Journal of Uncertain Systems
Vol.8, No.3, pp.222-226, 2014
Online at: www.jus.org.uk

Free Will in Non-Quantum Physics Implies that Either Energy-Momentum is Not Conserved or Symmetry is Violated

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Received 27 July 2013; Revised 11 August 2013

Abstract

It is known that in modern physics, dynamics is pre-determined: once we know the current state of the world, we can uniquely predict all future states, and thus, for each future measurement, we can uniquely predict the probabilities of all possible measurement results. From this viewpoint, everything in the world is pre-determined, nothing can change it. This determinism seems to be inconsistent with our intuitive understanding that even our everyday choices actually change the things around us – and thus, strictly speaking, change the state of the world. Since modern physics is thus inconsistent with our intuition, it is desirable to consider alternative physical theories which would allow free will. It turns out that such modifications have to be radical: for example, a recent paper showed that in quantum physics, free will leads to non-conservation of energy. In this paper, we show that a similar result can be proven in non-quantum case as well: namely, we show that in non-quantum physics, free will implies that either energy-momentum is not conserved or symmetry is violated. Since symmetry preservation is known to be related to conservation laws, adding free will to non-quantum or quantum physics indeed leads to similar consequences.

Keywords: free will in physics, energy-momentum conservation, symmetry in physics

1 Formulation of the Problem

Free will seems to be inconsistent with modern physics. Equations of modern physics are deterministic:

- in non-quantum physics, once the know the initial conditions, we can uniquely prescribe the state of the world at any future moment of time – and thus, the results of all the future measurements;
- in quantum physics, we can similarly predict the future quantum state of the world – and thus, for each future measurement, we can predict the *probabilities* of different possible measurement results; see, e.g., [1].

From this viewpoint, once the initial conditions are known, everything is pre-determined, there is no way to change the future.

Intuitively, however, we feel that we *can* change the future, that we make many decisions every day that affect our behavior – and thus, affect the world around us. Even a simple choice of what to eat for lunch changes the world – maybe this change is tiny, but it is there.

How can we reconcile physics with the intuitive idea of free will? Since modern physics, with its determinism, is inconsistent with our intuition about free will, it would be nice to modify the existing physics, so that the modified physical theories would allow free will.

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What is known: in quantum physics, free will leads to non-conservation of energy. The question of how to modify physics so as to allow free will was studied, e.g., in [2], where it was shown that in quantum physics, free will leads to non-conservation of energy.

What we do in this paper. The argument presented in [2] depends on specifics of quantum theory. It is therefore interesting to analyze to what extent a similar conclusion can be made in non-quantum physics. A partial analysis of this problem was made in [3]. In this paper, we continue this analysis and show that a similar result indeed holds in non-quantum physics as well.

2 Adding Free Will to Non-Quantum Physics: Analysis of the Problem and the Main Conclusion

How can we describe non-quantum physics. In quantum physics, all interactions between particles – be it electromagnetic, strong, weak, or gravitational – occur via exchange of the corresponding particles; see, e.g., [1]. For example, electromagnetic interactions are caused by exchange of photons, gravitational interactions are caused by exchange of gravitons, etc. In these terms, all the changes in the world are caused by local particle interactions. This is, in effect, why so-called Feynman diagrams, which describe all changes in terms of such interactions, are a successful tool in describing all known physical phenomena [1].

In such interactions, usually, only two particles interact with each other, since the probability that three particles get together at the same point in space-time can be safely ignored. Even when three particle do eventually interact, usually a detailed analysis shows that there is first a reaction between two of then, followed by the reaction between the product of the first interaction and the third particle.

From this viewpoint, a natural non-quantum analogue of this description is the world consisting of point particles which interact only locally, i.e., only via collisions. Each particle travels by its own until it meet another particle, at which point these two particles collide. Thus, to check whether free will is possible in this model, we need to check:

- whether it is possible to introduce free will at the stage when a particle travels on its own, and
- whether it is possible to introduce free will when two particles collide.

Our main assumptions: invariances and conservation laws. In our analysis, we will assume that all the processes are relativitistically invariant, i.e., that all the processes follow the same laws whether we consider a stationary coordinate system or a coordinate system associated with a body which inertially moved with some constant speed. In other words, we assume that the principle of relativity – as introduced already by Galileo – is valid: if we are in a ship which is going smoothly, and we cannot look outside the windows, then, no matter how many experiments we perform in a cabin, we will not be able to tell whether the ship is moving or standing still.

We would also like to assume that the energy is conserved. In relativity theory, what is energy in one coordinate system becomes momentum $\vec{p} = m\vec{v}$ in another one; both energy and momentum are components of the same 4-D *energy-momentum vector*. Thus, our actual assumption is that energy-momentum is conserved.

We also assume that symmetry is preserved, i.e., that if the initial state had some geometric symmetry – e.g., it was invariant with respect to rotations or shifts – then, since all the physical laws are invariant with respect to such geometric symmetries, we should be able to conclude that all future states have the same symmetry.

Let us use these assumptions to analyze how we can add free will to a non-quantum physical theory. In accordance with the above conclusion, we will consider two possible situations: when the particle travels on its own, and when the particle collides with another particle.

Situation when a particle travels on its own. Let us assume that a particle travels with a constant speed $\vec{v}$. Within our assumptions, can our free will affect this part of the trajectory?

For convenience, let us use a coordinate system associated with this particle. In this new coordinate system, this particle is immobile. Its state – as described by its location $\vec{x}$ and its velocity $\vec{v} = 0$ – is therefore invariant with respect to all rotations around the point $\vec{x}$. Due to our assumption that symmetry is preserved, we conclude that the future states of this particle (at least until it meet some other particle) should also be invariant with respect to all these rotations. This precludes the possibility of having this particle change its speed from 0 to some other value $\vec{v} \neq 0$, since any vector $\vec{v} \neq 0$ would not be invariant with respect to all rotations (and this would also violate conservation of momentum).

Thus, under our assumptions, no free will can change the particle, it will remain immobile in the coordinate system in which it was originally immobile – or, if we want to describe its motion in the original coordinate system, it will continue to go with the same speed in the same direction.

Situation when two particles collide. In this case, we can similarly select the coordinate system in which one of the particles is immobile. In this coordinate system, we have two colliding particles located at the same spatial point: the first particle has mass m_1 and velocity $\vec{v}_1 = 0$, the second particle has mass m_2 and velocity $\vec{v}_2$. We would like to use our assumptions to determine the velocities $\vec{u}_1$ and $\vec{u}_2$ that these particles will get after the collision.

First, let us notice that the original configuration is invariant with respect to all rotations around the vector $\vec{v}$. Thus, since we assumed that geometric symmetries are preserved, this means that the new configurations should also be invariant with respect to all such rotations. This means that the vectors $\vec{u}_i$ cannot have components in the directions orthogonal to $\vec{v}$ – else there would be no invariance. Thus, both vectors $\vec{u}_1$ and $\vec{u}_2$ must be parallel to the vector $\vec{v}$. So, if we select a coordinate system in which $\vec{v}$ is parallel to the axis $0x_1$, then for each of the vectors $\vec{v}$, $\vec{u}_1$, and $\vec{u}_2$, only their first coordinates are non-zeros. Let us denote these coordinates by v, u_1, and u_2.

For particle of mass m moving in the x_1-direction with a velocity v, its energy is equal to

$$\frac{m \cdot c^2}{\sqrt{1 - \frac{v^2}{c^2}}},$$

where c, as usual, denotes the speed of light, and the x_1-component of the momentum is equal to

$$\frac{m \cdot v}{\sqrt{1 - \frac{v^2}{c^2}}}.$$

Thus, for the two colliding particles, the relativistic energy-momentum conservation laws means that

$$\frac{m_1 \cdot c^2}{\sqrt{1 - \frac{u_1^2}{c^2}}} + \frac{m_2 \cdot c^2}{\sqrt{1 - \frac{u_2^2}{c^2}}} = m_1 \cdot c^2 + \frac{m_2 \cdot c^2}{\sqrt{1 - \frac{v^2}{c^2}}}; \tag{1}$$

$$\frac{m_1 \cdot u_1}{\sqrt{1 - \frac{u_1^2}{c^2}}} + \frac{m_2 \cdot u_2}{\sqrt{1 - \frac{u_2^2}{c^2}}} = \frac{m_2 \cdot v}{\sqrt{1 - \frac{v^2}{c^2}}}. \tag{2}$$

To simplify these equations, let us denote

$$\alpha_i \stackrel{\text{def}}{=} \frac{u_i}{\sqrt{1 - \frac{u_i^2}{c^2}}}.$$

In these terms, the equation (2) takes the form

$$m_1 \cdot \alpha_1 + m_2 \cdot \alpha_2 = p, \tag{3}$$

where

$$p \stackrel{\text{def}}{=} \frac{m_2 \cdot v}{\sqrt{1 - \frac{v^2}{c^2}}}$$

is known.

To similarly describe the equation (1), we can use the fact that

$$c^2+\alpha_i^2=\frac{u_i^2}{1-\frac{u_i^2}{c^2}}+c^2=\frac{u_i^2+c^2-u_i^2}{1-\frac{u_i^2}{c^2}}=\frac{c^2}{1-\frac{u_i^2}{c^2}}.$$

Thus,

$$\frac{c}{\sqrt{1-\frac{u_i^2}{c^2}}}=\sqrt{c^2+\alpha_i^2}. \tag{4}$$

So, if we divide both side of the equation (1) by c and use the formula (4), we get a simplified equation

$$m_1\cdot\sqrt{c^2+\alpha_1^2}+m_2\cdot\sqrt{c^2+\alpha_2^2}=E, \tag{5}$$

where

$$E\stackrel{\text{def}}{=}m_1\cdot c+\frac{m_2\cdot c}{\sqrt{1-\frac{v^2}{c^2}}}$$

is known.

By squaring both sides of equations (3) and (5), we get

$$m_1^2\cdot\alpha_1^2+m_2^2\cdot\alpha_2^2+2m_1\cdot m_2\cdot\alpha_1\cdot\alpha_2=p^2; \tag{6}$$

$$m_1^2\cdot(c^2+\alpha_1^2)+m_2^2\cdot(c^2+\alpha_2^2)+2m_1\cdot m_2\cdot\sqrt{c^2+\alpha_1^2}\cdot\sqrt{c^2+\alpha_2^2}=E^2. \tag{7}$$

Subtracting (6) from (7), we get

$$m_1^2\cdot c^2+m_2^2\cdot c^2+2m_1\cdot m_2\cdot\left(\sqrt{c^2+\alpha_1^2}\cdot\sqrt{c^2+\alpha_2^2}-\alpha_1\cdot\alpha_2\right)=E^2-p^2, \tag{8}$$

hence

$$\sqrt{c^2+\alpha_1^2}\cdot\sqrt{c^2+\alpha_2^2}=\alpha_1\cdot\alpha_2+C, \tag{9}$$

where

$$C\stackrel{\text{def}}{=}\frac{E^2-p^2-(m_1^2+m_2^2)\cdot c^2}{2m_1\cdot m_2}$$

is known (i.e., does not depend on the unknowns α_1 and α_2). Squaring both sides of the formula (9), we get

$$(c^2+\alpha_1^2)\cdot(c^2+\alpha_2^2)=\alpha_1^2\cdot\alpha_2^2+C^2+2C\cdot\alpha_1\cdot\alpha_2. \tag{10}$$

Opening parentheses, we get

$$c^4+\alpha_1^2\cdot c^2+\alpha_2^2\cdot c^2+\alpha_1^2\cdot\alpha_2^2=\alpha_1^2\cdot\alpha_2^2+C^2+2C\cdot\alpha_1\cdot\alpha_2, \tag{11}$$

i.e., after subtracting the product $\alpha_1^2\cdot\alpha_2^2$ from both sides, the equation

$$c^4+\alpha_1^2\cdot c^2+\alpha_2^2\cdot c^2=C^2+2C\cdot\alpha_1\cdot\alpha_2. \tag{12}$$

From equation (3), we can express α_2 as a linear function of α_1. Substituting this linear expression into the quadratic formula (12), we get a quadratic equation for the unknown α_1. One of the possible solutions is known: when both particles preserve their velocities $u_1=0$ and $u_2=v$ (i.e., when there is no collision). Thus, if there is a collision, α_1 coincides with the only other solution to the quadratic equation – i.e., it is uniquely determined by the initial conditions and our assumptions.

So, for collision, also, there is no room for chance, no free will can change the result.

Conclusion. We have shown that in the non-quantum physics, if we assume that energy-momentum is conserved and symmetry is preserved, then all the future states are uniquely determined by the initial conditions – and there is no room for free will. In other words, in non-quantum physics, free will implies that either energy-momentum is not conserved or symmetry is violated.

Discussion. In quantum physics, adding free will leads to non-conservation of energy. Since symmetry preservation is known to be related to conservation laws (this is the subject of the renowned Noether's theorem [1]), we can say that adding free will to non-quantum or quantum physics indeed leads to similar consequences.

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