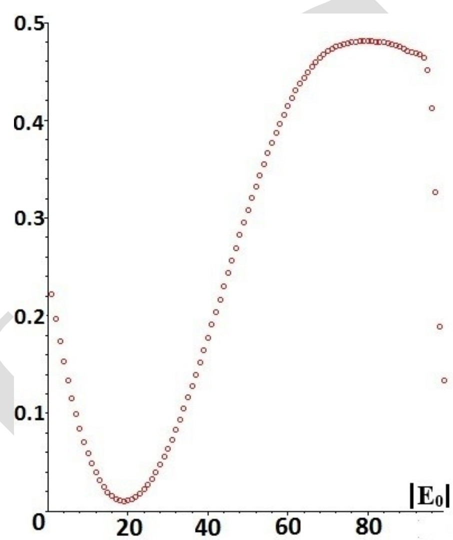

Fig. 2. Plot of the dependence of the relative quadratic discrepancy between the calculated and experimental values of the energy levels for the first eight levels of the lithium atom.

D.I.Blokhintsev [8] gave several examples of calculating specific measurements as interacting quantum systems (as De Witt and Graham noted, "...this book is a fascinating presentation of quantum mechanics and contains a brilliant consideration of measurement theory"). In particular, lecture 12 discusses the simplest example of a measuring device that determines the direction of movement of a microparticle with mass μ. Its initial state is a superposition of two plane waves here x is the particle coordinate, k is its momentum, andthe purpose of the device is to determine the sign.

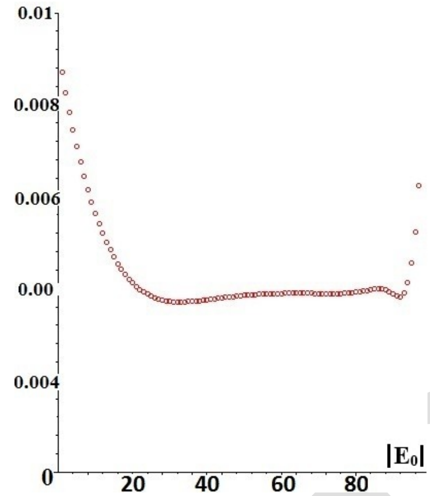

Fig. 3. Plot of the dependence of the relative quadratic discrepancy between the calculated and experimental values of the energy levels for the first four levels of the sodium atom.

It is shown in [8] that after scattering of a particle by a detector, it finds itself in two states that do not interfere witheach other. One of them corresponds to the movement to theright ($P > 0$), and the other to the movement to the left ($P < 0$), and it depends on the state in which the detectedparticle scattered by the detector: having a pulse $+k$ or a pulse K.

The first of these waves depicts scattering by atom A and its possible excitation (if n = 0), while atom B is not involved in the process. The second wave means the same scattering by atom B. Thus, the device violates the interference of states with various possible positions of the electron (near Q1 or near Q2) and and thus can be viewed as a an analyzer of the state of the electron. An excited atom (for example, A) can transfer its excitation energy to the neighboring atoms of the medium, which leads to heating of the neighborhood of A, and as a result, to local boiling of the liquid in the bubble chamber. Thus, irreversible processes arise that play the role of a detector. It is important for us to compare expressions (1)   (6) and (13)   (17), from which it follows that the functions φn(y Q) in this example just play the role of basic functions in QDF. They describe a measuring device.

III. CONCLUSION

In this work, it is shown that test (auxiliary) functions in quantum mechanics with nonnegative distribution functions (quantum mechanics Kuryshkin-Wodkevich - QDF), in fact, can and should be associated with the measurement process and measuring instruments. It turns out that exactly the non- Hermitian character of the Hamiltonians in QDF expresses this connection. Thus, the QDF, which has long been positioned as an alternative and exotic quantum theory, is increasingly taking shape as a quantum theory of measurements. The analogies of auxiliary functions in the QDF theory with wave functions in the examples of D. Blokhintsev measuring instruments mentioned in this paper, are promising areas of research which, in the framework of the study of quantum entanglement, can give a significant impetus to the development of quantum cryptography. This work, in this sense, should become a turning point in this reversal of the QDF to new applications. Numerous discussions with Leonid Sevastyanov about all related problems are highly appreciated.

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