Quantum Mechanical Probabilities Not Restricted to a Moment of Time(Abstracts of Doctral Dissertations)

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Quantum Mechanical Probabilities Not Restricted to a Moment of Time

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Abstract

Chap. I. Introduction
The standard quantum theory viewed as a probability theory has a special property. That is, probabilities are defined only for alternatives at a single moment of time. Then the following question arises: Is it possible to define quantum mechanical probabilities for alternatives not restricted to a single moment of time? This is the theme of this thesis. In this chapter we explain the aim and the background of this thesis and give an outline of the construction of it.

Chap. II. General Framework
A general framework is constructed which judges whether or not quantum mechanical probabilities can be defined for a given ES (Event Space). The framework provides two conditions: the classifiability condition (C·1) and the no-interference condition (C·2). C·1 requires that the propagator for the particle is decomposable into "components" each of which is associated with each alternative of the ES. C·2 is the consistency condition between the superposition principle for amplitudes and the sum rule for probabilities; it requires vanishing of interference between different components.

Chap. III. Euclidean Lattice Method
Euclidean lattice method is a mathematical technique which gives a new definition to sum over paths, a definition which may be wider than that of Feynman's path integral in configuration space. In Feynman's path integral, time is skeletonized but space is continuous. By contrast in Euclidean lattice method, we go over to Euclidean time and skeletonize not only time but also space, making Euclidean spacetime lattice. A random walk is defined on the lattice; a discrete sum over paths is introduced which sums up random-walk probabilities over discrete paths of the walk. The sum over paths in configuration space is then defined by Wick-rotating the "diffusion limit" of the discrete sum over paths. This technique was developed by Hartle for a free particle. This chapter reviews and extends it to the case of a nonzero potential. Some formulae are also provided for later use. The Euclidean lattice method makes the general framework developed in the previous chapter applicable to concrete examples of ES.

Chap. IV. Application of General Framework to Concrete Examples (I)

∼probability-undefinable cases∼

General framework is applied to ESI∼III with the help of the Euclidean lattice method. Negative results are obtained. For ESI and II, it is proved that C·1 (path-classifiability condition) does not hold. For ESIII, C·1 holds but C·2 (no-interference condition) is not satisfied. Therefore quantum mechanical probabilities cannot be defined for these three ES. It is discussed that whether C·1 holds or fails is governed by two factors: the non-differentiable property of virtual paths and the "coarseness" of alternatives.

Chap. V. Application of General Framework to Concrete Examples (II)

∼probability-definable cases∼

General framework is applied to ESIV and V with the help of the Euclidean lattice method. Positive results are obtained. As predicted in the previous chapter, C·1 holds for ESIV and V. In each case it is shown that there exists a specific class of initial amplitudes for which the interference vanishes between different alternatives. Therefore C·2 holds and probabilities can be defined if an initial amplitude belongs to the specific class. Values of probabilities are calculated. It is argued that, owing to the restriction of an initial amplitude, resultant probabilities are interpretable within the familiar measurement theory and they gain clear measurement theoretical meanings which are becoming to the values of the probabilities.

Chap. VI. Summary, Discussion and Remaining Problems

The study is summarized. Several questions are discussed which may arise. Remaining problems are also posed.