On Equivalence of Mass and Energy in Special Theory of Relativity

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ABSTRACT

In Contrast the comments to Mass and Energy. It is purposed to show that the equivalence mass and energy represent in the kinetic form in zeroth components of four-dimensional vectors.

Keywords : *Theory of relativity, Velocity, Equivalence mass and Energy etc.*

Introduction

On the achievement of the special theory of relativity is the statement about the equivalence of mass and energy, in a sense that the mass of a body increase with its energy includes kinetic energy. The mass depends on the velocity of the body. The relationship is unambiguously interpreted in the work of renewed physicists.

According to Newton's belief that the mass of a body does not change with increasing velocity and remains equal to the rest mass.

In 1975, SP Strelkov observed "The dependence of mass on velocity is a principal velocity is a principal proposition of Einstein's mechanics."

Further Richard Feynman in 1965 analysied "Because of the relation of mass and energy the energy associated with motion appears as an extra mass, so things get heavier when they move. Newton believed that was not the case, and that the masses stayed constant.

L. B. Okun in 1989 finds "The mass that increases with speed - that was truly incomprehensible. The mass of a body m does not change when it is in motion and, apart from the factor c, is equal to the energy contained in the body at rest. The mass m does not depend on the reference frame.

R. Resnick et al. (1992): "The concept of mass by Lev B. Okun (see Ref. (5) of this letter) summarizes the views held by many physicists and adopted for use in this book. But there is not universal agreement on the interpretation of equation $E_0 = mc^2$.

This equation tells us that a particle of mass m has associated with it a rest energy E_0. However the above eq. asserts that energy has mass. Here a serious confusion arose from the reversion to the Newtonian concept of mass.

Definition of mass

There are two different definitions of the interial mass, co-incident in the non-relativistic context.

Definition -

1. Mass is defined "as a number attached to particle or body obtained by comparison with a standard body whose mass is defined as unity"[9].
2. Mass is a measure of the inertia of a body

Now, We Procced under as,

A deep physical meaning is commonly ascribed to Einstein's Relation

$$E = mc^2 \qquad \ldots\ldots(1.1)$$

or,

$$E = \frac{Mc^2}{\sqrt{1-u^2/c^2}}; \qquad \ldots\ldots(1.2)$$

It is interpreted as the equivalence of mass and energy. This interpreted of Einstein's formula appears to be unavoidable if the quantity m defined by formula $E = mc^2$ is considered as a relativistic generalization of the concept of inertial mass.

In this case, formula (1.1) expresses the proportionality of the relativistic energy to the relativistic inertial mass. Since expression (1.1) is a universal one, we can replace E by m in all laws, and vice versa, and this expresses the equivalence of mass and energy to within a constant factor c^2 which, by a suitable choice of units, can be made equal to unity.

If expression (1.1) is given the above meaning, then it is necessary to regard it as a relativistically covariant one. However, from the four-dimensional point of view E is the zeroth component of the four-dimensional vector.

$$E_k = c\,P_k \qquad \ldots\ldots(1.3)$$

Therefore, the quantity *m* must be considered not as an invariant, but as the zeroth component of a four- dimensional vector.

$$M_k = P_k/c \qquad \ldots\ldots(1.4)$$

Consequently, If relation (1.1) is considered not as a definition of energy in terms of quantities appearing in equation

$$\frac{d}{dt}(m,u) = f,$$

$$\frac{d}{dt}(mc^2) = (uf), \qquad \ldots\ldots(1.5)$$

but as a new physical assertion, it also acquires meaning only when it is written as

$$E_k = m_k c^2 \qquad \ldots\ldots(1.6)$$

an independent physical meaning being ascribed here to the vectors E_k and m_k.

It is obvious that expression

$$m = \frac{M}{\sqrt{1-u^2/c^2}} \qquad \ldots\ldots(1.7)$$

for the inertial mass *m* has a covariant meaning only when it is considered as the zeroth component of an expression for a four-dimensional quantity m_k in terms of M and U_k, i.e., as the zeroth component of the vector

$$M_k = MU_k/c \qquad \ldots\ldots(1.8)$$

All the more, there is no covariant physical meaning in such a concept as "kinetic energy" defined by expression

$$(m-M)c^2 = Mc^2\left(\frac{1}{\sqrt{1-u^2/c^2}} - 1\right) \qquad \ldots\ldots(1.9)$$

Which, with $u << c$, coincides with the classical expression $Mu^2/2$. The first term of (1.8) is zeroth component of a four-dimensional vector, while the second term is a four-dimensional scalar. It is obvious that such a "hybrid" composed of a vector component and a scalar cannot be considered as a covariantly introduced physical quantity when we are dealing with velocities comparable to those of light. Only for velocities $u << c$ does the kinetic energy acquire the meaning of a three-dimensional scalar.

The quantities defined by expression (1.6), (1.1), (1.2), (1.9), and equations (1.5) have definite physical meaning only in the case of transitions from four-dimensional representations to three-dimensional ones associated with a fixed frame of reference, i.e., when the principle of relativity and the four-dimensional nature of space-time are ignored.

The latter procedure can be justified either in the case $u << c$, or as substitute for the rigorous theory intended for the reconciliation of the four-dimensional concepts of conventional classical physics. Indeed if relativistic covariance is ignored and the theory is constructed for a single frame of reference, then relativistic effects can be represented as a correction to take into account the fact that the "inertial mass" m appearing in the usual equations of mechanics (1.5) depends on the velocity according to the "law" (1.6). Then, the definition of energy E as the zeroth component of a four-dimensional momentum multiplied by c can be presented as the "law of the inertial nature of energy." Many misunderstandings and paradoxes arising in the interpretation of the formulas of relativistic mechanics occur because the so-called laws that can be justified only in a three-dimensional non-covariant formulation are interpreted from a relativistic four-dimensional point of view.

In the four-dimensional theory is no concept of inertial mass as a scalar varying with velocity, only the concept of proper mass M indissolubly linked with momentum and energy. Therefore, the "law of variation of inertial mass with velocity" can only be included in the four-dimensional theory if a generalization of "inertial mass" of the form (1.8) is introduced. However, such a generalization is artificial, since the mass vector M_k (1.8), apart from a constant factor of 1/c, does not differ in any way from the four-dimensional momentum vector P_k.

The same situation occurs in the case of Einstein's law $E = mc^2$. From the three-dimensional point of view this is indeed a law, because it links two qualitatively different quantities, one of which is a property of the motion, the other the property of the inertia of matter.

From the four-dimensional point of view, this relation is only meaningful when it is lowered to the status of a definition of the mass vectors are physically defined only through the momentum vector P, which is the only quantity with a direct physical meaning.

Einstein's relation (1.1) can be given another covariant meaning different from that of (1.6). This is the meaning with which this relation is used in nuclear dynamics. However, we will leave this problem until the next section where we discuss the laws of conservation of energy and momentum for system of particles.

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