Fitzgerald Lorentz Contraction: Real or apparent?

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Abstract.-After a summary introduction to Fitzgerald-Lorentz contraction, and a short revision of some classic and modern opinions on its real or apparent nature, this paper introduces two arguments proving that Fitzgerald-Lorentz contraction can only be apparent. The first of them also proves the deformed appearance disagrees with certain physical laws, pointing to a breaking of Lorentz symmetry that questions the Principle of Relativity. Being also consequences of Lorentz transformation, time dilation and phase difference in synchronization could only be apparent deformations, which open the debate on the physical meaning of Lorentz transformation.

1.-Introduction

The visualization of a physical object is accomplished by means of the rays of light that, reflected by the object, reach the corresponding optical device. Due to the finite speed of light and to the different distances light must traverse from the different parts of the object, not all reflected rays reach the device at the same instant. In consequence, Fitzgerald-Lorentz contraction (introduced in the next section) cannot be visually perceived, or photographed, as such a contraction in the direction of the relative motion, but as a sort of rotation known as *Penrose-Terrell rotation* [13], [16], [12]. Although the appropriate correction for these effects will reveal it to be (theoretically) present. In this work we will assume that all objects observed in relative motion are properly corrected and represented as actually contracted in the direction of the relative motion, in agreement with Fitzgerald-Lorentz contraction. Obviously, graphic representations are used for the sake of clarity but they are not necessary to the discussions; mathematical representations suffice. Lorentz transformation is all we need in order to translate between observations and measurements performed in different inertial reference frames in relative motion.

As we will see in the next sections, the real or apparent nature of Fitzgerald-Lorentz contraction remains open to discussion, although the discussion is not popular, to the point that some authors ignore the discussion exists. Most of the introductory and university textbooks on the special theory of relativity pay little attention, if any, to it. The discussions on the real or apparent nature of time dilation and phase difference in synchronization with relative motion are practically ignored in the literature on the special theory of relativity. And this is striking because the nature of these three consequences of relative motion must be the same, just because the three of them derive from the same Lorentz transformation. The discussion about the real or apparent nature of the Fitzgerald-Lorentz contraction is further complicated by other external discussions that put into question the very existence of an objective reality beyond human observers. Apart from reviewing some opinions on the real or apparent nature of Fitzgerald-Lorentz contraction, this work introduces a couple of arguments clearly pointing to the apparent nature of Fitzgerald-Lorentz contraction, and even to a breaking of Lorentz symmetry: some of the observed contractions are incompatible with the physical laws. This conclusion put into the test the (First) Principle of Relativity, according to which the laws of physics are the same in all inertial reference frames.

2.-Fitzgerald-Lorentz Contraction

In the year 1889 G. F. FitzGerald [4] and in the year 1892 H. A. Lorentz [11] proposed independently a *real* length contraction of moving objects in the direction of motion through the luminiferous aether in order to explain the negative results of the Michelson-Morley experiment. According to FitzGerald and Lorentz, the contraction was caused by changes in the intermolecular forces of moving bodies (where motion has to be understood as absolute motion). Since there were no reason to such changes, the proposal was considered as an *ad hoc* hypothesis. Fitzgerald-Lorentz contraction can be immediately deduced from Lorentz transformation. In effect, if x_{o1} and x_{o2} are the space coordinates of the two endpoints of a metric stick in its proper reference frame RF_o parallel to X_o, in the frame RF_v, whose spacial axis coincide with those of RF_o at a certain instant, and from whose perspective RF_o moves from left to right in the X_v direction with a constant velocity v, the corresponding coordinates x_{v1}, x_{v2} will be such that:

$$x_{o1} = \gamma(x_{v1} - vt_{v_1}) \tag{1}$$

$$x_{o2} = \gamma(x_{v2} - vt_{v_2}) \tag{2}$$

where γ is the relativistic Lorentz factor ($\gamma = (1/\sqrt{(1 - v^2/c^2})$. And being $t_{v1} = t_{v2}$ in the measurement performed in RF_v (to measure a moving stick we would have to measure the position of its endpoints at the same instant, otherwise one side will be displaced with respect to the other and we would get an erroneous measure of the stick), we will have:

$$x_{o2} - x_{o1} = \gamma(x_{v2} - x_{v1}) \tag{3}$$
$$x_{v2} - x_{v1} = \gamma^{-1}(x_{o2} - x_{o1}) \tag{4}$$

3.-Real or Apparent?

In the next discussion on the real or apparent nature of Fitzgerald-Lorentz contraction, and as a comparative reference, we will make use of a metal rod *MR* irreversibly deformed by a mechanical effort, as well as of a hollow transparent rod *TR* with an internal visible laser beam parallel the longitudinal axis of the rod (Figure 1). If the transparent rod is partially and obliquely submerged in water, and due to the refraction on light, the rod seems to be bent. But it is not actually bent, otherwise the laser beam would impact on the point *B*, in the place of the point *A* where it actually impacts. This is then an apparent deformation. In addition we will observe an apparent and impossible refraction of the laser beam, impossible because the laser light always propagates through the same medium, the air within the rod, and then no real refraction occurs.

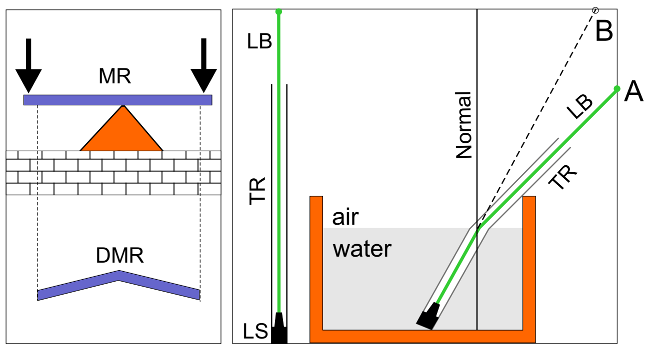

Fig. 1 – Real (left) and apparent (right) deformation. MR: metal rod; DMR: deformed metal rod; TR: transparent rod; LS: laser source; LB: laser beam

Something changes in the atomic structure of the actually deformed metal rod *MR*, and that change can be experimentally proved, for instance, by means of X-ray diffraction. This is not what happens in the apparently deformed rod submerged in water, as the point *A* of the laser beam proves. There is no controversy here: in the first case the deformation is real; in the second the deformation is only apparent. We have then an experimentally testable asymmetry between an apparent and a real deformation. So it makes sense to distinguish between real and apparent deformations. Furthermore, if we know the partially submerged rod is not really deformed despite that we see it deformed, what would be its most appropriate description when it is submerged in water, to say it is deformed or to say it is not?

We have just seen in the previous section that Fitzgerald-Lorentz contraction is an inevitable consequence of Lorentz transformation, and then of the principles of relativity. Now then, is that contraction real, as some contemporary authors (for instance [14], [8], [1]) claim, or apparent? Most of the authors of books on the special theory of relativity avoid dealing with this 'notorious controversy,' as Max Born called it [3]. On this controversy Anthony P. French wrote [5, pp. 113-114]:

> This discussion should make it clear that the question "Does the Fitzgerald-Lorentz contraction really take place?" has no single, unequivocal answer from a relativistic point of view. The whole emphasis is on defining what actual observations we must make if we want to measure the length of some object that may be in motion relative to us. And the prescription is simply that we measure the positions of its ends at the same instant as judged by us. What else could we possibly do? Thus the contraction, when we observe it, is not a property of matter but something inherent in the measuring process.

Could we say the same of the relativistic time dilation and phase difference in synchronization? In his now classical book on Einstein's relativity, Max Born wrote [3, pp. 254-55]:

> If we slice a cucumber, the slices will be larger the more obliquely we cut them. It is meaningless to call the sizes of the various oblique slices 'apparent' and call, say, the smallest which we get by slicing perpendicularly to the axis, the 'real' size. In exactly the same way a rod in Einstein's theory has various lengths according to the point of view of the observer. One of these lengths, the static or proper length, is the greatest but this does not make it more real than the others.

On the same issue, David Bohm wrote [2, Loc. 1253-71]:

> One may perhaps compare this situation to what happens when two people A and B separate, while still in each other's line of sight. A says that B seems to be getting smaller, while B says that A seems to be getting smaller. Why then does not B say that A seems to be getting larger? The answer is that each is seeing *something different*, i.e. the image of the world on his retina. There is no paradox in the fact that the image of A on B's retina gets smaller at the same time that the image of B on A's retina gets smaller. Similarly, there is no paradox in saying that A will ascribe a contraction to B's ruler, while B ascribes a contraction to A's simply because each is referring to *something different* when he talks about the length of an object.

In a contemporary university textbook of physics we can read [9, p. 1032]:

> Does a moving object really shrink? Reality is based on observations and measurements; if the results are always consistent and if no error can be determined, then what is observed and measured is real. In that sense, the object really does shrink.

That can be paraphrased as:

> Does a rigid rod partially submerged in water really bend? Reality is based on observations and measurements; if the results are always consistent and if no error can be determined, then what is observed and measured is real. In that sense, the rod really does bend.

Consider also the following quote from a university text (emphasis is mine) ([15, p. 42]):

> I need to warn you about language. I have said that a rod with length L_o as observed from its own frame has a shorter length L_v as observed from another frame. Often this result is stated as 'A rod with length L_o as observed from its own frame, appears to have a shorter length L_v as observed from another frame.' This statement is true: the rod appears to have shorter length L_v *because it does have shorter length* L_v. Using the term 'appears' gives the false impression that, when the rod is observed from a frame in which it moves, the rod really is of length L_o and only appears to be of length L_v. No. As observed from a frame in which it moves, *the rod really does have the shorter length* L_v.

And its corresponding paraphrase:

> I need to warn you about language. I have said that a straight rod is bent when observed partially submerged in water. Often this result is stated as 'A straight rod partially submerged in water appears bent' This statement is true: the rod appears bent *because it is bent*. Using the term 'appears' gives the false impression that, when the rod is observed partially submerged, the rod really is straight and only appears to be bent. No. As observed partially submerged, *the rod is really bent*.

And finally, the opinion of the editor of a well-known journal of physics (emphasis is mine), outraged that someone is trying to reopen the question about the real or apparent nature of the Fitzgerald-Lorentz contraction:

> Given that the [Fitzgerald-Lorentz] contraction is different when measured from different frames (but 0 in the rest frame), *it is evident that it is apparent*. [. . .] Nowadays, proponents of a real contraction are also proponents of an aether, contrary to Special Relativity. There is no experimental evidence for an aether. Furthermore, no contradiction of SR has been observed experimentally to date.

And what about time dilation and phase difference in synchronization (relativity of simultaneity), both derived from the same Lorentz transformation as Fitzgerald-Lorentz contraction? Are they also apparent, or are they real? In the last case, were are the experiments, or in its place the axioms, principles, or laws stating what consequences of Lorentz transformation are real and what are apparent? Considering the above opinions, the controversy on the real or apparent nature of Fitzgerald-Lorentz contraction seems to be more real than apparent. Now then, if Fitzgerald-Lorentz contraction were apparent, the following questions would also have to be considered (and, usually, they are not):

1. Are also apparent the dilation of time and the lack of simultaneity derived from the same Lorentz transformation as Fitzgerald-Lorentz contraction? If not, why some consequences of Lorentz transformation are real while some other are only apparent?
2. If all of them were apparent, would not Lorentz transformation be an operator to translate between real and apparent worlds?
3. If that were the case, to which reality should we focus our attention, to the actual or to the apparent reality, or to both of them?
4. Do all physical laws have the same form in all reference systems? To state that the laws of physics are the same in all reference frames means that in all references frames the same physical magnitudes have to be mathematically related, whatsoever be the mathematical relation, or that that mathematical relation has to be the same in all reference frames?

Usual as it may be, the question: does a moving object really shrink? is not correctly posed because motion is relative, according to the theory of special relativity. All we could say is that an object, when observed in relative motion, is *observed* contracted in the direction of the relative motion. Relative motion makes a moving object appear as contracted in the direction of the relative motion, and in such a way that if, in those conditions, we measures its length it will be shorter than if we do it when the object is at rest. In its proper reference frame, the object is, in fact, not contracted. And, obviously, no object can be really contracted and really non-contracted at the same time. It can be observed simultaneously as contracted and as non-contracted by two different observers that observe it in two different ways: in relative motion in the first case (contracted) and at rest in the second one (non contracted). But, in spite of certain authors, it cannot be really contracted and really non-contracted at the same time.

If Fitzgerald-Lorentz contraction were not apparent but real, a rod of a given proper length would exist simultaneously, and in the same universe, with an indefinite number of different real lengths, one for each possible relative velocity at which it could be simultaneously observed, and so that each of those lengths can only be observed at the appropriate relative velocity. Furthermore, if a physical effect has to have a physical cause we would be in the face of a physical effect, the multiple simultaneous contractions of a rod, without a physical cause explaining them. Occam's razor suggests all of those contractions of the rod could only be apparent, as it is apparent the deformation of the rod partially submerged in water. This conclusion will be confirmed by the arguments in the next sections. They will also prove the observed contractions are in some cases incompatible with the physical laws, so that such observations cannot be observations of a real physical world.

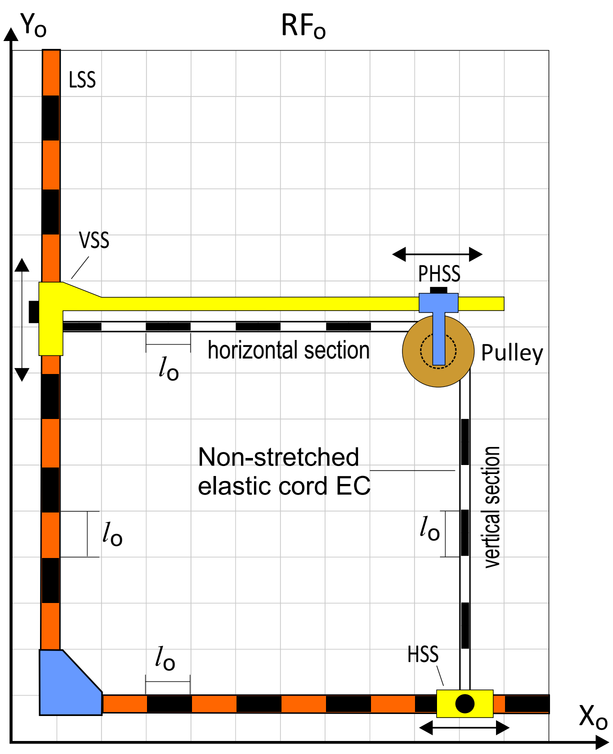

Fig. 2 – The elastic cord EC in its proper reference frame RF_o. According to the laws of mechanics, at equilibrium all black and white marks of the elastic cord must have the same length l_o be them in the horizontal or in the vertical section of the cord. VSS: vertical sliding support; HSS: horizontal sliding support; PHSS: pulley horizontal sliding support.

4.-The Elastic Cord

Let RF_o be the proper inertial reference frame of the mechanical device schematically depicted in Figure 2 in which an elastic cord EC rests on a single pulley around which it can freely run. Each end of EC is attached to a sliding support, the one vertical (VSS) and the other horizontal (HSS). The pulley can also slide in the horizontal direction by the slider PHS. This device allows to set EC in two sections of variable length, the one vertical and the other horizontal, and in such a way that EC is always at rest, without any force stretching it. Once set, the settings can be fixed by the appropriate screws. A metric scale consisting of a certain number of black marks of equal length l_o separated from each other by the same length l_o, is printed on EC and also on the arms of the L-shaped structure of the device, made of the strongest steel. The metric scale is printed on EC at rest, while it is not stretched by any force. Let us assume the X_o axis of RF_o is parallel to horizontal arms of the L-shaped structure and to the horizontal section of the elastic cord EC. By sliding the corresponding sliding supports, the lengths of the horizontal and vertical sections of EC can be changed without changing the rest state of EC. As expected, in RF_o the length of all metric marks remains constant and equal to l_o, be them in the horizontal or in the vertical section of the cord, and the same applies to the metric marks printed on the arms of the L-shaped structure, we can use as a comparative reference.

RF_v is an inertial reference frame whose spacial axes coincide with those of RF_o at a certain instant, and from whose perspective RF_o moves from left to right, in the X_v, direction with a uniform velocity v. In consequence, and according to Lorentz transformation, in RF_v the length of the vertical marks of the metric scale is also l_o, while the horizontal marks will have a contracted length $\gamma^{-1} l_o$. Exactly the same applies to the marks of the metric scale printed on the arms of the L-shaped structure we are using as a comparative reference. These observations imply that, for RF_v observers, the horizontal section of the elastic cord EC is contracted with respect to its vertical section, without any force acts on any of them, nor on the whole cord, which is attached at its two end and freely resting on the pulley, around which it can freely run. In these conditions it is mechanically impossible for EC to have one of its parts contracted with respect to any other. In consequence, the observations on the elastic cord *EC* in relative motion are incompatible with the laws of mechanics: it is impossible for an elastic cord to have parts differently stretched or contracted with respect to others parts being all parts at rest, without any force acting on them. On the other hand, the observed contractions in the horizontal marks of the elastic cord *EC* are the same as the observed contractions of the horizontal marks of the metric scale printed on the L-shaped structure, being both contractions derived from the same Lorentz transformation, and only from the same Lorentz transformation. Hence, we should conclude such contractions cannot be real but apparent, as apparent as the refractive deformation of the above transparent rod partially submerged in water. And, as in the case of the impossible apparent refraction of the laser beam, the appearance of the elastic cord *EC* is incompatible with the physical laws.

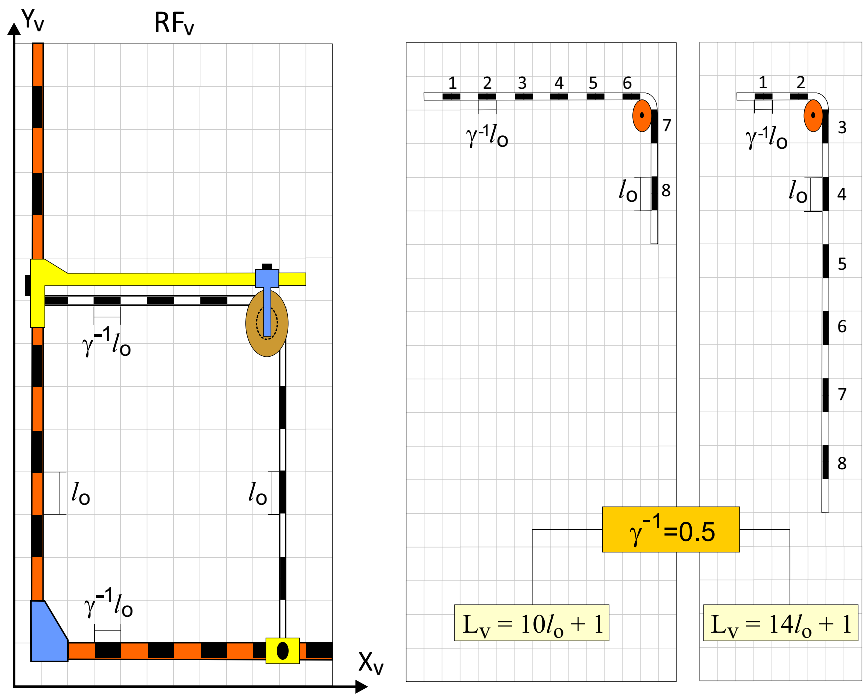

Fig. 3 – Left: In RF_v, from which RF_o moves from left to right in the X_v direction, the length of the horizontal metric marks are contracted by a factor γ^{-1} while the vertical marks maintain its proper length l_o. Right: The mechanical tension of any part of the cord seems to change when it changes its position from the horizontal to the vertical section and vice versa. As a consequence, the whole length of the elastic cord seems also to change depending on the number of horizontal and vertical white and black marks.

Since the above device allows to change the length of the horizontal and the vertical sections of the elastic cord *EC* without changing its mechanical rest state, some additional consequences can be drawn from the observations made in RF_o and in RF_v. Indeed, let n be the number of metric black and white marks. Assume *EC* is always set with an integer number of both horizontal and vertical marks and that the length of *EC* around the pulley is also the length l_o of a mark. Assume n_h marks are in the horizontal section. In RF_o the length L_o of the whole cord will be given by:

$$L_o = n_h l_o + (n - n_h) l_o = n l_o \tag{5}$$

However, in RF_v the length L_v of the cord is variable, depending on the number n_h of horizontal marks:

$$L_v = n_h \gamma^{-1} l_o + (n - n_h) l_o \tag{6}$$

$$= l_o(\gamma^{-1} n_h + n - n_h) \tag{7}$$

$$= l_o(n - n_h(1 - \gamma^{-1})) \tag{8}$$

So, as the number n_h of horizontal marks increases the cord's length L_v decreases. Obviously these changes of length disagree with what is expected from the laws of mechanics: the same elastic cord at mechanical rest cannot have different lengths when measured at the same relative velocity, without any force acting on it, and depending only on the numbers of horizontal and vertical marks. The observers in RF_v would have to conclude that Fitzgerald-Lorentz contraction can only be apparent, as is apparent the bending of the rod partially submerged in water. Otherwise, they would have to explain how an elastic cord at mechanical rest is not uniformly stretched. And how is it possible for it to have different lengths at the same mechanical rest state when measured at the same relative velocity.

In short, all observers in relative motion with respect to RF_o should consider the possibility their observations and measurements are distorted by relative motion in such a way they cannot get conclusions physically acceptable on what happens in RF_o. In this sense, only the observers in RF_o may conclude their observations and measurements agree with what is expected from the physical laws. Therefore, Fitzgerald-Lorentz can only be apparent. And, what is worse, that appearance is not always compatible with the physical laws. Consequently, the world observed through Lorentz transformation not always corresponds to an actual physical world. Obviously, this conclusion goes against the Principle of Relativity.

5.-Measuring Distances with a Laser Beam

Consider now a rod R placed parallel to the X_o axis of its rest frame RF_o, and provided with a laser distance meter (LDM) located at one end of the rod. LDM emits a laser beam that is reflected on a mirror at the other end of the rod and returns to LDM, whose screen displays in alphanumeric terms half the total distance light travels while performing the measurement, which is the proper length L_o of the rod (Figure 4, left). Let RF_v be another reference frame from whose perspective RF_o

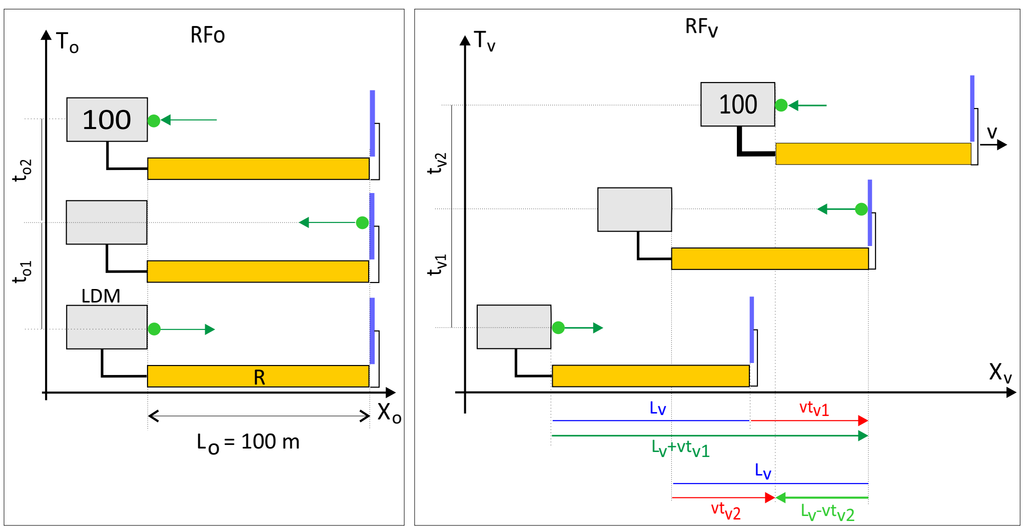

Fig. 4 – Left: The rod R and its laser distance meter LDM in its proper reference frame RF_o. Right: The rod R and its laser distance meter LDM in the frame RF_v.

moves at a uniform velocity v parallel to the X_v axis of RF_v. It is immediate to prove that, in this frame, light travels $2\gamma L_o$ in each measurement (Figure 4, right). In effect, let t_{v1} be the time light travels from LDM to the mirror, and t_{v2} the time it travels in the opposite direction, from the mirror to LDM. We will have:

$$ct_{v1} = L_v + vt_{v1} \tag{9}$$

$$ct_{v2} = L_v - vt_{v2} \tag{10}$$

$$t_{v1}(c-v) = L_v;\ t_{v1} = L_v/(c-v) \tag{11}$$

$$t_{v2}(c+v) = L_v;\ t_{v2} = L_v/(c+v) \tag{12}$$

$$t_{v1} - t_{v2} = \frac{2vL_v}{c^2 - v^2} \tag{13}$$

Thus, in RF_v light travels in each measurement a distance d given by:

$$d = (L_v + vt_{v1}) + (L_v - vt_{v2}) \tag{14}$$

$$= 2L_v + v(t_{v1} - t_{v2}) \tag{15}$$

$$= 2L_v + v\frac{2vL_v}{c^2 - v^2} \tag{16}$$

$$= 2L_v\Big(1 + \frac{v^2}{c^2 - v^2}\Big) \qquad (17)$$

$$= 2L_v \frac{c^2}{c^2 - v^2} \qquad (18)$$

$$= 2L_v\gamma^2 \qquad (19)$$

$$= 2\gamma L_o \qquad (20)$$

Therefore, if LDM shows also in RF_v half the distance light travels in each measurement, it should display γL_o. But, will it display γL_o or L_o? The next discussion analyzes both alternatives. Since $\gamma \neq 1$, except if the relative velocity is zero, if in RF_v the screen of LDM shows γL_o, we would have to conclude that LDM's screen shows simultaneously an indefinite number of different results, one for each possible observer in a different state of relative motion with respect to LDM (i.e. with respect to RF_o), which is obviously impossible. The reading of LDM's screen is then universal: the same for all reference frames. This makes RF_o special: it is the only frame in which LDM's screen shows half the distance light travels in that frame while performing the measuring of R's length, which is also the length of the rod directly measured by RF_o observers by means of their appropriate measurement rulers.

On the contrary, all observers in relative motion with respect to RF_o, except those moving parallel to the Y_o axis of RF_o, will measure, by means of their corresponding measurement clocks and rulers, a length of the rod that do not coincide with the measurement carried out by LDM and numerically displayed on its screen. Assume that thousands of inertial reference frames are equipped with thousand of identical rods with identical LDMs. All of them will work correctly in their proper reference frames, but when observed in relative motion they do not: they will display a measurement that do not coincide with the measurements carried out in each reference frame by means of its corresponding measurement clocks and rulers. Furthermore, the disagreement will be exactly the same in all of them whenever they move at the same relative velocity. Obviously, this cannot be the consequence of random malfunctions. We would have to conclude that the physical laws driving the functioning of a LDM are not the same depending if they are observed at rest or at relative motion. Or, much more plausible, we would have to conclude the rod R has an actual and unique length, the one displayed on the screen of LDM, that coincides with length measured in its rest frame RF_o by means of its measurement rulers. As in the argument of the elastic cord, this conclusion also goes against the Principle of Relativity.

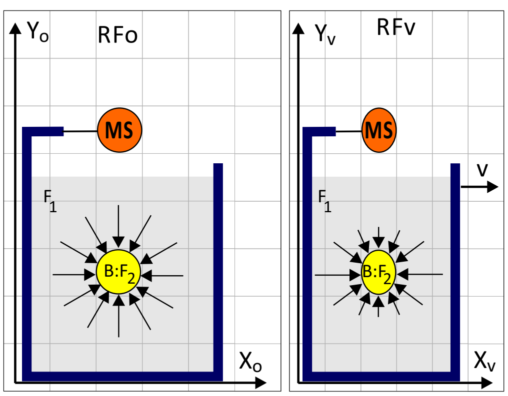

Fig. 5 – A bubble of a fluid F_2 in hydrostatic equilibrium within another fluid F_1, as seen from its proper frame RF_o (left) and from other reference frame RF_v that moves relative to RF_o with a velocity v in the X_o direction (right). MS: metallic sphere used as comparative reference.

6.-Hidrostatic Pressure

The next short argument illustrates the type of proofs that are rejected by some relativists because it not only proves that Fitzgerald-Lorentz contraction is apparent but also that, as in the case of the elastic cord, that appearance is not compatible with the physical laws. As we will see, the reasons given for such a rejection are unsustainable. Let B be a bubble of a certain fluid F_2 in hydrostatic equilibrium within another fluid F_1. As a comparative reference we will us a metallic sphere MS made of the strongest steel with the same size and shape as the bubble. In its proper frame RF_o, the bubble has a spherical shape due to the fact that the hydrostatic pressure is the same in all directions. In RF_v, from whose perspective RF_o moves at a uniform velocity v parallel to the axis X_v of RF_v, the bubble and the metallic sphere MS have the same ellipsoidal shape according to Fitzgerald-Lorentz contraction in the direction of the relative motion. But in the case of the bubble, this ellipsoidal shape is not compatible with the hydrostatic laws, according to which the hydrostatic pressure is the same in all directions, so that the only possible free shape of a burble F_2 at equilibrium within the fluid F_1 is a sphere. Note that RF_v and RF_o are inertial reference frames moving with respect to each other at the uniform velocity v. In these conditions Lorentz transformation applies, although some relativistic claim it does not because of the forces shaping the burble of F_2 within F_1. For the same reason, Lorentz transformation would not apply in any case in which intervene any solid object, as clocks, rods, rules and the like, because all solid objects are also shaped by forces, in this case electromagnetic forces.

7.-Discussion

As noted above, some authors propose that an object cannot be at the same time contracted and non-contracted, depending on the way it is observed (at relative motion or at rest). Some others propose that an object can be contracted for some observers and non-contracted for some others. And some others put into question the very existence of an objective reality beyond human observers (by the way, a proposal incompatible with the own existence of human observers, because, according to it, the objective history of life from which human observers have evolved could not have been possible without human observers). The above arguments prove that to consider Fitzgerald-Lorentz contraction as a real contraction goes against the First Principle of relativity: not all physical laws would be the same in all reference frames. Therefore, the only consistent interpretation of Fitzgerald-Lorentz contraction is that it is only apparent. Let us now compare Fitzgerald-Lorentz contraction with the deformation of the partially submerged rod:

1. Fitzgerald-Lorentz contraction is real in the same sense it is real the bending of the partially submerged rod: both perceptions are not hallucinations of the observers. And both are perfectly explainable in physical terms.
2. Thousands of experiments confirm the details of the deformation (Snell Law) in the case of the submerged rod. And thousand of experiments confirm the observed Fitzgerald-Lorentz contraction.
3. Both deformations are consequences of two particular ways of observing an object: in relative motion in the case of Lorentz transformation, and partially submerged in water in the case of the partially submerged rod.
4. If we observe a partially submerged rod we can easily reconstruct its actual shape and size by a simple application of Snell law of light refraction. In the same way, if we observe a Fitzgerald-Lorentz contracted object we can also reconstruct its real (proper) shape and size by means of Lorentz transformation.
5. Both deformations are reversible in the sense that by removing the rod from the water and by decreasing the relative velocity to a null velocity both rods recover their original (proper) size and shape.
6. By changing the inclination of the partially submerged rod, the level of deformation will also change. Similarly, by changing the relative velocity at which an object is observed, the degree of its contraction in the direction of the relative motion will also change.
7. Both deformations occur without a mechanical effort acts on the deformed objects.
8. The above experiment of the transparent rod and the laser beam proves that refractive deformations are only apparent. The above experiments of the elastic cord *EC* and the laser digital meter *LDM* proves Fitzgerald-Lorentz contraction is only apparent.
9. Should we use a partially submerged rod or a non-submerged rod to describe the shape of an actual rod? Should we use a rod at relative motion or a rod at rest to describe the rod?
10. The transparent rod partially submerged in water and its laser beam could not be used to get conclusions on what really happen in the physical world because the observed refraction of the laser beam within the rod is impossible: it always propagates through the same medium. Similarly, the partially contracted and partially non-contracted elastic rod without any force acting on it is not compatible with the known physical laws.

Being a consequence of Lorentz transformation, if Fitzgerald-Lorentz contraction is apparent so will be any other consequence of such a transformation, as is the case of time dilation and phase difference in synchronization (relativity of simultaneity), unless the theory of special relativity explicitly declares them real, or it be proven they are real. If Fitzgerald-Lorentz contraction, time dilation and phase difference in synchronization were only apparent, Lorentz transformation would be an operator to convert between an actual reality and an apparent, deformed, reality. And what is worse, a deformed reality that could be in disagreement with the physical laws. And in those conditions a pertinent question would be if the observations and measurements performed in an apparent and deformed reality could serve to get general physical conclusion on what really happen in the real physical world, provided that a real physical world do exist.

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