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Coordinate Transformations from Galileo to Lorentz

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Annotation. It is shown how Galilean transformations naturally going over into Lorentz transformations, depending on changes in the kinematic conditions of the reference systems under study. Such an evolution of equations is an independent derivation of Lorentz transformations based on the laws of classical mechanics. It is established that any Lorentz transformations are based on the universal Rule of simultaneity, the observance of which makes transformations feasible regardless of the type, speed, direction of mutual movement of these systems and their number. This rule made it possible to find previously unknown transformation equations, in particular, such as combined Galileo–Lorentz transformations, as well as mirror transformations, when the subject of research is not coordinates, but clock readings in the studied reporting systems, or the speeds of these systems.

Keywords. Galileo transformations, Lorentz transformations, special theory of relativity.

Introduction

A feature of any coordinate transformations is that the calculation results obtained in the first equation (direct transformation) and substituted into the second equation (inverse transformation) give the initial data for the first equation. In other words, the arguments of the forward and backward functions depend on their opposite functions.

Currently, Galileo's transformations are usually attributed to classical physics [2, p.22].

$$x' = x - vt \qquad\qquad x = x' + vt'$$
$$t' = t \qquad\qquad t = t' \tag{1}$$

Relativistic physics is based on Lorentz transformations [1, p.11]:

$$x' = \frac{x - vt}{\sqrt{1 - v^2/c^2}} \qquad\qquad x = \frac{x' + vt'}{\sqrt{1 - v^2/c^2}}$$
$$t' = \frac{t - vx/c^2}{\sqrt{1 - v^2/c^2}} \qquad\qquad t = \frac{t' + vx'/c^2}{\sqrt{1 - v^2/c^2}} \tag{2}$$

It is believed that the transition from Lorentz transformations to Galilean transformations is possible based on the correspondence principle ($v << c$), but the reverse transition from Galilean transformations to Lorentz transformations is impossible.

Of course, both opinions are wrong, and that's why:

In the first case, the transition is indeed possible, but under different conditions. But the very principle of correspondence, adopted in relativism, is erroneous, since the expression ($v/c = 0$) can always be compensated by ($x \rightarrow \infty$), and then the equation for the direct transformation (2) will take the following form:

$$x' = x - vt \qquad\qquad t' = t - vx/c^2$$

That is why the inequality ($t' \neq t$) for transformation (2) will always be preserved, regardless of the ratio (v/c).

The second statement is also erroneous, since it has recently been possible for the first time to derive Lorentz transformations from the standpoint of classical mechanics without the help of postulates and other assumptions [4] [5] [6]. The discovered new properties of coordinate transformations using the Lorentz method made it possible to find previously unknown transformation equations, which will be discussed later.

The transition from Galilean transformations to Lorentz transformations

In the Galilean transformation (1) it is assumed that the origin of coordinates of the two reference frames (K) and (K') at the initial moment at ($t = 0$) coincide and the initial coordinates are equal to ($x = x'$).

However, these transformations are never considered for the model when at ($t = 0$) the origin of the two reference frames (K) and (K') are shifted by ($\Delta x', \Delta x$). Under such conditions, the initial coordinates (x) and (x') of the two systems will no longer be equal to each other ($x' = x + \Delta x'$).

For the special case when the axes (X) and (X') are parallel, the Galilean transformations will have the following form:

$$x' = x - vt + \Delta x' \qquad\qquad x = x' + vt' - \Delta x$$
$$t' = t \qquad\qquad t = t' \tag{3}$$

In general, when the (X) and (X') axes are not parallel, the coordinate transformations will have the following entry:

$$x' = \frac{x - vt}{k_S} \qquad x = \frac{x' + v't'}{k_S'}$$
$$t' = t \qquad t = t' \tag{4}$$

where: $k_S\, k_S' = 1$

$k_S = x/(x + \Delta x')$ or $k_S = v/v$,

Note that in this transformation ($v \neq v'$), since ($t = t'$) when ($x \neq x'$). Graphically, the inequality ($x \neq x'$) can alternatively be represented as the movement of the system (K') at some angle (α) to the system (K), and then ($k_S = \cos\alpha$).

The coefficients (k_S) and (k_S') entered into the equations and named as "simultaneity coefficients" are matching parameters, and are defined as

$$k_S\, k_S' = 1 \tag{5}$$

The product of the coefficients (k_S) and (k_S') is a condition called the "Rule of simultaneity", under which the Lorentz transformations are always performed, regardless of the form of writing the equations.

In transformations, the velocity parameters (v) and (v') may have different natures. In one case, these are the actual velocities of two reference frames (K) and (K') moving relative to the third, privileged one (K_0). And in another case, for two reference frames, this is the actual velocity (v'), for example, of the system (K') and the vector velocity (v) for the system (K).

So, in the well-known Lorentz transformation (2), a mathematical technique is used when, in calculations, the actual velocity (v') of a reference system is replaced by coordinate time (t'), following the principle:

$$\frac{x}{x'} = \frac{vt}{v't} = \frac{vt}{vt'} \tag{6}$$

Such mathematical formalism excludes from calculations a single time frame for the movement of two systems, thereby making the transition from the time invariant to the velocity invariant. With the replacement of the invariant, transformations (4) will have a different form:

$$x' = \frac{x - vt}{k_S} \qquad x = \frac{x' + vt'}{k_S'}$$
$$t' = \frac{t}{k_S} \qquad t = \frac{t'}{k_S'} \tag{7}$$

where: $k_S\, k_S' = 1$

$k_S = x/(x + \Delta x')$

This example clearly shows the essence of the fundamental error in the modern method of obtaining transformations (2), when, at the stage of introductory conditions, the initial coordinates (x) and (x') are set equal in magnitude [3, p.213]. And then the existing inequality ($\Delta t = t' - t$), which naturally follows from equation (6) as:

$$1 \neq \frac{t}{t'} \quad ,$$

in the special theory of relativity, it began to be interpreted only as "time dilation".

Meanwhile, it is possible to leave both invariants in equations (4) or (7).

$$x' = \frac{x - vt}{k_S} \qquad x = \frac{x'}{k_S'} + vt'$$
$$t' = t \qquad t = t' \tag{8}$$

where: $k_S\, k_S' = 1$

$k_S = x/(x + \Delta x')$

And although the actual velocity of the second object (v') is formally absent, it is nevertheless taken into account through the coefficients (k_S) and (k_S').

Coordinate transformations using the Lorentz method have another important feature – they take into account the obvious difference in readings, we emphasize, the readings of clocks ($\Delta t'$) located in different frames of reference (K) and (K').

And here it is necessary to make some clarifications regarding ($\Delta t'$). So, in the special theory of relativity, concepts such as "clock readings" and "synchronicity of their course" are not particularly shared and are considered identical [1, p.6, 13].

This is certainly a mistake, since identical clocks running synchronously have the same periods of oscillation of their pendulums ($T = T'$). But their readings may be different ($\Delta t_0' = t' - t$), and this difference in readings will always be constant. An example is the time zone, when readings in neighboring time zones differ by one hour, and all clocks in all neighboring zones run synchronously ($t_{UTC-1} < t_{UTC+0} < t_{UTC+1}$).

In turn, the non-synchronicity of the movement of different clocks means that the periods of oscillation of their pendulums do not coincide ($T \neq T'$). In this case, the readings of such watches will be correlated as ($t' = k_t t$), where: ($k_t = T/T'$).

It turned out that for Lorentz transformations it is important to know the initial parameters of these discrepancies: either ($\Delta t_0' = t' - t$), or ($k_t = T/T'$), or both at the same time, and thereby determine the clock desynchronization parameter ($\Delta t'$):

$$\Delta t' = \Delta t_0' + k_t\, t$$

For this case, when the transformation takes into account not only the initial offset of the reference system ($\Delta x'$), but also, very importantly, the initial discrepancy in the readings of the clocks ($\Delta t' = \Delta t$) located in these systems is taken into account. Then the coordinate transformations for the two reference systems will have the following form:

$$x' = \frac{x - vt}{k_S} \qquad x = \frac{x' + vt'}{k_S'}$$
$$t' = \frac{t}{k_S} - \Delta t \qquad t = \frac{t' + \dfrac{x'\Delta t'}{x + \Delta x'}}{k_S'} \tag{9}$$

In this case, the coefficients (k_S) and (k_S') are determined according to the Rule of Simultaneity, which has the following entry:

$$k_S\, k_S' = 1 - \frac{v\,\Delta t'}{x + \Delta x'} \tag{10}$$

As we can see, an observer located in the frame of reference (K) is able to know the time of future events not only by his own clock (t), but also by the clock of the opposite system (K'), which from the very beginning has other readings with a difference of ($\Delta t'$).

The second observer, located in his frame of reference (K'), is also able to correctly determine the moment of the same event from the readings of his incorrectly running clock (t'), and also calculate the time (t) for the first observer located in the system (K).

This is the uniqueness of the mathematical apparatus of the Lorentz transformations (9) – even with non-synchronously running clocks, the transformations of the coordinates will always be performed. This is explained by the fact that the change in the parameter ($\Delta t'$) is compensated by corresponding changes in the coefficients of simultaneity (k_S, k_S') according to the Rule of simultaneity (10).

For the special case when the initial coordinates of the two reference systems (K') and (K) are equal to ($x = x_0'$), i.e. ($k_S = 1$), and the clock readings have obviously different readings by the value ($\Delta t'$), the equations of coordinate transformations (9) will have the following entry:

$$x' = x - vt \qquad\qquad x = \frac{x' + vt'}{k_S'}$$

$$t' = t - \Delta t' \qquad\qquad t = \frac{t' + \dfrac{x'\Delta t'}{x_0'}}{k_S'}$$

где: $k_S = 1$, $k_S' = 1 - \dfrac{v\,\Delta t'}{x_0'}$

It is clear that in the absence of an initial offset of the reference frames ($\Delta x' = 0$) and the absence of an initial difference in the clock readings ($\Delta t' = 0$), the Lorentz transformations (9) take the form of Galileo transformations (1).

An important consequence follows from this:

If the condition ($\Delta x' = 0$) and ($\Delta t' = 0$) is set for the two reference frames under study (K') and (K), then in this case the Lorentz transformations definitely do not apply, since under these conditions coordinate transformations can only be carried out using Galilean transformations.

There are some limitations in the transformation for three reference systems (K, K', K_0), since the difference in clock readings ($\Delta t'$), called the "time scale offset", is set externally and determined through the ratio of parameters (v), (V) and (x), which is adjusted by the amount of the offset ($\Delta x'$) of the systems (K) and (K') in terms of the coefficient (k_S):

$$\Delta t' = \frac{v\,x}{k_S\,V^2}$$

Then the general transformations of coordinates by the Lorentz method, applied to three reference systems, will have the following form:

$$x' = \frac{x - vt}{k_S}$$

$$t' = \frac{t - \beta x/V}{k_S}$$

where: $\beta = v/V$

v – velocity between reference frames (K') and (K);

V – velocity between reference frames (K) and (K_0).

The Simultaneity of Rule for this case will have the following entry:

$$k_S\, k_S' = 1 - \beta^2 \tag{12}$$

The well-known Lorentz transformations (2) are a special case of general transformations (11) in which ($V = c$) and ($k_S = k_S'$). It is clear that in this record, the reference frames (K') and (K) are initially shifted by $(\Delta x')$ at $(t = 0)$, and the readings of the clocks located in these systems initially differ by $(\Delta t')$.

For the special case when $(\Delta x' = 0)$, i.e. when $(x = x')$, the duration of movement of both systems will also be equal $(t = t' - \Delta t')$, although the clock readings will be different $(t \neq t')$. It is clear that equations (9) and (11) are equivalent.

This transformation method is universal and can be used for other types of motion, for example, for rotational motion. In this case, the angular coordinates (φ, φ') are the subject of transformations:

$$\varphi' = \frac{\varphi - \omega t}{k_S} \qquad \varphi = \frac{\varphi' + \omega t'}{k_S'}$$

$$t' = \frac{t - \omega \varphi/\Omega^2}{k_S} \qquad t = \frac{t' + \omega \varphi'/\Omega^2}{k_S'} \tag{13}$$

where: $k_S\, k_S' = 1 - \omega^2/\Omega^2$

ω – angular velocity between reference frames (K') and (K);

Ω – angular velocity between reference frames (K) and (K_0).

Here, too, the initial difference of the angular parameters is present in the calculations $(\Delta\varphi' = \varphi - \varphi')$. And therefore , the interpretation of the initial difference $(\Delta\varphi')$ in the special theory of relativity as a reduction in the length of the arc in comparison with the radius is a profound misconception.

In the model of four reference systems, when the three systems (K_1'), (K_2') and (K) move relative to the privileged one (K_0), the coordinate transformation for any pair of reference systems is output through double transformations, for example, as follows:

$$(K_1' - K) + (K_2' - K) = (K_1' - K_2')$$

The peculiarity of this transformation is the choice of a pair of reference frames, the relative velocity of which is assumed to be absolute. It depends on which value of the velocity will be taken into account in the equation under the parameter (V).

It can be (V), (v_1), (v_2), $(V + v_1)$, $(V + v_2)$ or $(v_1 + v_2)$.

For example, for two reference frames (K_1') and (K_2') moving at speeds (v_1) and (v_2) relative to the system (K), which, in turn, moves at a speed (V) relative to a privileged one (K_0), the coordinate transformation will look like:

$$x_2' = \frac{x_1'(1+\beta_1\beta_2) - (v_1+v_2)\,t_1'}{k_{S1}\;k_{S2}} \qquad\qquad x_1' = \frac{x_2'(1+\beta_1\beta_2) + (v_1+v_2)\,t_2'}{k'_{S1}\;k'_{S2}}$$

$$t_2' = \frac{t_1'(1+\beta_1\beta_2) - (\beta_1+\beta_2)\,x_1'/V}{k_{S1}\;k_{S2}} \qquad\qquad t_1' = \frac{t_2'(1+\beta_1\beta_2) + (\beta_1+\beta_2)\,x_2'/V}{k'_{S1}\;k'_{S2}} \tag{14}$$

where: $k_{S1}\,k'_{S1} = (1 - \beta_1^2)$, $\beta_1 = v_1/V$

$k_{S2}\,k'_{S2} = (1 - \beta_2^2)$, $\beta_2 = v_2/V$

The appearance of an additional correction factor in the numerator in the form of $(1+\beta_1\beta_2)$ is explained by the following.

In the Lorentz transformation, the change in any parameters is compensated by the coefficients (k_S, k_S') – this is the whole point of the Simultaneity Rule. And since the coefficients $(k_{S1}\;k'_{S1})$ and $(k_{S2}\;k'_{S2})$ remained the same in transformation (14), an additional adjustment by $(1+\beta_1\beta_2)$ was required for the parameters (x_1', t_1') and (x_2', t_2') in order for the transformation to be feasible.

Meanwhile, equations (14) can be modified, i.e., the record from the double transformation can be converted to the usual record (11). To do this, the product of the coefficients $(k_{S1}\;k_{S2})$ must be adjusted to $(1+\beta_1\beta_2)$ as:

$$k_S = (k_{S1}\;k_{S2})/(1+\beta_1\beta_2)$$

This means that the new coefficients of simultaneity are no longer equal to each other $(k_S \neq k_S')$ and, according to the Rule of Simultaneity, will be defined as:

$$k_S\,k_S' = 1 - (v_1 + v_2)^2/V^2 \tag{15}$$

Then the same transformations (14) will take a different form, namely:

$$x_2' = \frac{x_1' - (v_1+v_2)\,t_1'}{k_S} \qquad\qquad x_1' = \frac{x_2' + (v_1+v_2)\,t_2'}{k_S'}$$

$$t_2' = \frac{t_1' - (v_1+v_2)\,x_1'/V^2}{k_S} \qquad\qquad t_1' = \frac{t_2' + (v_1+v_2)\,x_2'/V^2}{k_S'} \tag{16}$$

where: $k_S\,k_S' = 1 - (v_1+v_2)^2/V^2$

$k_S = x_1'/x_2'$ by $(t_1' = 0)$

Another type of transformation should be mentioned – these are combined transformations (Galileo–Lorentz transformations), when both Galileo and Lorentz transformations are applied simultaneously for a group of three or four reference frames, in the presence of portable motion.

Consider coordinate transformations, for example, for three reference frames, when Lorentz transformations are performed between the $(K - K')$ systems. In this case, we will assume that the reference frame (K') is moving in the system (K'') with velocity (v_2), i.e. there is a portable motion in which the mutual coordinates can be determined using Galilean transformations. Then, taking into account the additional portable motion, the coordinate transformations will look like this:

$$x' = \frac{x - v_1 t}{k_S} - v_2 t \qquad x = \frac{x' + v_1 t' + v_2 t}{k_S'}$$

$$t' = \frac{t}{k_S} - \Delta t' \qquad t = \frac{t' + \dfrac{x' \Delta t'}{x + \Delta x'}}{k_S'} \tag{17}$$

where: $k_S\, k_S' = 1 - \dfrac{v \Delta t'}{x + \Delta x'}$

In this case, the time parameter (t/k_S') in the inverse transformation can be calculated in another way, namely as: $[(t' + \Delta t')\, k_S/k_S']$.

Let's change the conditions and assume that the reference frame (K'') moves in the system (K') with a velocity (v_2), the mutual coordinates of which are determined using Galilean transformations. Then the combined transformations, for example, for four reference frames where parameter (V) is present, will have a record similar to equations (16).

The rule of simultaneity makes it possible to express coordinate transformations in relative quantities and thereby, for example, exclude the relative velocity (v) between systems (K) and (K') from equations (11). Denote $(v = \mathcal{B} V)$, and then the Lorentz transformations for the three reference frames can be written as:

$$x' = \frac{x - \mathcal{B}Vt}{k_S} \qquad x = \frac{x' + \mathcal{B}Vt'}{k_S'}$$

$$t' = \frac{t - \mathcal{B}x/V}{k_S} \qquad t = \frac{t' + \mathcal{B}x'/V}{k_S'} \tag{18}$$

where: $k_S\, k_S' = (1 - \mathcal{B}^2)$

Here, the coefficient $(\mathcal{B})$ acts as an independent coefficient set from the outside, which determines certain kinematic parameters.

The peculiarity of equations (18) is that both coefficients can take a value equal to one $(k_S = 1)$, $(k_S' = 1)$, and at the same time the transformations remain feasible. This circumstance does not contradict the Rule of simultaneity (12), since the compensation of the initially existing asymmetry (vx/V^2) is transferred to the numerators of the equations through the parameter $(\mathcal{B})$. Such a mathematical technique with the transfer of the compensation mechanism to the numerator does not affect the result of the transformations, and at the same time it allows you to determine the internal content (essence) of the transformations themselves.

Let's give the coefficient (k_S, k_S'), as well as (V) a value equal to one. Then, at ($\mathcal{B} = \sqrt{1 - k_S\, k_S'}$), the Lorentz transformations transform into Galilean transformations:

$$a' = a - b \qquad\qquad a = a' + b'$$
$$b' = b \qquad\qquad b = b' \tag{19}$$

In the case when ($\mathcal{B} = \sqrt{1 + k_S k_S'}$), the Lorentz transformations are simplified to their primary basis:

$$a' = a - \sqrt{2}\, b \qquad\qquad a = -(a' + \sqrt{2}\, b')$$
$$b' = b - \sqrt{2}\, a \qquad\qquad b = -(b' + \sqrt{2}\, a') \tag{20}$$

As we can see, the Lorentz transformations in their structure are a system of equations consisting of two interrelated Galilean transformations.

The application of Lorentz transformations for four reference frames with a double transformation takes the form:

$$a'' = 3a' - 2\, b \qquad\qquad a' = \frac{a'' + 2b''}{3}$$
$$b'' = b' \qquad\qquad b' = b'' \tag{21}$$

The coefficients "2" and "3" obtained are the result of a double transformation, while the equations themselves, as an independent mathematical apparatus, may have different meanings, and the formalism of the transformations will not change. However, the main thing here is something else – the equality of the second variables ($b'' = b'$), i.e. time, follows from the double transformation. It follows from this that equations (21) are also essentially Galilean transformations.

It should be added that for any arbitrary change of parameters (v), (V), (Δt), either all simultaneously or individually, the Lorentz transformations for any type of record always remain feasible.

This means that the Rule of simultaneity makes it possible to apply all the above Lorentz transformations to non-inertial reference frames.

The rule of simultaneity makes it possible to obtain mirror transformations when the subject of research is not coordinates, but the duration of movement (time). This means that in the absence of clocks in the reference systems, the clock readings (t') in the system (K') and the travel time (x/v) of the system (K) are determined through the parameters of the traveled path (x', x), for example, by the number of kilometer bars traveled. In this case, the mirror transformations will look like this:

$$t' = \frac{t_0 - x/v}{k_S} \qquad\qquad t_0 = \frac{t' + x'/v}{k_S'}$$
$$x' = \frac{x - v\Delta t}{k_S} \qquad\qquad x = \frac{x' + v\,\Delta t'\, t'/t_0}{k_S'} \tag{22}$$

where: $k_S\, k_S' = 1 - \dfrac{\Delta t'}{t_0}$

$$k_S = 1 - \frac{t_0}{t_0 + \Delta t'}$$

t_0 – the planned time period in the system (K), during which it should reach a certain point in space;

$\Delta t'$ (Δt) – the desynchronization parameter for clocks located in different reference frames ($\Delta t' = t' - t_0$) at ($x = 0$);

x', x – the traveled path of each of the reference frames (K') and (K).

Consider the following example, when the subject of research is the second derivatives, i.e. the velocities of movement of two reference systems (K) and (K').

Let these systems move with velocities (v) and (v'). At the moment ($t = 0$), the system (K') begins to move with some acceleration (a). Let's assume that the clock in the system (K') is going wrong and the parameter of its desynchronization is ($\Delta t'$). Then the Lorentz transformations for the two reference frames will have the following notation:

$$v' = \frac{v - at}{k_S} \qquad v = \frac{v' + at'}{k'_S}$$

$$t' = \frac{t}{k_S} - \Delta t' \qquad t = \frac{t' + \dfrac{v'\Delta t'}{v + \Delta v'}}{k_S'} \tag{23}$$

where: $k_S\, k_S' = 1 - \dfrac{a\Delta t'}{v + \Delta v'}$

$$k_S = \frac{v}{v + \Delta v'}$$

$$\Delta v' = v' - v$$

Here, the parameters (v), ($\Delta v'$), (a) and ($\Delta t'$) can also change according to an arbitrary law, and the transformations will not lose their properties.

This example is notable for the fact that the second derivative (acceleration) acts as an invariant. This circumstance once again confirms that artificially making an invariant to any parameter is a feature of the methodology of converting some parameters into others and vice versa.

For three reference frames, when at the moment ($t = 0$) the system (K) begins to move relative to the privileged reference frame (K_0) with acceleration (g), the Lorentz transformations for the velocities (v') and (v) will have the following form:

$$v' = \frac{v - at}{k_S} \qquad v = \frac{v' + at'}{k_S'}$$

$$t' = \frac{t - av/g^2}{k_S} \qquad t = \frac{t' + av/g^2}{k_S'} \tag{24}$$

where: $k_S\, k_S' = 1 - a^2/g^2$

In this case, the accelerations (v), (a) and (g) can be variables that can be changed according to an arbitrary law.

Discussion

The presented research results are important because they directly relate to the special theory of relativity and refute all those interpretations of Einstein that he once gave to the properties of Lorentz transformations.

The first example. According to the existing methodology [2, p.25] [3, p.219] from the direct time transformation (11), when ($k_S = k_S'$) and ($v = c$), the "time dilation" will be determined by the formula:

$$\Delta t' = \frac{\Delta t}{k_S}$$

However, at a constant value ($v/c = const$), the coefficient (k_S) can take any value except zero. Therefore, based on the paradigm of the special theory of relativity, time should slow down or accelerate depending on the arbitrary choice of the value of the coefficient (k_S) by the observer, or on the initial displacement of the reference frames ($\Delta x'$).

It is clear that such an interpretation of the properties of transformations certainly looks like a complete absurdity.

Further. From the transformations for the two systems (9), in which the speed of light parameter (c) is missing, the formula for "time dilation" at ($k_S = k_S'$) will be somewhat different.

$$t' = \frac{t}{\sqrt{1 - \dfrac{v\,\Delta t'}{x + \Delta x'}}}$$

Following the concept of special relativity, we see that at a constant velocity (v) of the system (K'), the "time dilation" depends not only on the displacement of the reference frames ($\Delta x'$) at the initial moment, but also on the readings of the initially incorrect, we emphasize, incorrectly running clock ($\Delta t'$).

It is clear that this is an absurdity, and in order to avoid it, it should be recognized that in the Lorentz transformations, measures of duration (sec) and dimension (meter) are immutable measures regardless of the kinematics of the reference systems under study.

It should also be remembered that conventional measures of duration and dimension are not material entities, but act as comparative (abstract) instruments (measures) that have emerged as a result of the agreement of society, and therefore measures are inherently immutable quantities.

The second example. An important property of coordinate transformations is that they take into account not only the different duration of movement of the reference frames under study, but also the deliberate out-of-sync in the clock readings. And therefore, the question: is such a clock running correctly in the system (K') or not becomes optional, since the desynchronization parameters of the second clock in the transformations are automatically compensated in accordance with the Rule (5) (10) (12).

This means that the second observer in the reference frame (K') can always correctly determine the moment of simultaneity of events by his incorrectly running clock.

It follows from this that the question of clock synchronization in different reference frames, as a justification for the relative simultaneity and then the physical deceleration of time [1, p.3], is completely far–fetched.

Thus, it can be argued that in Lorentz transformations, the simultaneity of events is absolute.

The third example. This is the absence of a ban on movement at superluminal speed, since at ($v > c$) the Lorentz transformations are feasible, which, in fact, directly follows from equations (11, 12). This circumstance refutes the conclusion that coordinates (x') and time (t') are imaginary for ($v > c$) [2, p.24], since in this case the coefficients (k_S) and (k_S') take opposite signs.

Example four. This is a mathematical technique underlying transformations with the replacement of coordinate (real) velocity by coordinate time. Such a technique by itself does not establish cause-and-effect relationships in physical phenomena and, as a result, cannot generate new physical laws.

Additionally, we note that any coordinate transformation is always a comparison procedure that determines the relative location of two objects in space without their physical interaction. Consequently, there is absolutely no reason to associate coordinate transformations with the emergence of new physical laws.

Conclusions

The Lorentz transformations are Galilean transformations that take into account: the initial displacement of the reference frames, the direction of their movement, and the initial difference in clock readings, including the out–of-sync of their pace.

Coordinate transformations using the Lorentz method are always performed if the correction coefficients for the forward (k_S) and reverse (k_S') transformations obey the Rule of simultaneity.

Lorentz transformations are applicable for both inertial and non-inertial reference frames.

In coordinate transformations using the Lorentz method, measures of duration (time) and dimension (extent) are immutable measures regardless of the kinematic state of the reference systems under study.

In Lorentz transformations, making a parameter invariant is a feature of the methodology used to determine the mutual coordinates, as well as other parameters of these comparisons. The transfer of an invariant from measurement measures to their derivative does not generate new physical laws.

The uniqueness of the Lorentz transformation equations cannot be the reason for the appearance of any new physical laws. This is because when determining the relative position of two objects in space, i.e. when determining their mutual coordinates, there is no interaction between these objects. In other words, the method of measuring the relative position of objects in space does not generate new physical phenomena.

The Lorentz coordinate transformations are based on the concept of absolute simultaneity, otherwise coordinate transformations would not be possible. This means that the simultaneity of events is absolute.

Thus, the shown variant of coordinate transformations by the Lorentz method, which naturally follows from the Galilean transformations, is a mathematical apparatus in which, from the standpoint of classical physics, all kinematic parameters are consistent, consistent and logical.

This circumstance indicates that in order to derive Lorentz transformations, there is no need to resort to the help of any postulates and invent any principles - they are simply superfluous.

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