

Outline of the method

§3

The key to the possibility of such an interpretation lies in the notion of correlations between subsystems of composite systems, and its proper exploitation, which are described by state functions.

Subsystems of such composite systems do not, in general, possess an independent state function. That is, in general a composite system can not be represented by a single pair of subsystem states, but can be represented only by a superposition of such pairs of subsystem states. For example, the Schrödinger wave function for a pair of particles, $\Psi(\underline{x}_1, \underline{x}_2)$, cannot generally be written in the form $\Psi = \phi(\underline{x}_1)N(\underline{x}_2)$ but only in the form $\Psi = \sum_i a_{ij} \phi^i(\underline{x}_1)N^j(\underline{x}_2)$. In the latter case there is no single state (wave function) for particle 1 alone or particle 2 alone, but only the superposition of such cases. In fact to any arbitrary choice of state for one subsystem there will correspond a (relative) state for the other subsystem, ^{which will generally depend upon the chosen state for the first} so that the state of a subsystem is not independent, but correlated to the state of the ^{first} ~~other~~ subsystem. Such correlations between systems arise from interaction of the systems, and from our point of view all measurement and observation processes are to be regarded simply as interactions between the observer or measuring apparatus and object-system which produce strong correlations.

It is then a consequence of regarding the observer as a subsystem of the composite system observer+object-system that after interaction there will not, in general exist a single observer state, but a superposition, each element of which

^{relative} contains a definite observer state and a corresponding object-system state. It is also a consequence of the superposition principle for state functions that if the observation is performed upon an object system not in an eigenstate of the measurement, that the result will be a superposition of states, each of which describes an observer which has obtained a different result of observation, and for which the ^{relative} system state is nearly the eigenstate corresponding to the observed result, the whole superposition being combined with the coefficients of the expansion of the original object system ^{state} in terms of the eigenfunctions of the measurement. Thus each element of the resulting superposition describes an observer to whom it appears that the ^{object state} system has been transformed into ^{the corresponding} an eigenstate. It is in this sense that the usual assertions of Process I appear to hold on a subjective level to each observer described by an element of the superposition. We shall see also that correlation plays a fundamental role in preserving consistency when several observers are present, and are allowed to interact with one another as well as other object systems (compare notes).

Since in actuality all interactions are of a finite character, and all measurements imprecise to some degree, we shall want to be able to speak of the degree of correlation between systems, as well as to be able to use such phrases as a state function is nearly an eigenfunction, or an operator A has a nearly definite value,

In order to develop a language for interpreting our pure wave mechanics for compound systems we shall find it useful to develop precisely the quantitative definitions of such notions as the sharpness of a state function ψ to an eigenfunction of an operator A , i.e. "the sharpness of A ", and the degree of correlation between subsystems of a composite system, or of pairs of operators in the subsystems, so that we can use these notions in an unambiguous manner. The mathematical development of these notions will be carried out in the next chapter (II) using some concepts borrowed from information theory. We shall develop general definitions of information and correlation, as well as some of their more important properties. While we shall use the language of probability theory in this section to facilitate the exposition, we shall nevertheless subsequently apply the mathematical definitions directly to state-functions without reference to any probability models, i.e. we shall replace the probabilities in the formulae of chapter II by square amplitudes without, however, making any assertions that they represent probabilities.

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We shall also see that the existence of a strong correlation between an operator A in one subsystem and an operator B in the other ~~implies the~~ possibility of representing the composite system state as a superposition of states for each of which one subsystem is in an eigenstate of its operator while the other subsystem is in an approximate eigenstate of its operator, the approximation improving with stronger correlation. Thus such a correlation implies the existence of a superposition of ~~states~~ composite states ~~so that~~ for which both A and B are nearly definite.

We shall also see that the existence of a strong correlation between an operator A in one subsystem and an operator B in the other implies the possibility of a representation of the composite system state as a superposition, for each element of which both A and B have nearly definite values, the degree of this definition improving with the degree of correlation.

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for the state function ψ . In the next chapter (II) we shall develop the tools for such a description using some concepts borrowed from information theory. There we shall develop general definitions of information and correlation, as well as several of their more important properties. In this section we shall use the language of probability theory to facilitate the exposition, although we shall subsequently apply these definitions directly to state functions without reference to any probability models, i.e., we shall replace the probabilities ~~the probabilities in~~ in the formulae of II by square amplitudes without, however, making any assertions that they represent probabilities.

We shall then investigate the quantum formalism of composite systems (II), particularly the possibilities of the representation of such a system as a superposition of states with definite subsystem states, the concept of relative state functions, and the meaning of the representation of subsystems by non-interfering mixtures of states characterized by density matrices. We shall also see that there is a characteristic correlation between subsystems of a composite system.

← insert This will be followed by an investigation of abstract measuring processes (IV), considered simply as correlation inducing interactions between subsystems of a single isolated system, and the representation of the resulting state as a superposition of states for which the two subsystems have nearly definite values for the measured quantity. Ideal observers are then introduced and treated

in the same fashion, and the validity of process I as a subjective phenomenon, is deduced. The abstract ~~discussion~~^{treatment} is then supplemented (2) with a discussion of real processes, the existence and meaning of macroscopic objects of fairly well defined boundaries and shapes from ^{the joint} view of their atomic constitution and the wave mechanics of their constituent particles, as well as the justification of assigning single (representative) state functions to ~~the whole~~^{such} objects.

The final ^{chapter} section summarizes the situation, discusses further the advantages of the viewpoint, and some disadvantages of the ~~methodology~~ ~~and~~ and

and gives a full discussion to and discusses further the advantages of the theory, as well as the difficulties of the other alternatives.