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On the empirical evidence of special relativity

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Abstract.-From an unusual perspective, this article examines the experimental confirmation of the spacetime deformations predicted by special relativity. A perspective that includes three relevant critical aspects: the necessary symmetry (never verified) of the experimental confirmations; the universality of the relativistic deformations, always suspiciously independent of the physical and chemical nature of the deformed or altered objects (e.g., rulers and clocks); and the absence of direct physical causes of those deformations and alterations, the only cause being the fact that the deformed or altered objects are always observed in uniform motion. Apart from remembering that such experimental confirmations could also be confirming other theories (e.g. H. Ives' theory of absolute space and time), we consider here the possibility that the observed and measured relativistic spacetime deformations are only apparent deformations, as in the case of refractive deformations; or that they are the consequence of making observations and measurements in a supposedly continuous spacetime that in reality is discrete (discontinuous). In any case, this article demonstrates that certain relativistic deformations are incompatible with some basic laws of mechanics, as is the case with the pendulum that oscillates faster in one direction than in the opposite direction; or with the force-free elastic band that is observed to be stretched more in some parts than in others.

Keywords: symmetry of relativistic deformations, universality of relativistic deformations, acausal deformations, apparent deformations, spacetime continuum, discrete space-time, relativistic pendulum, relativistic elasticity.

1 Introduction

In 1949 the theory of special relativity was already considered to be sufficiently confirmed by empirical evidence. In the words of H. Margenau (quoted in [16, p. 1]):

> Relativity theory is so well confirmed by experience that its denial is all but unthinkable.

In our days (end of the year 2022) the theory of special relativity is considered to be fully confirmed by experience. It is also still considered a very difficult theory that only a few are able to understand [1, p. 8]:

> When the theories of relativity were experimentally confirmed, the red carpet was rolled out despite (or perhaps because of) the fact that almost no one understood them.

Although the purpose of this article is not to discuss on the difficulties of understanding the special relativity, it will be worthwhile to dedicate a few brief words to it, which also have some introductory value. In reality there is almost nothing to understand in the theory of special relativity: it is sufficient to accept without proof (accept, not understand) its two fundamental principles[1], and apply to them some rather basic mathematics in order to derive the equations that transform the observations made in different reference frames. And the equations that come out are no longer the classical equations of Galileo Transformation, but the equations of the new Lorentz Transformation. And that is all. The novelty is that the application of the Lorentz Transformation (LT) has strange consequences on space and time when the objects and events involved are observed in uniform motion: length contraction, time dilation and local simultaneity instead of universal simultaneity. But having strange consequences is not the same as being difficult to understand.

Note, moreover, that the two principles of the special relativity refer to reference frames, which in reality are abstract objects based on the infinitist mathematics of the continuum, which could be inconsistent. The fundamental laws (statements that are not proved) of the experimental sciences should not refer to abstract objects such as reference frames. And in fact they never do, except in the case of the two relativistic principles underlying special relativity.

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[1] P1: The laws pf physics are the same in all reference frames.
P2: The speed of light is the same in all reference frames.

Returning to the experimental confirmation of the most famous scientific theory of all times, today it is considered so duly confirmed by empirical facts that it behaves as if it were a new fundamental law of logic: if something does not agree with special relativity, that something is considered false; no more; and whatever that something is. In my opinion, there is no more anti-scientific attitude. This paper examines the empirical confirmation of special relativity from different perspectives that relativistic orthodoxy never takes into account:

1. The symmetry of confirmations: If from an inertial reference frame A a spacetime deformation is observed in another inertial reference frame B, *at the same time* and from the reference frame B the same deformation has to be observed in the reference frame A. A symmetry that, as far as I know, has never been confirmed.
2. The universality of confirmations: all objects contract in the direction of relative motion in exactly the same way, irrespective of their composition and internal structure: wood, paper, steel, elastic bands, glass etc., all contract the same and without any external force explaining the contraction. And the ticking of clocks also dilates in the same way in all imaginable kinds of clocks: mechanical, electrical, electronic, biological, etc. without a cause that explains the alteration of the corresponding mechanisms causing their respective periodic events (tic-tac) used to measure time. Of course, modern clocks that display the time on large alphanumeric displays call into question inertial time dilation and relativistic local simultaneity, unless those displays simultaneously show as many different times as different relative velocities at which they can be observed [12].
3. As will be seen in this article, in some relativistic spacetime deformations there are violations of the fundamental physical laws: for example, elastic ribbons that are stretched more in some parts than in others without any force acting on them; or pendulums that swing faster in one direction than in the other.
4. Relativistic deformations could be only apparent, as is the case with refractive deformations (see below). Or they could be the consequence of explaining the world as if spacetime were continuous when in fact it is discrete. The Lorentz factor, key to the Lorentz Transformation, has the same algebraic form as the factor that converts between the continuous and discrete versions of Pythagoras' Theorem, a key theorem in geometry.
5. The empirical confirmations of special relativity could also be of other theories. One such theory will be recalled here.

In any case, one should not lose sight of the fact that the special relativity is a theory of the spacetime continuum, and this is an infinitist concept based on the Axiom of infinity, an axiom that assumes the Actual Infinity Hypothesis, which could be an inconsistent hypothesis. That possibility should have stimulated the interest of physicists in the formal consistency of the infinitist mathematics they use as a formal language in all their theories. I did so for almost thirty years, and found more than forty proofs of that inconsistency. The reader can find them in [14], or one of the simplest in [13]. Now, if the spacetime continuum is inconsistent, can the theory of special relativity be consistent?

2 A comparative reference: refractive deformations

As an illustrative and comparative reference for relativistic spacetime deformations observed between inertial reference frames, we will use here the apparent deformation of a rigid rod when it is observed, as illustrated in Figure 1, partially submerged in two media with different refractive indices (e.g. air and water). In our case, the rod is made of transparent glass and is equipped with a visible laser beam emitted inside it, from its lower end and in a direction coinciding with the longitudinal axis of the rod. The deformation observed in the rod due to refraction of light needs no introduction. Although the deformation is not real but apparent, as shown by the trajectory of the visible laser beam VLB emitted from inside the rod: as the laser light always moves through the same internal medium (air) of the rod, it is not refracted and follows a rectilinear trajectory parallel to the rod wall. Therefore, if the rod were actually deformed, the laser beam would follow the path (b) in place of the observed path (a) (Figure 1). Consequently, and as everyone knows, the rod does not actually deform: the observed deformation is only apparent. This refractive deformation of the rod has three very remarkable characteristics, which make it suspect of being precisely an apparent deformation, not a real one:

1.- The refractive deformation of the rod is independent of the physical and chemical nature of the rod. It is the same for all conceivable rods: wood, glass, pvc, steel, etc. The deformation does not depend on the chemical composition of the rod, nor on its internal structure.

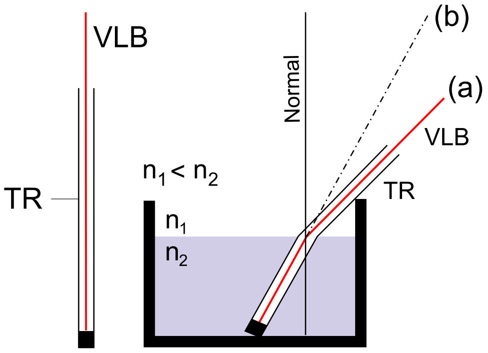

Figure 1 – Left: the transparent rod TR and its visible laser beam VLB. Right: the glass rod partially immersed in air and water (n_1 and n_2 are the refractive indices respectively of air and water).

2.- There is no physical reason that could explain the observed deformation of the rod, except the refraction of light.

3.- The deformation is the consequence of a way of observing the rod: partially immersed in two media, each with a different refractive index. The deformation disappears when we stop observing it under these conditions and observe it immersed in a single medium.

We will see below that exactly the same thing happens with the relativistic deformations of space and time due to the uniform relative motion. We can confirm experimentally, and as many times as we want, Snell's Law describing the refractive deformation of the rod, but the rod is not actually deformed.

3 The first experimental verification of time dilation

The first suggestion that the ticking of clocks could change with motion was published in 1887. And perhaps the first suggestion of how this alteration could be experimentally verified came from a debate between A. Einstein and W. Ritz, but at that time the experiment was considered unfeasible. Some twenty years later, in 1938, the experiment was performed by H. E. Ives and G. R. Stilwell [11, 8, 7, 9, 10], a brief modern review can be found in [6].

Herbert Eugene Ives (1882-1953) was an American physicist and engineer who did much of his work at Bell Laboratories, where he was Director of Research in the area of electro-optics. He also developed an important critical work on Einstein's theories of relativity. He is often considered the most important opponent of his time to such theories. Although he was and is best known for the so-called Ives-Stilwell experiment, with which he demonstrated for the first time the real dilation of time.

Ives-Stilwell used an anode-ray Dempster tube and the Transversal Doppler shift of the radiation emitted by the moving particles. The spectrographic analysis produced results compatible with the Larmor-Lorentz predictions. Or, in other words, compatible with Ives' own theory of absolute space and time and with Einstein's theory of relativity. As is well known, after the Ives-Stilwell experiment, many experimental verifications of (relativistic) time dilation have been carried out. But here we are interested in the first one for the following reasons:

1. It so happens that, invariably, whenever the Ives-Stilwell experiment is cited, it is cited to indicate that it was the first experimental verification of Einstein's theory. But it is (almost) never noticed that it was also an experimental proof of Herbert Ives' theory of absolute space and time. A theory that also allowed Ives to explain the anomaly of Mercury's orbit, previously explained by Einstein in 1916, but with methods of classical mechanics that do not need to curve spacetime. Einstein knew about the Ives-Stilwell experiment and its results, although he never cited them (just as he never cited the Sagnac effect or the Michelson-Gales experiment) [15, p. 44, 84-85].

2. We are then before experimental results that are compatible two very different theories (and surely with others): Einstein's relativity and Ives' theory of absolute space and time. A very significant detail, but invariably forgotten by the most fervent believers of Einstein's relativity.

3. As with most time dilation experiments, the Ives-Stilwell experiment took place within the strong gravitational field of the Earth. This detail should be kept in mind when claiming that these experiments demonstrate inertial time dilation, i.e., due exclusively to uniform rectilinear motion.

4 Symmetry of the empirical confirmations of SR

An important requirement of experimental confirmations of SR is that they must be symmetric: If from an inertial reference frame A it is observed that in all physical objects of another inertial reference frame B there is a length contraction in the direction of relative motion between the two frames (FitzGerald-Lorentz contraction), then, at the same time, from the reference frame B it must also be observed in all objects of A exactly the same length contraction in the same direction of relative motion between the two frames.

The same is true for the inertial dilation of time: if from the reference frame A it is observed that all clocks of the reference frame B run slower than the proper clocks of A, from the reference frame B it is to be observed that all clocks of A run slower than the proper clocks of B.

And whatever the events are, two simultaneous events in A occurring a non-zero distance apart in the direction of relative motion will be observed as non-simultaneous in B. And two simultaneous events in B occurring one non-zero distance apart in the direction of relative motion will be observed as non-simultaneous in A.

As far as I know, all experimental confirmations of the special relativity have been only in one of the two directions, from A to B; or from B to A. But a complete confirmation requires both confirmations at the same time, as Einstein himself pointed out on several occasions:

> The laws by which the states of physical systems undergo change are not affected, whether these changes of state be referred to the one or the other of two systems of co-ordinates in uniform translatory motion [5, p. 41].
>
> It is clear that the same results hold good of bodies at rest in the “stationary” system, viewed from a system in uniform motion [5, p. 49].
>
> ...[...] shows that the clock goes slower than if it were at rest relatively to K’. These two consequences, which hold, mutatis mutandis, for every system of reference, form the physical content, free from convention, of the Lorentz Transformation [4, p. 38].

This double requirement is at the basis of Herbert Dingle’s criticism which, in my opinion, has not been satisfactorily answered. Herbert Dingle (1890-1978) was an eminent 20th century physicist, a specialist in spectroscopy applied to astronomy, President of the Royal Astronomical Society from 1951 to 1953, co-founder of the British Society for the History of Science, President of Commission 41 of the International Astronomical Union, Professor at Imperial College (Department of Physics) and University College London (History and Philosophy of Science). He was also considered an expert in special and general relativity, fields he taught for several years. Dingle was also the author of a popular book on special relativity: *Relativity for All* [2]. From 1958 until his death in 1978, Dingle developed a critique of special relativity that had no effect on the scientific community of his time (or ours), despite his reputation and tireless effort. In 1972 he published a text summarizing his efforts and the silence of the vast majority of the scientific community: *Science at the Crossroads* [3].

It follows from Dingle’s argument that if there is only a single objective reality, then the ticks of clock A are and are not slower than those of clock B; and the ticks of clock B are and are not slower than those of clock A. And if there is no single objective reality, there would have to exist as many different (superimposed) realities as relative velocities at which to observe the clocks A and B (personal synthesis of the author of this article).

5 Real or apparent deformations?

In the case of the FitzGerald-Lorentz contraction there is (at least since 1950) a clear division of opinion on its real or apparent nature. Proponents of its apparent nature (the majority) would have to decide whether inertial time dilation and inertial local simultaneity are also apparent. If they are not, and being all of them consequences of the same Lorentz Transformation (LT), they would have to explain why some deformations are apparent and others are real (LT says nothing about it). And if all of them are apparent, they would have to admit that the theory of special relativity is only a set of formulas (TL) that convert the non-deformed reality into deformed realities that do not really exist.

Proponents of the real nature of the FitzGerald-Lorentz contraction have to explain how it is possible for all macroscopic objects to exist in the same reality and at the same time with a potentially infinite number of different sizes: one for each possible relative velocity at which they can be observed. Or, alternatively, how a potentially infinite number of simultaneous and overlapping realities can coexist, as many as the relative velocities at which their macroscopic objects can be observed (including the relative velocities at which they can be observed in the future).

6 Universality of the relativistic deformations

A very remarkable, and almost never discussed, aspect of the relativistic spacetime deformations is their universality. Indeed, provided they are observed with the same relative velocity $v = kc$, $(0 < k < 1)$, all objects will be contracted in the direction of relative motion by the same factor $\sqrt{1-k^2}$, irrespective of their size, composition and internal structure. A steel cube and a foam-rubber cube will undergo the same degree of contraction in the direction of relative motion.

And as in the case of the contraction of physical objects, time dilation is also universal: the same for all conceivable kinds of clocks: mechanical, electrical, electronic, atomic, chemical, biological, etc. Whatever the mechanisms that produce their periodic events, they all slow down by the same factor $(1/\sqrt{1-k^2})$ when observed with the relative velocity $v = kc$, $0 < k < 1$.

There is also a loss of synchronicity in the direction of relative motion: clocks that are synchronized in their own reference frame (where they are observed at rest), are not synchronized when they are observed in relative motion, the desynchronization φ being:

$$\varphi = \frac{kd_o \cos\alpha_o}{c\sqrt{1-k^2}} \tag{1}$$

where d_o is the proper distance of the two clocks and α_o the proper angle formed by the straight line joining the clocks in their proper reference frame with the relative velocity at which they are observed. The desynchronization φ is the same for all imaginable clocks, whatever the mechanism or process that produces their corresponding periodic events with which they measure time. It depends only on their proper separation in the direction of relative motion and on the relative velocity kc at which they are observed. An inevitable consequence of the Lorentz Transformation of very difficult physical explanation.

7 Impossible deformations

Besides being symmetric and universal, some relativistic deformations are incompatible with the basic laws of mechanics. We will see, in conclusion, two examples (many more can be seen in [12]). The first (the elastic cord) is a consequence of the FitzGerald-Lorentz contraction; the second (the impossible pendulum) is a consequence of local simultaneity. Both are relativistic consequences of the Lorentz Transformation.

7.1 The elastic cord

In the reference frame RF_o, a flexible elastic cord rests free of forces in the X_oY_o plane of RF_o. The elastic cord is scaled with yellow and black marks of the same length L_o, some of which are parallel to the X_o axis, and some of which are parallel to the Y_o axis. Since the cord is at rest and no force acts on it, all the yellow and black marks have the same length, and this is in fact what is observed in its proper reference frame RF_o. (Figure 2, left). Things are very different when this elastic cord is observed from a reference frame RF_v that coincides with RF_o at a given instant, and from whose perspective RF_o moves with a uniform velocity $v = kc$, $(0 < k < 1)$ parallel to the increasing direction of X_v. (Figure 2, right): all marks parallel to the X_v axis are observed with length L_v, which according

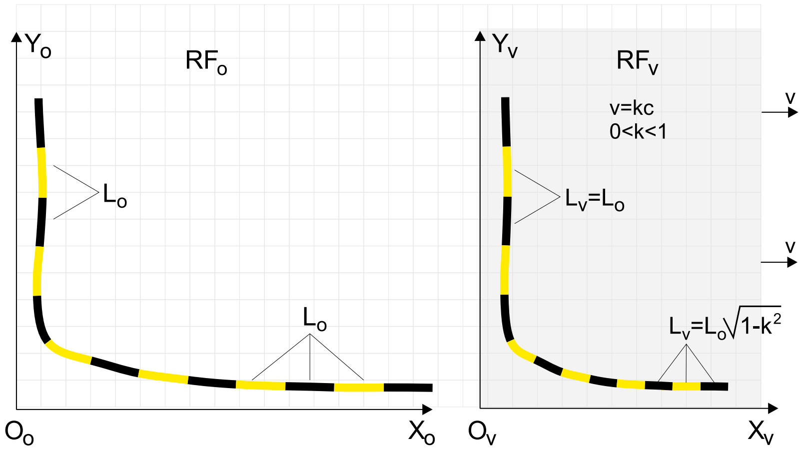

Figure 2 – The elastic cord at rest in the X_oY_o plane from its proper reference frame RF_o (left), and from the RF_v reference frame (right).

to the FitzGerald-Lorentz contraction will be:

$$L_v = L_o\sqrt{1-k^2} \tag{2}$$

while all the marks parallel to its Y_v axis are observed with the same length L_o, being obviously:

$$L_v < L_o \tag{3}$$

The observers in RF_v will therefore observe a force-free elastic string with some marks more stretched than others, which is impossible for an elastic string at rest and free of forces. Consequently, for all observers except those of RF_o and those moving parallel to Z_o, the elastic cord is observed with some parts stretched more than others, without any stretching force acting on them. Obviously, this is contrary to the laws of mechanics governing the behavior of elastic materials. The conclusion can only be that the FitzGerald-Lorentz contraction is apparent, as apparent as the deformation of the rod partially immersed in water. But in this case, moreover, what is observed is incompatible with the basic laws of mechanics, which in a formally consistent universe could only be confirming the apparent nature of the deformation.

7.2 THE IMPOSSIBLE PENDULUM

Before begin the argument on the impossible pendulum (a consequence of local simultaneity) let us recall the following words of H. Weyll dated 1922 (quoted in [16, p. 1]):

> We are to discard our belief in the objective meaning of simultaneity; it was the great achievement of Einstein in the field of the theory of knowledge that he banished this dogma from our minds, and this is what leads us to rank his name with that of Copernicus.

It is also worth remembering that the idea of simultaneity is not precisely an arbitrary dogma but an idea deeply rooted in observation and inductive knowledge. It may or may not be true, but what is certain is that it is not a dogma but the result of millenary human experience. Simultaneity is, moreover, indispensable to establish nothing less than the Second Law of Logic: one thing and its opposite are not possible *at the same time* (see Relativity and the Laws of Logic in [12]).

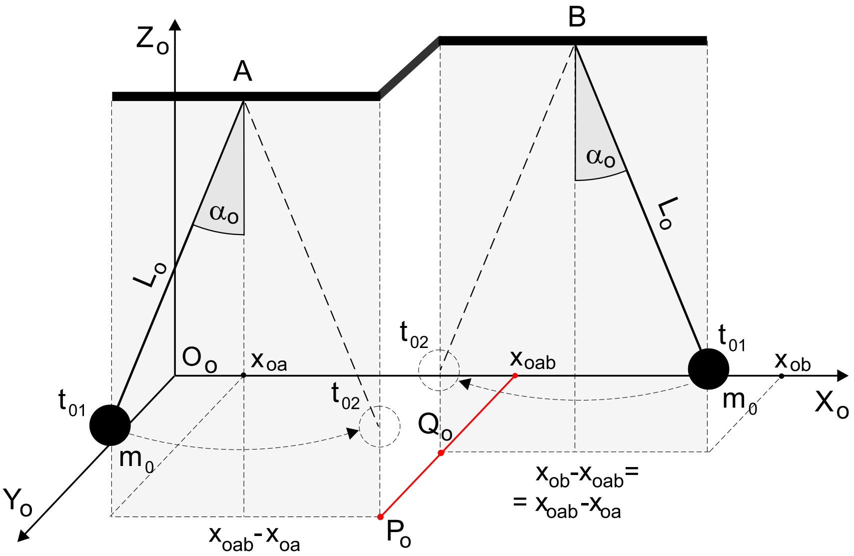

Figure 3 – Two identical pendulums A and B in their proper reference frame RF_o just at the instant t_{o1} when they start to oscillate.

The scenario of the impossible pendulum argument is depicted in Figure 3. In that scenario, two identical (and ideal) pendulums swing under the same conditions in planes parallel to the X_oZ_o plane of their proper reference frame RF_o. And they swing as follows:

1. At the instant t_{01} of RF_o both pendulums begin to swing simultaneously and in the same conditions defined by the angle α_o.
2. The pendulum A begins to oscillate from its initial position whose coordinate on the X_o axis is x_{oa}. This first oscillation of A is to the right (the increasing direction of the X_o axis of RF_o).
3. The pendulum B begins to oscillate from its initial position whose coordinate on the X_o axis is x_{ob}. This first oscillation of B is to the left (the decreasing direction of the X_o axis of RF_o).

4. At instant t_{o2} of RF_o the balls of both pendulums reach the end of their first oscillation, which in each case occurs at a different point P_o and Q_o, although both points have the same coordinate x_{oab} on the X_o axis.
5. Both pendulums have the same amplitude of oscillation:

$$x_{oab} - x_{oa} = x_{oab} - x_{ob} \tag{4}$$

6. At the instant t_{o2} both pendulums begin their second oscillation: the pendulum A to the left, and the pendulum B to the right, until reaching again their initial positions, and then they begin their third oscillation analogous to the first one.
7. According to the laws of mechanics, for both pendulums the oscillations to the right require the same time as the oscillations to the left.
8. The oscillations of both pendulums are repeated a certain number of times with a certain frequency.

We will now examine the oscillations of the two pendulums A and B from the perspective of the inertial reference frame RF_v which, as in the case of the elastic band, coincides at a certain instant with the reference frame RF_o (the proper reference frame of both pendulums at rest), and from whose perspective RF_o moves with velocity $v = kc$, $(0 < k < 1)$, parallel to the X_v axis, in the increasing direction of the X_v axis of RF_v. It is important to note that both RF_o and RF_v are two inertial reference frames to which special relativity can be applied, even though the motions of the pendulums are non-uniform. The argument that follows is only a consequence of the Lorentz Transformation, independently of the particular implications of the two relativities (special and general).

Since in RF_o the two pendulums A and B start to oscillate simultaneously at the instant t_{o1} and in the same conditions (α_o), in the reference frame RF_v (Figure 4), and according to LT, they also oscillate in the same conditions (now $\alpha_v = \arctan(\sqrt{1-k^2}\tan\alpha_o)$, but they do not start to oscillate simultaneously: A starts a time δt_{v1} before B, because when in RF_o both pendulums start to oscillate they are separated in the direction of the relative motion by a proper distance d_o given by (Figure 3):

$$d_o = x_{ob} - x_{oa} \tag{5}$$

$$= 2L_o \sin\alpha_o \tag{6}$$

where L_o is the proper length of each of the two pendulums. Consequently, the pendulum A starts its first oscillation a time δt_{v1} before the pendulum B starts its first oscillation, which follows from the Lorentz Transformation, and is given by:

$$\delta t_{v1} = \frac{k(x_{ob} - x_{oa})}{c\sqrt{1-k^2}} \tag{7}$$

Consequently, the observers in RF_v will have to describe the oscillations of the pendulums A and B as follows:

1. The pendulum A starts its first oscillation before the pendulum B.
2. When the pendulum B starts its first oscillation, the pendulum A has already covered part of its first oscillation.
3. Both pendulums end their first oscillation at the same instant t_{v2} and at two points P_v and Q_v with the same coordinate x_{vab}, because the proper distance in the direction of relative motion between the points P_o and Q_o of RF_o where the pendulums A and B respectively end their first oscillation is zero.
4. Both pendulums have the same amplitude of oscillation:

$$\sqrt{1-k^2}(x_{oab} - x_{oa}) = \sqrt{1-k^2}(x_{oab} - x_{ob}) \tag{8}$$

5. Both pendulums begin their second oscillation at the same instant t_{v2}.
6. The pendulum A finishes its second oscillation a time $\delta t_{v2} = \delta t_{v1}$ before the pendulum B.
7. When the pendulum A moves from left to right, it moves slower than the pendulum B.
8. When the pendulum A moves from right to left, it moves faster than the pendulum B.

Thus, according to the observers in RF_v, i.e., according to the Lorentz Transformation:

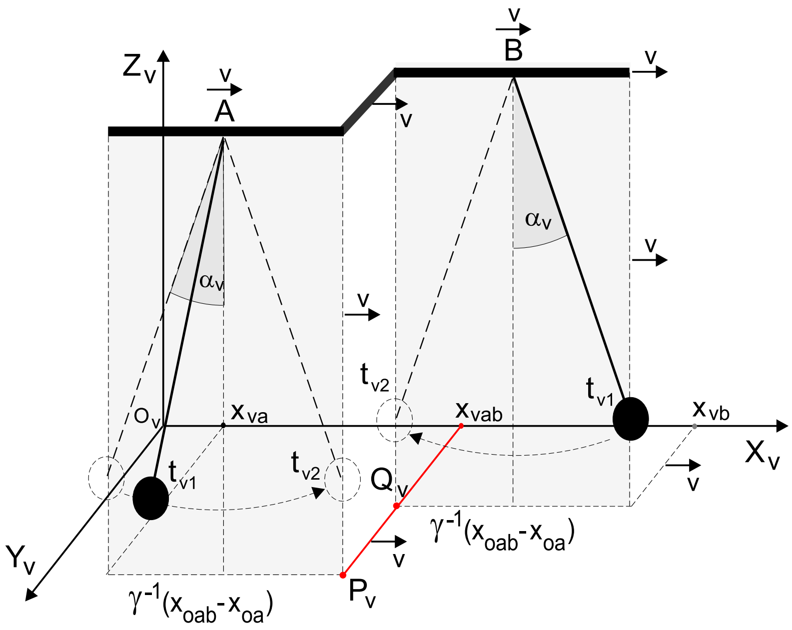

Figure 4 – The pendulums A and B from the perspective of the reference frame RF_v.

1. Two identical pendulums that begin to swing under the same conditions do not swing in the same way.
2. At least one of the pendulums go slower when it oscillates in one direction than when it oscillates in the opposite direction (!). As the reader can easily check, the Lorentz Transformation is the reason why in RF_v the two pendulums swing asymmetrically (faster in one direction than in the other).

These consequences deduced from the Lorentz Transformation are incompatible with all theoretical and empirical knowledge about the oscillation of real pendulums and ideal pendulums.

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