5. Measuring lengths

Links to the book and to other chapters of the book.

5.1 Introduction

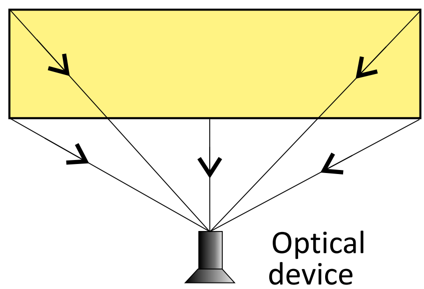

Figure 5.1 – Each reflected ray follows a different trajectory towards the optical device. This is why for relative velocities approaching the speed of light, FitzGerald-Lorentz contraction is not seen as a simple contraction in the direction of the relative motion.

The visualization of a physical body is accomplished by means of the rays of light that, reflected by the physical body, 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 physical body, 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 [289, 356, 254]. Although the appropriate correction for these effects will reveal it to be present.

In this book we will assume that all physical objects observed in relative motion will be 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. The Lorentz Transformation is all we need in order to translate between observations and measurements made in different inertial reference frames in relative motion.

As we will see in the next section, the real or apparent nature of FitzGerald-Lorentz contraction remains open to discussion, although the discussions are not very popular. Most of the introductory and university textbooks on special relativity (SR) 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 SR. And this is striking because, be it real or apparent, the nature of these three consequences of relative motion should be the same, just because they all are consequences of the same Lorentz Transformation, unless it is specified which consequences are real and which are not; which is not the case in the current theory of special relativity.

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 chapter introduces the debate on the real or apparent nature of some relativistic consequences of the Lorentz Transformation.

5.2 FitzGerald-Lorentz contraction

In the year 1889 G. F. FitzGerald [136], and in 1892 H. A. Lorentz [232], proposed independently a *real* length contraction[1] of moving objects in the direction of motion through the luminiferous ether in order to explain the negative results of the Michelson-Morley experiment (see Chapter 3 on Michelson-Morley experiment). According to FitzGerald and Lorentz, the contraction was caused by changes in the intermolecular forces of the moving bodies (where motion has to be understood as absolute motion through the ether). But in the absence of a generally accepted reason for such changes, they ended up being considered by most authors as an ad hoc hypothesis.

But FitzGerald-Lorentz contraction can be immediately deduced from the Lorentz Transformation. In effect, if x_{o1} and x_{o2} are the space coordinates of the two endpoints of a metric stick in RF_o parallel to X_o, in the frame RF_v, that coincides with RF_o at a certain instant and from whose perspective RF_o moves in the direction of the increasing x_v (from left to right) with a constant

[1] In the case of FitzGerald the proposal was an expansion in the direction orthogonal to motion [230, p. 39-41].

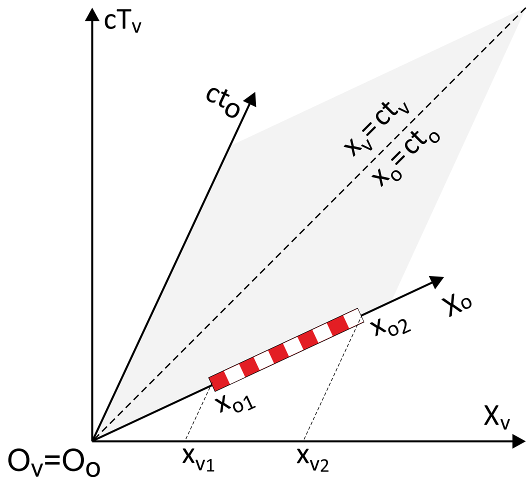

Figure 5.2 – Spacetime diagram of a metric stick whose proper space coordinates are x_{o1} and x_{o2}.

velocity v (Figure 5.2), the corresponding coordinates x_{v1}, x_{v2} will be such that:

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

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

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:

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

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

5.3 Real or apparent?

In the next discussion on the real or apparent nature of FitzGerald-Lorentz contraction, and by the way of conceptual reference, we will make use of a metal rod irreversibly deformed by a mechanical effort, as well as of a hollow transparent rod with an internal visible laser beam emitted from its lower end in the direction parallel the longitudinal axis of the rod (Figure 5.3).

If the transparent rod is partially and obliquely submerged in water, and due to the refraction of light, the rod seems to be bent. But in reality it is not bent, since otherwise the laser beam would end in the point B, instead of in the point A where it actually ends. It is then an apparent deformation. In addition we will observe an apparent refraction of the laser beam, apparent because the laser light always propagates through the same medium within the rod and then there is not an actual refraction of the laser beam, so that it follows a rectilinear trajectory parallel to the wall of the rod.

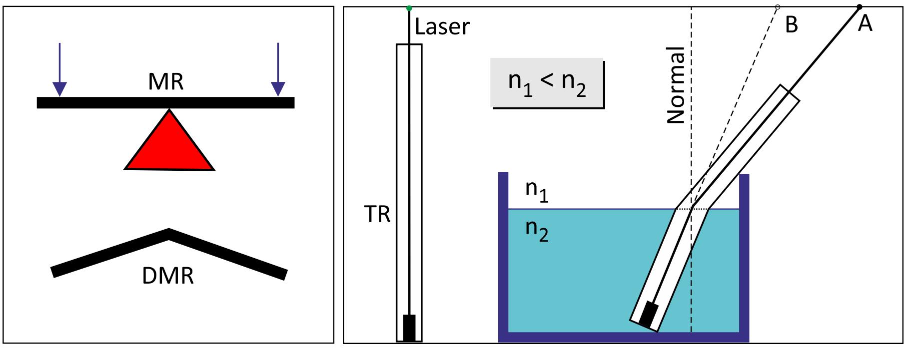

Figure 5.3 – Real (left) and apparent (right) deformation. MR: metal rod; DMR: deformed metal rod; TR: transparent rod.

Something changes in the atomic structure of the actually deformed metal rod, 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. And 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 the Lorentz Transformation, and then of the principles of relativity, Einstein himself considered the Lorentz contraction to be a real observable phenomenon [205, p. 43]. Now then, is that contraction real as some contemporary authors claim (for instance [345, 147, 30]) or apparent? Most of the authors of books on SR avoid dealing with this *notorious controversy*, as Max Born called it [54]. On this controversy Anthony P. French wrote [140, 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

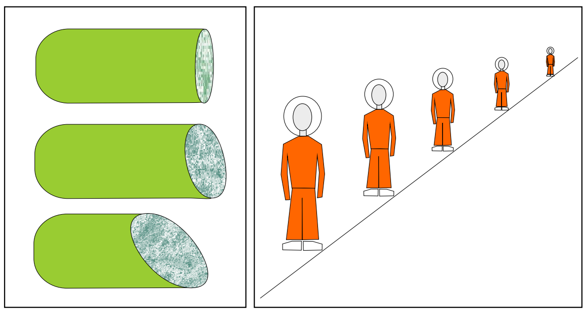

Figure 5.4 – Born's cucumber and Bohm shrinking men.

Born wrote (the cursive is mine) [54, 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 [52, 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.

Figure 5.4 illustrates both arguments. In a contemporary university textbook of physics we can read [162, 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.

Finally, consider the following quote from a university text (the cursive is mine) ([350, 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.

Its corresponding paraphrase, could be:

> 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 what about the visible laser beam inside the rod? The following is a text by the editor of a well known journal of physics (emphasis is mine).

> 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 ether, contrary to Special Relativity. There is no experimental evidence for an ether. Furthermore, no contradiction of SR has been observed experimentally to date.

And what about time dilation and the 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, where is the axiom, principle or law stating which consequences of the Lorentz Transformation are real and which 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 time dilation and phase difference in synchronization derived from the same Lorentz Transformation as FitzGerald-Lorentz contraction?
2. If not, why some consequences of the Lorentz Transformation are real while some other are only apparent?
3. If all of them were apparent, would not the Lorentz Transformation be an operator to translate between real and apparent worlds?
4. 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?
5. Would be the proper reference frame of an observer equivalent to a moving one?
6. In which way, if any, this affects the Principle of Relativity?

7. Do all physical laws have the same form in all reference frames? As we will see in a Chapter 12, the law of the reflection of light on a mirror inclined at 45º in the proper reference frame RF_o of the mirror is different from the same law in RF_v. In fact, if i is the angle of incidence and r the angle of reflection; v the relative velocity: $v = kc$, $(0 \leq k < 1)$; and θ_o is the angle the incident ray of light makes with the Y_o axis of RF_o, then the law of reflection in RF_o is:

$$i = r \tag{5}$$

while in RF_v is:

$$\begin{aligned} i = r + \pi/2 + \arctan\left(\frac{1 + k\csc\theta_o}{\sqrt{1-k^2}\cot\theta_o}\right) - \\ - \arctan\left(\frac{\sqrt{1-k^2}\tan\theta_o}{1 + k\sec\theta_o}\right) - \\ - 2\arctan\sqrt{1-k^2} \end{aligned} \tag{6}$$

For instance if θ =30º then i =75º, r=118.7555º. (see Chapter 12 for details). Could we say that the law of the reflection of light is the same in RF_o and in RF_v? Evidently, in the rest frame RF_o it holds $k = 0$, and then (6) becomes (5). Is it the same thing $i = r$ as $i \neq r$?

8. 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 and in all circumstances?

In the remainder of this book we will address these and other related questions.

According to our g-observer (see item 38, page 16), 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 relative velocity at which it can be 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 that explains them, except that of being observed at different relative velocities.

In addition, the observed contraction is independent from the physical nature (chemical composition and crystallographic structure) of the contracted object. 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 following argument.

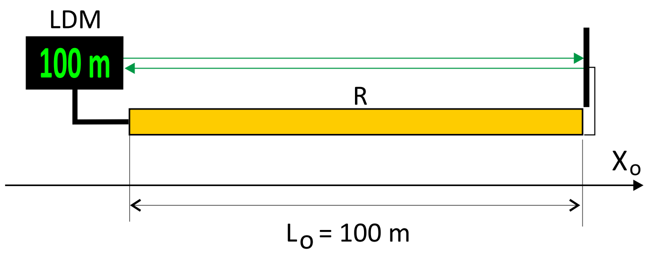

Figure 5.5 – The rod R and its laser distance meter LDM in its proper reference frame RF_o.

5.4 Measuring distances with a laser beam

Let R be a rod parallel to the X_o axis of its proper reference frame RF_o. A laser distance meter (LDM) is placed at one of the ends of the rod R. 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 R (Figure 5.5). Let RF_v be another reference frame that coincides with RF_o at a certain instant and from whose perspective RF_o moves according to our standard conditions (with a uniform velocity v parallel to the axis X_v in the sense of the increasing x_v). It is immediate to prove that, in this frame, light travels $2\gamma^2 L_v = 2\gamma L_o$ in each measurement (Figure 5.6). 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:

$$ct_{v1} = L_v + vt_{v1} \tag{7}$$

$$ct_{v2} = L_v - vt_{v2} \tag{8}$$

$$t_{v1}(c - v) = L_v;\; t_{v1} = L_v/(c - v) \tag{9}$$

$$t_{v2}(c + v) = L_v;\; t_{v2} = L_v/(c + v) \tag{10}$$

$$t_{v1} - t_{v2} = \frac{2vL_v}{c^2 - v^2} \tag{11}$$

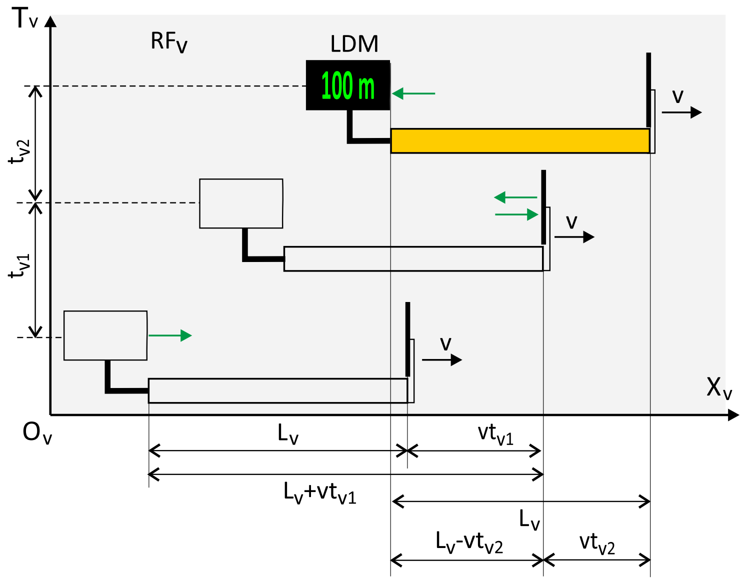

Figure 5.6 – The rod R and its laser distance meter LDM in the frame RF_v.

In RF_v light travels in each measurement along a distance d given by:

$$d = (L_v + vt_{v1}) + (L_v - vt_{v2}) \tag{12}$$

$$= 2L_v + v(t_{v1} - t_{v2}) \tag{13}$$

$$= 2L_v + v\frac{2vL_v}{c^2 - v^2} \tag{14}$$

$$= 2L_v\Big(1 + \frac{v^2}{c^2 - v^2}\Big) \tag{15}$$

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

$$= 2L_v\gamma^2 \tag{17}$$

$$= 2(\gamma^{-1}L_o)\gamma^2 \tag{18}$$

$$= 2\gamma L_o \tag{19}$$

Therefore, if the screen of 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 a potentially infinity number of different numerical 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 in that frame, whatever the orientation of R.

In consequence, for all observers in relative motion with respect to RF_o, except those moving parallel to Y_o or parallel to Z_o, the rod R has two different lengths, the universal alphanumeric result (L_o) displayed on LDM's screen, and the length calculated from their own indirect (LT) measurements. And since a rod cannot have simultaneously two different lengths, all observers must conclude only one of them could be the length of the rod. And being L_o the only universal length, the one observed by all observers in the screen of LDM, be them or not at relative motion with respect to LDM, they should conclude this is the real length of the rod, while the relative length they indirectly measure is only an apparent length of the rod.

Alternatively, the observers of RF_v might think that LDM does not work correctly and gives an error Er defined by:

$$Er = L_o(1-\gamma) \tag{20}$$

$$= L_o\Big(1 - \frac{1}{\sqrt{1-k^2}}\Big);\ v = kc;\ 0 < k < 1 \tag{21}$$

which strangely depends on their relative velocity $v = kc$. Consequently, we would have to admit that LDM *simultaneously* commits a potentially infinite number of different errors: a different error for each possible different relative velocity at which it can be observed, in the past, in the present, and in the future. Which is rather unbelievable. It seems much more reasonable that the FitzGerald-Lorentz contraction is only apparent.

6. Length contraction

Links to the book and to other chapters of the book.

6.1 Apparent deformation

As a comparative reference, we will use again the apparent deformation of a rod when it is observed partially submerged in water, as Figure 6.1 illustrates. As in the previous chapter, the rod is made of transparent glass and is equipped with a visible laser beam emitted from its lower end in the direction parallel to the wall of the rod. The observed deformation of the rod

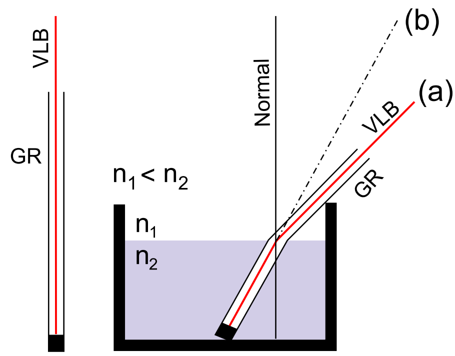

Figure 6.1 – Left: glass rod GR and its internal and visible laser beam VLB. Right: the glass rod partially submerged in water (n_1 and n_2 are the refractive indexes respectively of air and water).

due to the refraction of light needs no explanation. Though the deformation is not real but apparent, as the trajectory of the internal laser beam easily demonstrates: since the laser light always moves through the same medium within the rod, it does not refract and follow a rectilinear trajectory parallel to the wall of the rod. So, if the rod were actually deformed the laser beam would follow the trajectory (b) depicted in the Figure 6.1 in the place of the observed trajectory (a). Therefore, the rod is not deformed in a real way but in an apparent way.

6.2 The elastic cord

In the reference frame RF_o, an elastic and flexible cord rests free of forces on the plane X_oY_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 parallel to the Y_o axis. Since the cord is at rest and no force acts on it, all yellow and black marks have the same length, and this is in fact what is observed in RF_o (Figure 6.2, left). Things are quite different when this

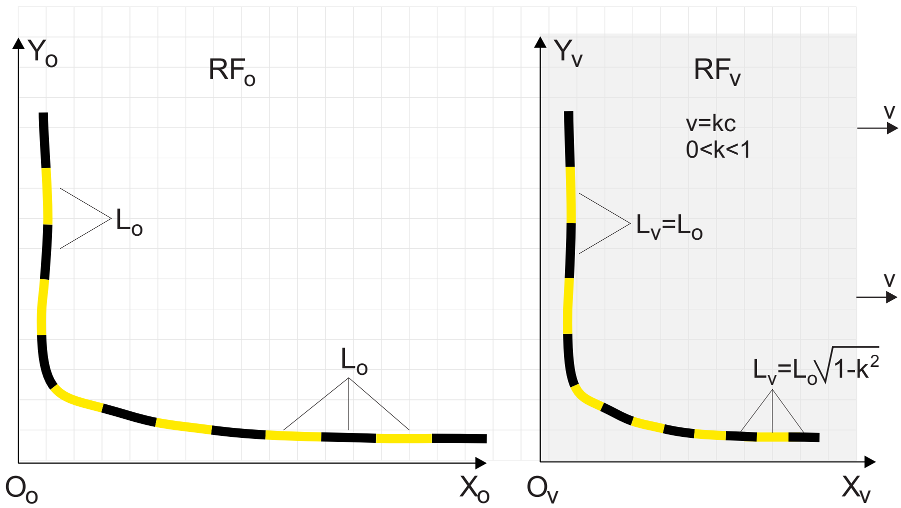

Figure 6.2 – The elastic cord at rest on the plane X_oY_o of its proper reference frame RF_o (left), and from the reference frame RF_v (right).

elastic cord is observed from the reference frame RF_v that, as always in this book, coincides with RF_o at a certain instant, and from whose perspective RF_o moves according to our conventions: with a uniform velocity v parallel to the increasing X_v. As Figure 6.2 (right) illustrates, all marks parallel to the X_v axis are observed with a length L_v, that according to LT will be:

$$L_v = \gamma^{-1} L_o \tag{1}$$

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

$$L_o > L_v \tag{2}$$

The observers in RF_v will, therefore, observe an elastic cord free of forces with some marks more stretched than others, which is impossible for an elastic cord completely free of forces. In consequence, for all observers, except those in RF_o and those moving parallel to Z_o, the elastic cord is observed with some parts more stretched than others, without any force acting on it. Obviously, this goes against the laws of mechanics governing the behaviour of elastic materials. The conclusion can only be that FitzGerald-Lorentz contraction is apparent, as apparent as the deformation of a rod partially submerged in water.

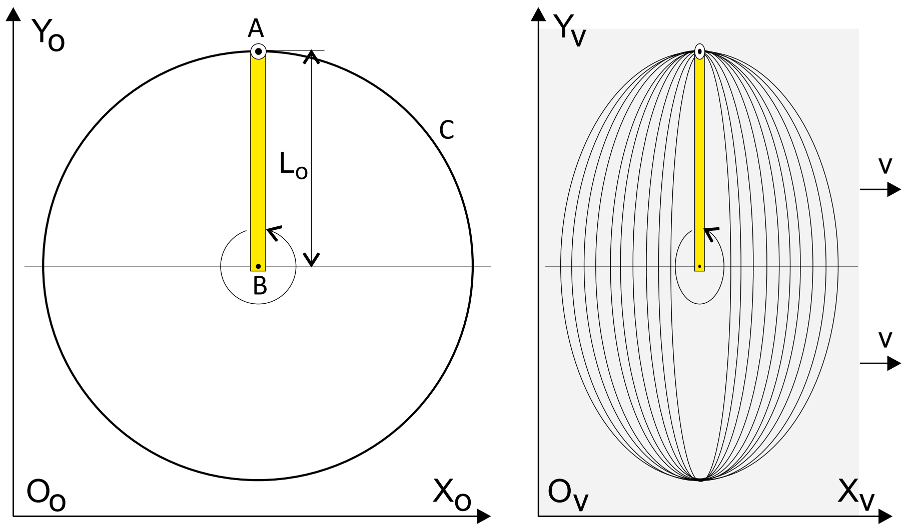

Figure 6.3 – Drawing a circle C (left) and a potentially infinite number of ellipses (right).

6.3 Circle and ellipses

Let AB be a rigid rod in its proper reference frame RF_o. The rod AB, whose proper length is L_o, is fixed at its end B around which it can rotate. In the other end A of the rod there is a drawing device by means of which the observers in RF_o draw a circle C (Figure 6.3, left). According to SR and LT, for the observers in RF_v the circle C is not a circle but an ellipsis, whose main axes have a length L_o and $\gamma^{-1}L_o$. And being γ^{-1} depending of the relative velocity v, the observers in different inertial referent frames RF_{v1}, RF_{v2}, RF_{v3},... will observe different ellipses (Figure 6.3, right).

If FitzGerald-Lorentz contraction were a real contraction, each time the RF_o observers draw a circle with the rod AB, they would really draw a potentially infinite numbers of different ellipses, each for a possible relative velocity at which the draw can be observed. Obviously, this conclusion is not compatible with the amount of ink used in the drawing... Therefore, the FitzGerald-Lorentz contraction is not real but apparent, as apparent as the deformation of a rod partially immersed in water.

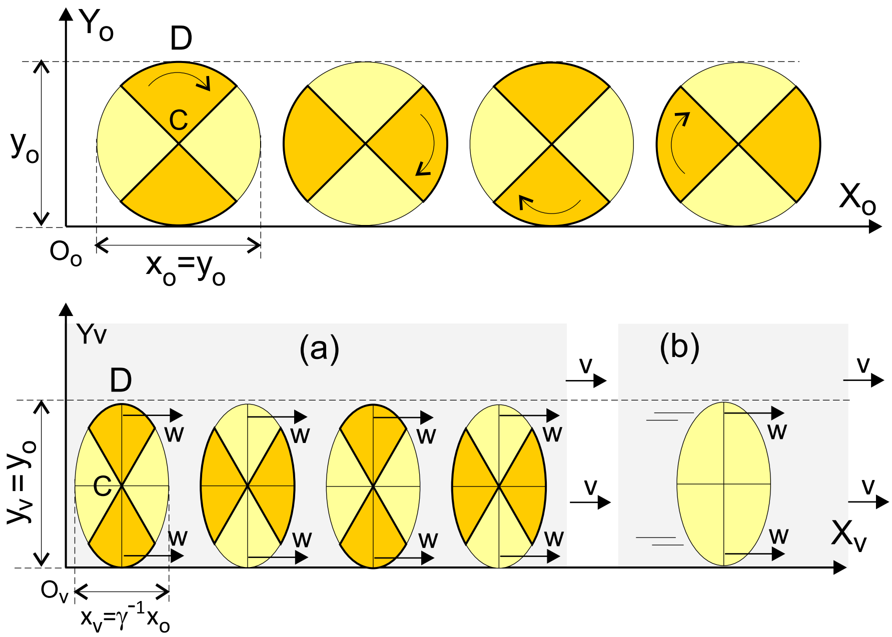

Figure 6.4 – Up: the rolling disk D in RF_o. Bottom (a): the rolling disk D as seen from RF_v. (b) The rolling disk in RF_v will be seen in uniform translation along X_v with its greatest axis moving parallel to the axis Y_v while its colored quadrants deform and rotate around its center C.

6.4 The rolling disk

Consider now a (perfectly circular) disk D made of the strongest steel. D is uniformly rolling on the axis X_o of the inertial reference frame RF_o. The disk D is divided into four equal colored quadrants to better appreciate its rotation around its center C (Figure 6.4, up). In RF_o nothing extraordinary is observed: the disk D is always observed as a perfectly circular disk that rolls on the axis X_o, i.e. that rotates uniformly around its center C at the same time it moves with a uniform rectilinear velocity parallel to X_o.

Let now describe, according to the Lorentz Transformation, the rolling of D from the point of view of the reference frame RF_v. In the frame RF_v, the disk D is also observed always with the same shape, but in this case (and due to FitzGerald-Lorentz contraction in the direction of the relative motion) its shape is not circular but ellipsoidal, being its main axes given by:

$$\text{Vertical axis: } y_v = y_o \tag{3}$$

$$\text{Horizontal axis: } x_v = \gamma^{-1} x_o = \gamma^{-1} y_o \tag{4}$$

Without its colored quadrants (Figure 6.4, bottom, (b)), it would also be impossible to observe the rolling of the disk and we would observe it moving with a uniform rectilinear velocity w parallel to X_v, while the rolling of an ellipsoidal disk would require that its major axis successively rotates from the vertical position to the horizontal position and vice versa; and the same apples to its minor axis. But this is not what is observed in RF_v. In this frame, the rolling disk will always be observed as an ellipsoidal disk with the same major vertical axis y_v and the same minor horizontal axis x_v, both moving parallel to X_v. At the same time the colored quadrants will serve to observe they rotate internally at the same time they deform in a complicated way without any deforming force acts upon the disk (Figure 6.4, bottom, (a)). It is as if the inside of an object is spinning without its external shape being spinning.

In conclusion, the rolling of the circular disk D (its rotation around its center and its translation parallel to X_o) is converted by LT into a uniform translation of an ellipsoidal disk that is continuously deformed internally without any force acts upon it. No theory of relativity (neither special nor general) can account for:

1. How an ellipsoidal disk can roll while its major and its minor axes maintain the same orientation, respectively vertical and horizontal.
2. How a physical object made of the strongest steel can be continuously and internally deformed without any force acts upon it.

There is, however, a very simple explanation of all these phenomena: FitzGerald-Lorentz contraction is not real but apparent, as apparent as the deformation of a rod partially submerged in a glass of water.

6.5 Annual tree growth rings

As Figure 6.5 shows, the annual growth rings of any tree in its proper reference frame RF_o are approximately circular, indicating the growth of the tree is similar in each direction. However, when the transversal section of any of these trees is observed from RF_v the corresponding growth rings will be observe as ellipses rather than as circles, indicating an asymmetrical growth of the tree: always smaller in the direction of relative motion.

If the FitzGerald-Lorentz contraction were real, each tree in its proper reference frame would have to growth in a potentially infinite number of asymmetrical manners, one for each possible relative velocity at which its growing rings can be observed. The alternative that each tree growths in a unique manner seems much more realistic and in accord with all we know on biological metabolism, growth and natural resources. And this alternative

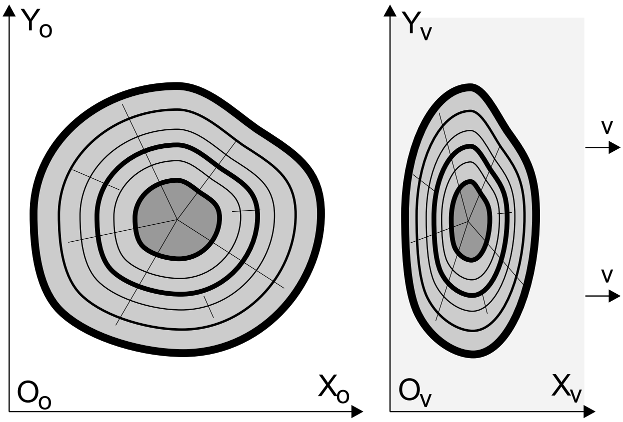

Figure 6.5 – Annual growth rings of any tree in its proper reference frame RF_o (left), and in RF_v (right).

implies that FitzGerald-Lorentz contraction is not real but apparent, as in the case of the rod partially submerged in water.

6.6 The rigid glass rod

Let now AB be a hollow cylindrical rod with a diameter of 1 cm and a length of 2 m made of very thin glass. It rest on its proper reference frame free of external forces. The rod AB, which can rotate any angle around its center C, is initially placed in the vertical position, parallel to the Y_o axis. Assume now that, at a constant temperature of $0^{\underline{o}}$C, it is slowly rotated to the horizontal position (Figure 6.6).

For the observers in RF_o nothing happens during the rotation, except the rotation. So, once rotated to the horizontal position, AB will continue to be a hollow cylindrical rod of thin glass with a diameter of 1 cm of and a length of 2 m. Assume, finally, the rotation is done and undone any number of times. They will always observe the same result: the glass rod AB does not change neither its length nor its diameter.

It could be claimed that for the observers in RF_v, the rotation of AB cannot be explained in the exclusive terms of SR because a uniform rotation is not a uniform motion because of the continuous changes in direction (though RF_o and RF_v are inertial reference frames). However, they will be able to observe and measure the initial and final state of the glass rod. According to LT, for the observers in RF_v the rod AB will have 2 m length and a diameter of γ^{-1} cm in the vertical position, and $\gamma^{-1}2$ m length and a diameter of 1 cm in the horizontal position.

So, they must conclude that whatsoever happens during the successive ro-

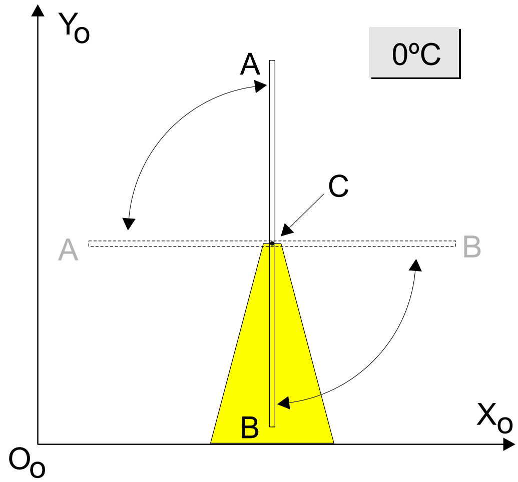

Figure 6.6 – The hollow cylindrical rod AB made of very thin glass can rotate at the constant temperature of 0°C from the horizontal position to the vertical position, and vice versa.

tations, the final consequences are always the same: the rigid glass rod will be successively stretched and contracted in length, and widened and narrowed in diameter, always at the same constant temperature of 0°C.

But the above conclusion of the RF_v observers is not compatible with the science of rigid materials: it is impossible that a hollow cylindrical rod made of very thin glass can be stretched and contracted an indefinite number of successive times, always at the same temperature of 0°C, without breaking. Therefore, those observers must consider the possibility that the relativistic length contraction determined by LT is not real but apparent, as apparent as the deformation of a rod partially immersed in water.

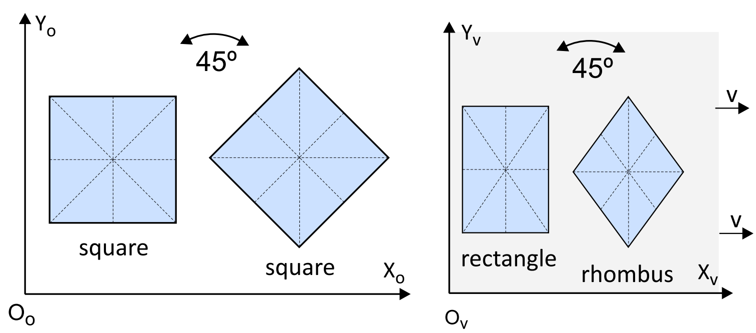

Figure 6.7 – Rotating a square crystal.

Figure 6.7 represents a square sheet of glass resting in the X_oY_o plane of its proper reference frame RF_o. As expected in RF_o, successive rotations of 45° clockwise and counterclockwise maintain the square shape of the crystal sheet. The reader can develop his own argument about what happens from the perspective of RF_v.

6.7 Hydrostatic 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 all precedent cases, 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 make use of a metal sphere MS, made of the strongest steel, with the same size and shape as the bubble (Figure 6.8). 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, the bubble and the metallic sphere MS have the same ellipsoidal shape in accord with FitzGerald-Lorentz contraction in the direction of the relative motion.

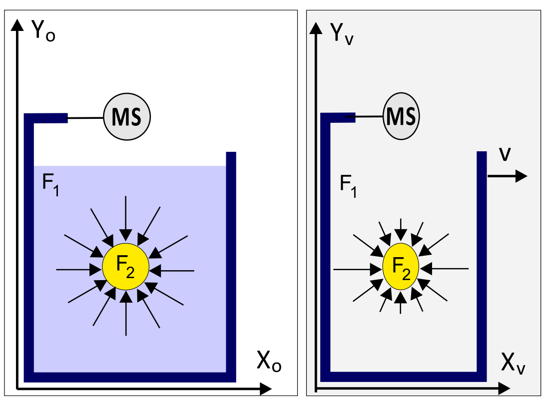

Figure 6.8 – A bubble of a fluid F_2 in hydrostatic equilibrium within another fluid F_1, as seen from its proper reference frame RF_o (left) and from other reference frame RF_v from whose perspective RF_o moves with a velocity v parallel to the axis X_v (right). MS: metallic sphere used as comparative reference.

But in the case of the bubble, its ellipsoidal shape is not compatible with the hydrostatic laws, according to which the hydrostatic pressure within a fluid 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 the 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, the 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.

6.8 Laser length meter

This section makes use of a set of rods each equipped with a laser meter (LM) that measures the length of its corresponding rod and displays on a screen the result of the measurement in the decimal numbering system. In the reference frame RF_o a set of twelve of such rods are disposed on the plane X_oY_o as Figure 6.9 shows: two rods parallel to the axis X_o, two rods are parallel to

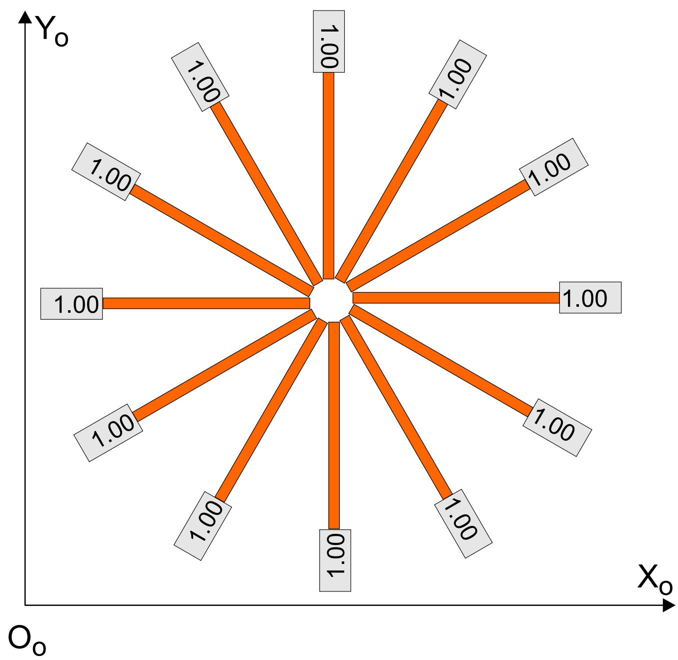

Figure 6.9 – The set of 12 rod equipped with laser distance meters in their proper reference frame RF_o.

the axis Y_o, and each rod makes an angle of 30º with the next one in both clockwise and anticlockwise senses. Assuming all rods have the same length, say 1.00 m, this will be the length displayed in the screen of each of their respective LM. The robotic observers in RF_o confirm this is the exact length of each rule. So, all LM work correctly.

From the perspective of the reference frame RF_v, all LM of RF_o malfunction in the sense that the numerical digits displayed in their corresponding screens are wrong, except the corresponding to the two rods placed parallel to the axis Y_v. Though the relevant question is not the malfunction of all those laser meters LM, the relevant question is that they malfunction according to a strict rule: the error Er of each laser meter LM whose rod makes an angle α_o with X_o is given by:

$$Er = 1 - \sqrt{\gamma^{-2}\cos^2\alpha_o + \sin^2\alpha_o} \tag{5}$$

$$= 1 - \sqrt{1 - k^2\cos^2\alpha_o} \tag{6}$$

where $v = kc$, $0 < k < 1$, $\gamma^{-2} = 1 - k^2$. We must therefore conclude:

a) When observed in relative motion, all LMs malfunction, except those placed perpendicular to the relative velocity.

b) The malfunction is not random but strictly regulated according to the law (6), which essentially (and inexplicably) depends on the relative velocity kc at which they are LT- measured, which in turns implies that all LM *simultaneously* commit a potentially infinite number of different errors, one for each possible different relative velocity at which they can be observed.

The above conclusions are unsustainable. It seems much more realistic to consider that relativistic length contractions are not real but apparent, as apparent as the deformation of a rod partially immersed in water.

Of course, the arguments presented so far to demonstrate the apparent character of the FitzGerald-Lorentz contraction are not the only ones that can be developed. The reader can develop his or her own. You could, for example, use Beer-Lambert's Law and the absorption of light by transparent and semi-transparent materials.

In the following chapters new arguments will be constructed that point in the same direction of the apparent nature of the relativistic deformations of space and time. The three next chapter address the question of the relativistic deformations of time.

6.9 Discussion

As noted in Chapter 5, 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 (recall for instance the case of the elastic cord, or the case of the hydrostatic pressure).

Therefore, the only consistent interpretation of FitzGerald-Lorentz contraction is that it can only be apparent. Let us now compare FitzGerald-Lorentz contraction with the deformation of the rod partially submerged in the glass of water:

1. The FitzGerald-Lorentz contraction is real in the same sense that the bending of the partially submerged rod is real: 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 in the case of the submerged rod (Snell Law). And several 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 FitzGerald-Lorentz contraction, and partially submerged in water in the case of the rod.

4. If we observe a rod partially submerged in water we can easily reconstruct its actual shape and size by a simple application of Snell Law of the refraction of light. 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 the relativistic factor γ.

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 value both objects 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. There is a potentially infinite number of apparent deformations of the submerged rod: each for each of the different inclinations it can be partially submerged in water. There is a potentially infinite number of different FitzGerald-Lorentz contractions of an object: each for each of the different relative velocities at which it can be observed.
8. Both deformations occur without a mechanical effort acts on the deformed objects.
9. The refractive deformation is independent of the physical and chemical nature of the deformed materials. The same is true for the FitzGerald-Lorentz contraction. Apparent deformations can be independent of the nature of the deformed objects, but what kind of real deformation of an object is that which does not depend on the nature of the object?
10. The above argument of the transparent rod and the laser beam proves that refractive deformations are only apparent. The above arguments on length contraction prove FitzGerald-Lorentz contraction can only be apparent.
11. Should we use a partially submerged rod or a non-submerged rod to describe the shape of an actual rod? Should we use an object at relative motion or the same object at rest to describe the object?
12. 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. Appearances can also be deceptive.

Being a consequence of the 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. In this book we will continue to discuss the apparent or real nature of all the consequences of Lorentz's transformation.

If FitzGerald-Lorentz contraction, time dilation and phase difference in synchronization were only apparent, LT would be an operator to convert between an actual reality and an apparently deformed reality. And what is worse, a deformed reality that could be in disagreement with the known physical laws. In those conditions a pertinent question would be if the observations and measurements performed in an apparently deformed reality would serve to get general physical conclusions on what really happen in the real physical world (provided that a real physical world do exist!).