

C O P Y

25 May 1956

Dr. Alexander W. Stern  
Blegdamsvej 17  
København Ø

Dear Dr. Stern:

Many thanks for your kind letter of May 20, and for your extensive comments on Everett's paper. Also I am grateful for the time you and Professor Bohr and Aage Peterson and other friends have spent in reviewing Everett's ideas, both in the special seminar and otherwise.

I fully recognize that there are many places in Everett's presentation that are open to heavy objection, and still more that are subject to misinterpretation. To make the whole discussion consistent at every point with what we know about the measuring problem is going to be a very heavy task. On it I would like to make sure that Everett has the benefit of a number of weeks in Copenhagen. I have already written him to this effect.

I would not have imposed upon my friends the burden of analyzing Everett's ideas, nor given so much time to past discussions of these ideas myself, if I did not feel that the concept of "universal wave function" offers an illuminating and satisfactory way to present the content of quantum theory. I do not in any way question the self consistency and correctness of the present quantum mechanical formalism when I say this. On the contrary, I have vigorously supported and expect to support in the future the current and inescapable approach to the measurement problem. To be sure, Everett may have felt some questions on this point in the past, but I do not. Moreover, I think I may say that this very fine and able and independently thinking young man has gradually come to accept the present approach to the measurement problem as correct and self consistent, despite a few traces that remain in the present thesis, draft of a past dubious attitude. So, to avoid any possible misunderstanding, let me say that Everett's thesis is not meant to question the present approach to the measurement problem, but to accept it and generalize it.

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Realizing that the exchange of a few letters is not going to be enough to clear up many deep issues, let me nevertheless outline the point of view of Everett's thesis in my own words:

(1) WAVE FUNCTION IN THE CONVENTIONAL FORMALISM

(a) One recalls the familiar distinction in quantum mechanics between the system under study and the many varieties of apparatus which can be used to study it. (b) A complete observation with one choice of equipment leaves the system in a well defined quantum state. (c) This state, and its free evolution with time, are described by a wave function that depends upon the system coordinates alone. (d) This wave function, and the wave equation that it obeys, together form a machinery to predict in a way free of all contradictions the outcome of one or another type of measurement made with one or another of the complementary varieties of apparatus at the disposal of the observer.

(2) WAVE FUNCTION IN EVERETT'S FORMALISM

(a) Nothing prevents one from considering a wave function and its time evolution in abstracto; that is, without ever talking about the equipment which originally prepared the system in that state, or even mentioning the many alternative pieces of apparatus that might be used to study that state. (b) A state function as used in this sense has absolutely nothing to do with the state function as used in the customary discussion of the measurement problem, for now no means of external observation are admitted to the discussion. (c) Why in the world talk of a wave function under such conditions, for it in no way measures up to the role of the wave function in the customary formulation, that we accept without question? (d) Because it is proposed, of Everett's free volition, to formulate a new physical theory, as a step of free creation. (e) In this theory, as in every new theory, the quantities that enter have roles and positions that will be defined and determined by the logical structure of the theory itself. (f) The greatest possible confusion will result if the

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mathematical quantities in Everett's theory, such as the wave function, are thought of as having the purpose that the wave function fulfills in the customary formulation. (g) The present draft of the thesis by no means keeps clear throughout this distinction between the idea of wave function in the two formulations, let alone the ideas of observer and measurement. (h) Everett's "universal wave function" is not to be thought of as subject to external observation. Every idea of a observation from outside is to be rejected. (i) If the universal wave function is not subject to external observation, is it not as you put it "a matter of theology"? To this question I should be frank in saying I have no complete answer, nor am I sure that it is necessary to give one. Is there any difference on this score between Everett's universe and Laplace's universe? No one seriously believed that it would be a practical possibility ever to know at one moment the position and velocity of every particle, but that these quantities nevertheless had it was convenient to postulate<sup>A</sup> that the "universal wave function" well defined values. Likewise Everett postulates had at one moment a well defined dependence upon the state variables, and therefore also a well defined dependence upon these variables at every other moment. (j) This postulate is a creative act, beyond any step by step pre-justification. (k) The justification must instead lie in the internal consistency of the resulting theory and in its consequences. (l) The very meaning of the word "consequences" has to be defined within the framework of the theory itself, not by applying to Everett's concept of wave function epistemological considerations that refer to "wave function" in the completely different context of the usual formalism.

(3) EVERETT'S SYSTEM

(a) Everett develops his theory in the following spirit: (this is not the theory, but how he goes about constructing it): Follow the evolution of the wave function with time, and look for connections between regions of maximum in the wave function and the kind of

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happenings we encounter. (b) The connection is meant to supply the possibility of a complete model for our world. (c) For this reason the system must contain a sufficiently large number of degrees of freedom to admit subsystems that can be compared to the observers of our world. (d) The idea is accepted, and is essential to Everett's analysis, that these subsystems are sufficiently complex to simulate all that human beings do, including acting, observing, and recording. (e) Thinking and communication between these model observers and also postulated on a basis that I should like to express in the following way. (f) These subsystems or model observers have arisen within the overall system by organic evolution: reproduction and destruction or survival. (g) Mutual assistance being indispensable to survival, these subsystems have learned to communicate with each other about their experiences. (h) The kind of physics that occurs does not adjust itself to the available words; the words evolve in accordance with the kind of physics that goes on. (i) Thus thinking, experimentation and communication - or psychophysical duplicates thereof - are all taken by Everett as going on within the model universe. (j) As thinking can take place on various levels, from the most rudimentary and mechanical to the most highly complex, so the system that forms the model universe can be so primitive that in it there is no place for anything that we would call reason, or so complex that it admits all the irreversibility of measurements as we know them.

(4) THE PHYSICS OF EVERETT'S SYSTEM

(a) Whether simple or complex, the model universe has properties that are fixed by the universal wave function. (b) The nature of the statements that can be made within Everett's theory is not fixed by the pattern of the usual quantum formalism at all. (c) Instead, it is determined by the postulates and rules of calculation that he lays down in his thesis, and which I will not attempt to recapitulate here. (d) For clarity, every deduction that comes out at this level of

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discussion ought to bear the phrase "in the model universe". Such words as "correlation" and "observer" ought to bear quite different names, to emphasize the absolutely fundamental distinction between the model universe and the real physical world. (e) Everett's theory receives its test number one, the test of logic, by its internal self consistency down to this point.

(5) RELATION BETWEEN EVERETT'S SYSTEM AND PHYSICS AS WE DO IT.  
(a) None at all? No, because Everett traces out a correspondence between the "correlations" in his model universe on the one hand, and on the other hand what we observe when we go about making measurements. (b) The closeness and clarity of this correspondence is test number two of his theory. (c) Has the closeness of the correspondence been proven in the second draft of Everett's thesis, that you have? In large measure, in my opinion; but there are still logical loopholes left. I believe Everett can fill in the missing steps in this material. (d) Has the nature of the correspondence been made clear, including the sharp distinction between the model universe and the ideas we use in everyday quantum physics? Far from it, in my opinion. What I have written in this letter is a very feeble attempt to go a very small ways beyond Everett in clarifying this issue. The full job will be a heavy task, but I have confidence that Everett can accomplish it if he can have the benefit of some weeks in Copenhagen to struggle out these problems. So I hope to hear from him that he will find it possible to come.

I am taking the liberty to send copies of this letter to (1) Niels Bohr and Aage Peterson and to (2) Hugh Everett, as well as to forward to Everett a copy of your letter to me. If further discussion of these problems takes place at Copenhagen, I shall appreciate learning how far the points that I have numbered in this letter for convenience of reference might be found acceptable.

Thank you again for your kindness in writing. Please accept best regards for yourself and your wife and daughter.

Sincerely yours, (John A. Wheeler)