The Physical Meaning Of The Wavefunction II

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Manuscript submitted to viXra.org on Saturday, June 20, 2015.

Abstract: The hottest and one of the major unresolved problems of today's quantum mechanics is the physical meaning of the wave function. The debate about the physical meaning of the wave function raises broader issues as well. In brief, the difficulties stemmed from an apparent conflict about the existence of an objective reality existing independent of the human mind and consciousness. The purpose of this publication is to investigate the meaning of the wave function by analyzing the relationship between the wave function and Einstein's special theory of relativity and. As we will see, the wavefunction and "co-ordinate" time of Einstein's special theory of relativity are identical.

Key words: Quantum theory, relativity theory, unified field theory, causality.

1. Introduction

Conceptual difficulties are associated with quantum mechanics since its inception, despite of quantum mechanics extraordinary predictive successes. One "defining" part of quantum mechanics is the Schrödinger's equation. Quite naturally, Schrödinger's equation is to quantum mechanics what Newton's second law of motion is to classical mechanics. A determining part of Schrödinger's equation is the wave function. The nice fact is that quantum mechanics with its revolutionary implications meets still with serious difficulties in telling us what is the physical meaning of the wave function. As already stated, reconsidering basic concepts of one of the most successful theories in the history of human science, a very natural question which all scientists who are concerned about the physical meaning of the wave function is, what could be the correct starting point to solve this problem. This publication will overcome the difficulties about the physical meaning of the wave function posed by quantum mechanics by strictly following Einstein in his proposal of to accept a physical reality as a kind of objective reality, a physical reality which is independent of the human being, his consciousness and his mind.

The purpose of the present article is not to put forward a new and complete self-consistent interpretation of quantum mechanics which is able fully to highlight the explicative power of this revolutionary theory. But to fully appreciate the novel aspects contained in this work, it is more than necessary and highly useful to recall, clarify and elaborate about some basic notions needed to solve the problem of the physical meaning of the wave function. To complete this short overview, it is straightforward to convince oneself that this is to be a major undertaking if not a (theoretical) impossibility.

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2. Definitions

2.1. **Thought Experiments**

The general importance, acceptance and enormous influence of properly constructed models or (real or) thought experiments (as devices of scientific investigation) is backgrounded by some important and common features. One main way to do this, is to develop a model, in which the different, fundamental terms of the quantum formalism find a correspondence. Such a model is able to produce new predictions and new explanations. Especially, under conditions where it is too expensive or too difficult to run a real experiment a model or a thought experiment can help us to prove how to deal with some basic properties of the nature in a mathematically and logically consistent and appropriate way. Again, it is necessary to highlight the possibility of a thought experiment to get the right against or in favor of a theory or a hypothesis. However, it is worth being mentioned that a thought experiment can draw out a contradiction in a theory and thereby refuting the same. Furthermore, models and thought experiments used for diverse reasons in a variety of areas are at the end no substitute for a real experiment.

2.2. **Definition. The Relativistic Energy Of A System** ${}_{R}E$

Let

$${}_{R}E$$

denote the total energy of a system.

Scholium.
Reacall, due to Einstein, matter/mass and energy are equivalent.
“Da Masse und Energie nach den Ergebnissen der speziellen Relativitätstheorie das Gleiche sind und die Energie formal durch den symmetrischen Energietensor ($T_{\mu\nu}$) beschrieben wird, so besagt dies, daß das G-Geld [gravitational field, author] durch den Energietensor der Materie bedingt und bestimmt ist.“ [1]

2.3. **Definition. The Co-ordinate or Relativistic Time And Proper Time Of A System**

Let

$${}_{R}t$$

denote the relativistic (i. e. co-ordinate time). Let

$${}_{0}t$$

denote the proper time.

Scholium.
An accurate **clock in motion slow down** with respect a stationary observer (observer at rest). The proper time ${}_{0}t$ of a clock moving at constant velocity *v* is related to a stationary observer's coordinate time ${}_{R}t$ by Einstein’s relativistic time dilation [2] and defined as

$$ {}_0t = {}_R t \times \sqrt[2]{1 - \frac{v^2}{c^2}} \tag{1} $$

where ${}_0t$ denotes the “proper” time, ${}_Rt$ denotes the “relativistic” (i. e. stationary or coordinate) time, *v* denotes the relative velocity and *c* denotes the speed of light in vacuum. Equally, it is

$$ \frac{{}_0t}{{}_Rt} = \sqrt[2]{1 - \frac{v^2}{c^2}} \tag{2} $$

or

$$ \frac{{}_0t}{c^2} \times \frac{c^2}{{}_Rt} = \sqrt[2]{1 - \frac{v^2}{c^2}} \,. \tag{3} $$

Coordinate systems can be chosen freely, deepening upon circumstances. In many coordinate systems, an event can be specified by one time coordinate and three spatial coordinates. The time as specified by the time coordinate is denoted as coordinate time. Coordinate time is distinguished from proper time. The concept of proper time, introduced by Hermann Minkowski in 1908 and denoted as ${}_0t$, incorporates Einstein’s *time dilation effect.* In principle, Einstein is defining time exclusively for every place where a watch, measuring this time, is located.

"... Definition ... der ... Zeit ... für den Ort, an welchem sich die Uhr … befindet ..." [3]

In general, a watch is treated as being at rest relative to the place, where the same watch is located.

"Es werde ferner mittels der **im ruhenden System** befindlichen **ruhend**en Uhren die Zeit t [i. e. ${}_Rt$, author] des ruhenden Systems ... bestimmt, ebenso werde die Zeit τ [${}_0t$, author] des **bewegten System**s, in welchen sich relativ zu letzterem **ruhend**e Uhren befinden, bestimmt..." [4]

Only, the place where a watch at rest is located can move together with the watch itself. Therefore, due to Einstein, it is necessary to distinguish between clocks as such which are qualified to mark the time ${}_Rt$ when at rest relatively to the stationary system R, and the time ${}_0t$ when at rest relatively to the moving system O.

"Wir denken uns ferner eine der Uhren, welche **relativ zum ruhenden System ruhend** die Zeit t [${}_Rt$, author], **relativ zum bewegten System ruhend** die Zeit τ [${}_0t$, author] anzugeben befähigt sind ..." [5]

In other words, we have to take into account that both observers have at least one point in common, the stationary observer R and the moving observer O are at rest, but at rest relative to what? The stationary observer R is at rest relative to a stationary co-ordinate system R, the moving observer O is at rest relative to a moving co-ordinate system O. Both co-ordinate systems can but must not be at rest relative to each other. The time ${}_Rt$ of the stationary system R is determined by clocks which are at rest relatively to that stationary system R. Similarly, the time $_0t$ of the moving system O is determined by clocks which are at rest relatively to that the moving system O. In last consequence, due to Einstein's theory of special relativity, an accelerated clock ($_0t$) will measure a smaller elapsed time between two events than that measured by a non-accelerated (inertial) clock ($_Rt$) between the same two events.

2.4. **Definition. The Normalized Relativistic Time Dilation Relation**

As defined above, due to Einstein's special relativity, it is

$$\frac{_0t}{_Rt} = \sqrt[2]{1-\frac{v^2}{c^2}}. \tag{4}$$

The normalized relativistic time dilation relation [6] follows as

$$\frac{_0t^2}{_Rt^2} + \frac{v^2}{c^2} = 1. \tag{5}$$

2.5. **Definition. The Mathematical Identity Of A System** $_RS$

Let

$$_RS \equiv {_RE} + {_Rt}. \tag{6}$$

denote the mathematical identity of energy and time of a system.

Scholium.
The notion $_RS$ can but must not be the mathematical equivalent of a very simple form of space. Following Aristotele's principle of the excluded middle, *tertium no datur*, it is important to stress out, that **all but energy** is denoted as time. Consequently, there is no third between energy and time, a third is not given.
Let

$$_OS \equiv {_OE} + {_Ot} \tag{7}$$

where $_0E$ denotes the 'rest' energy and $_0t$ denotes the 'proper' time. Consequently, due to special relativity it is

$$_OS \equiv \sqrt[2]{1-\frac{v^2}{c^2}} \times {_RS}. \tag{8}$$

2.6. **Definition. The Matter** $_RM$

Let

$$_RM \equiv \frac{_RE}{c^2} \equiv \frac{_R\hat{H}}{c^2}, \tag{9}$$

where $_RM$ is (the quantum mechanical operator of) matter (and not only of mass [7]), c is the speed of the light in vacuum and $_R\hat{H}$ is the Hamiltonian operator.

2.7. **Definition. The Gravitational Field** ${}_R G$

The wavefunction of the gravitational field ${}_R G \equiv {}_R \Gamma$ describes the gravitational field completely. In general, it is

$${}_R G \equiv {}_R \Gamma \equiv {}_R N - {}_R M \; . \qquad (10)$$

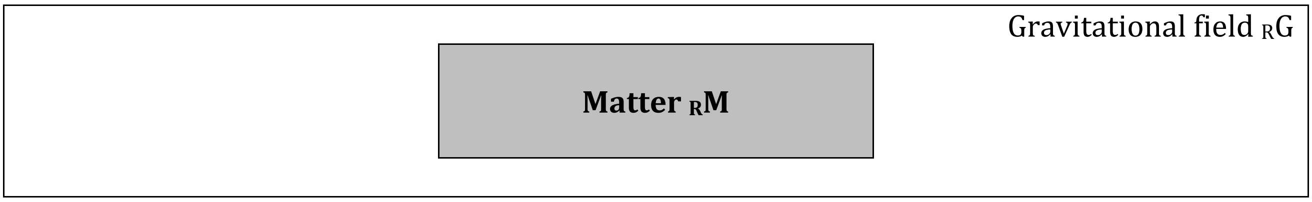
where ${}_R M$ denotes matter (and not only of mass).

Scholium.
In our understanding, the relationship between matter and gravitational field is based on Einstein's definition of **matter** (i. e. not only mass) ex negativo. Einstein himself pointed out that everything but the gravitational field has to be treated as matter. Thus far, matter as such includes *matter in the ordinary sense* and the *electromagnetic field* as well. In other words, there is no third between matter and gravitational field. Einstein himself wrote:

"Wir unterscheiden im folgenden zwischen 'Gravitationsfeld' und 'Materie', in dem Sinne, daß alles außer dem Gravitationsfeld als 'Materie' bezeichnet wird, also nicht nur die 'Materie' im üblichen Sinne, sondern auch das elektro-magnetische Feld. " [8]

Einstein's writing translated into English:
>> We make a distinction hereafter between 'gravitational field' and 'matter' in this way, that we denote everything but the gravitational field as 'matter', the word matter therefore includes not only matter in the ordinary sense, but the electromagnetic field as well. <<
In terms of set theory we would obtain the following picture.

${}_R N$



This approach to the relationship between matter and gravitational field is sometimes also referred to as the *de Broglie hypothesis* since all matter can exhibit wave-like behavior. Thus far, so called "matter waves", a concept having been proposed by Louis de Broglie in 1924, are a central part of the theory of quantum mechanics and a subject of ongoing debate too.

2.8. **Definition. The Mathematical Identity Of A System** ${}_R N$

From the standpoint of a stationary (fix) observer R let us define

$${}_R N \equiv {}_R M + {}_R G \qquad (11)$$

where ${}_R M$ denotes the matter and ${}_R G$ denotes the (wavefunction of the) gravitational field. From the standpoint of a moving observer O we define

$$_{O}N \equiv_{O} M +_{O} G \tag{12}$$

where $_{0}M$ denotes the matter from the standpoint of a moving observer and $_{0}G$ denotes the gravitational field from the standpoint of a moving observer.

Scholium.
In the context of general relativity, Einstein himself demands that everything but the gravitational field has to be treated as matter. Thus far, matter as such includes matter in the ordinary sense and the electromagnetic field as well. In other words, there is no third between matter and gravitational field. In other words, matter and gravitational field are determining $_{R}N$.

2.9. **Definition. The Relationship Between $_{R}S$ and $_{R}N$**

Let

$$_{R}N \equiv \frac{_{R}S}{c^{2}} . \tag{13}$$

2.10. **Definition. The Schrödinger equation**

The famous Schrödinger equation [9], a partial differential equation which describes how a quantum state of a system changes with time. The Schrödinger equation **for any system**, **no matter whether relativistic or not**, no matter how complicated, has the form

$$_{R}\hat{H} \times {}_{R}\Psi(t) = i\hbar \frac{\partial}{\partial t} {}_{R}\Psi(t), \tag{14}$$

where *i* is the imaginary unit, $\hbar = \frac{h}{2 \times \pi}$ is Planck's constant h divided by 2xπ, the symbol $\frac{\partial}{\partial t}$ indicates a partial derivative with respect to time t, $_{R}\Psi(t)$ is the wave function of the quantum system, and $_{R}\hat{H}$ is the Hamiltonian operator.

2.11. **Axioms.**

The following theory is based on the following axiom.

Axiom I.

$$+1 = +1. \tag{Axiom I}$$

3. Theorems

3.1. **Theorem. The Physical Meaning Of The Wave Function.**

Claim.
In general, the wave function and the notion co-ordinate time $_{R}t$ are identical. It is

$$_{R}t = {}_{R}\Psi(t) \tag{15}$$

Proof.
Starting with Axiom I it is

$$+1 = +1 . \tag{16}$$

Multiplying this equation by it

$$_{R}E = {}_{R}E . \tag{17}$$

Multiplying by $_{R}t$ we obtain

$$_{R}E \times {}_{R}t = {}_{R}E \times {}_{R}t . \tag{18}$$

The model studied by us is completely describe and defined by the equation. The famous Schrödinger equation itself is able to describe this model (quantum mechanical system), no matter whether relativistic or not, no matter how complicated, too. Thus far we equate this equation with the Schrödinger equation and do obtain

$$_{R}E \times {}_{R}t = {}_{R}\hat{H} \times {}_{R}\Psi(t), \tag{19}$$

Following Dirac in his approach, the total relativistic energy is equivalent with the Hamiltonian. There is no more energy in the system then described by the total relativistic energy $_{R}E$ and equally the same energy is completely described by the Hamiltonian operator. Both energies are equivalent or it is $_{R}E = {}_{R}\hat{H}$. Rearranging the equation above, we obtain

$$_{R}\hat{H} \times {}_{R}t = {}_{R}\hat{H} \times {}_{R}\Psi(t) \tag{20}$$

Dividing both sides by $_{R}\hat{H}$, we obtain

$$_{R}t = {}_{R}\Psi(t) \tag{21}$$

Quod erat demonstrandum.

Manuscript submitted to ViXra.org (Saturday, June 20, 2015)

Scholium.

In quantum mechanics, the Hamiltonian, named after the Irish mathematician Hamilton, is a quantum mechanical operator corresponding to the total energy of a quantum mechanical system and usually denoted by H. By analogy with classical mechanics and special relativity, the Hamiltonian is the sum of operators i. e. corresponding to the total energy (i. e. potential and kinetic energies) (of all the particles) associated with a quantum mechanical system and can take different forms depending on the situation. The total (relativistic or non-relativistic) energy of a system is transformed into the Hamiltonian which acts as a source of the wavefunction and upon the wavefunction to generate the evolution of the wavefunction in time and space. The Hamiltonian operator H is Hermitian. According to the expansion postulate, the wavefunction can be expanded as a series of its eigenfunctions where an eigenfunction belongs to an eigenvalue of H. Consequently, an eigenstate of the operator H is one in which the energy is perfectly defined. Thus far, an important property of Hermitian operators is that their eigenvalues are real. The total energy operator H is determined as

$$ {}_{R}\hat{H} = i\hbar \frac{\partial}{\partial t}. $$

For our purposes, the (non-relativistic or relativistic) Hamiltonian is corresponding to the total energy of a quantum mechanical object or system. Thus far, it is

$$ {}_{R}E = {}_{R}\hat{H} = i\hbar \frac{\partial}{\partial t} $$

where $_{R}E$ is identical with the notion "total relativistic energy" of a (quantum mechanical) system. Thus far, in general, it is ${}_{R}\Psi(t) = {}_{R}t$ where $_{R}t$ on the first view has nothing in common with the wavefunction. We multiply this equation by 1. Finally, it follows that ${}_{R}\Psi(t) = 1 \times {}_{R}t$ which is equivalent to ${}_{R}\Psi(t) = \frac{a}{1} \times \frac{1}{a} \times {}_{R}t$. We define $b \times e^{-c} \equiv \frac{1}{a} \times {}_{R}t$. The original equation changes too ${}_{R}\Psi(t) = a \times b \times e^{-c}$. Now we define $d = a \times b$. In general, it is ${}_{R}\Psi(t) = d \times e^{-c}$. All the changes of the identity ${}_{R}\Psi(t) = {}_{R}t$ have no influence on the equivalence time $_{R}t$ and the wave function $_{R}\Psi(t)$, these changes are just a concrete form of $_{R}t$.

4. Discussion

The theory quantum mechanics, perhaps the most revolutionary theory in the history of science, has raised innumerable questions to physicists, chemists and philosophers of science. Strictly speaking, the wave function is still one of the pillars of quantum mechanics. The most important feature of the theory of quantum mechanics is the physical meaning of the wave function. Due to our proof above, there is nothing mysterious with the wave function. The wave function is existing independently of human mind and consciousness and something objective. The wave function is the quantum mechanical equivalent of the notion co-ordinate time $_{R}t$ of the special theory of relativity. In particular, it is ${}_{R}t = {}_{R}\Psi(t)$.

5. Conclusion

The problem of the physical meaning of the wave function is solved. The wave function is quantum mechanical analogue of the notion time $_{R}t$ of the theory of special relativity.

Manuscript submitted to ViXra.org (Saturday, June 20, 2015)

Acknowledgment

I am very happy to have the opportunity to express my deep gratitude to the Scientific Committee of the conference “Quantum Theory: from foundations to technologies (QTFT)”. This paper was one part my presentation at the QFTF conference at Linnaeus University, Sweden, June 8-11, 2015.

Appendix

None.

References

[1] Albert Einstein, “Prinzipielles zur allgemeinen Relativitätstheorie“, *Annalen der Physik*, vol. 55, no. 4, pp. 241-242, 1918.
[2] Albert Einstein, “Zur Elektrodynamik bewegter Körper,“ *Annalen der Physik*, vol. 322, Issue 10, p. 904, 1905.
[3] Albert Einstein, “Zur Elektrodynamik bewegter Körper,“ *Annalen der Physik*, vol. 322, Issue 10, p.893, 1905
[4] Albert Einstein, “Zur Elektrodynamik bewegter Körper,“ *Annalen der Physik*, vol. 322, Issue 10, p. 898, 1905.
[5] Albert Einstein, “Zur Elektrodynamik bewegter Körper,“ *Annalen der Physik*, vol. 322, Issue 10, p.903-904, 1905.
[6] Ilija Barukčić, ”The Relativistic Wave Equation,” *International Journal of Applied Physics and Mathematics,* vol. 3, no. 6, pp. 387-391, 2013.
[7] Albert Einstein, “Zur Elektrodynamik bewegter Körper,“ *Annalen der Physik*, vol. 322, Issue 10, pp.891-921, 1905.
[8] Albert Einstein, “Die Grundlage der allgemeinen Relativitätstheorie,” *Annalen der Physik*, vol. 354, Issue 7, pp. 802-803, 1916.
[9] Erwin Schrödinger, “An Undulatory Theory of the Mechanics of Atoms and Molecules”, *Physical Review*, vol. 28, no. 6, pp. 1049-1070, 1926.

Manuscript submitted to ViXra.org (Saturday, June 20, 2015)