Theoretical Distinction between Relativistic Theories

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The aim of this work is to discuss the way in which it is possible the choice between the different theories interpreting the principle of relativity, *i.e.*: Lorentz-Poincaré's theory, based on the existence of a privileged reference frame, and special relativity theory, based on the opposite assumption. It is shown that the results of experiments made in an inertial frame are the same for both theories. Nevertheless, the choice can be done in the light of other theoretical and experimental reasons.

Introduction

In a recent work [1] a possible experimental distinction between the results of Lorentz-Poincaré's interpretation of the relativity principle and those of special relativity theory has been analysed. To clarify the involved concepts, we will extend the analysis in a more complete way, especially because we disagree about an essential point.

The ideal experiment is carried out by means of two identical rockets placed initially at rest in a moving inertial reference frame (S'), where they are separated by a distance *D*; jointly with a rod of length *D*, which has one end firmly attached to the head rocket (rocket A) and the other end next to the rear rocket (rocket B).

Then, both rockets are accelerated in the opposite direction to that of the velocity v_1 of S' with respect to a privileged reference frame S. The acceleration is made simultaneously for S', in such a way that the distance between the rockets is always the same for this frame. Finally, after the acceleration process, both rockets move uniformly at a speed *V* measured in S'. Therefore, they will be at rest in a third inertial frame S'' (figure 1).

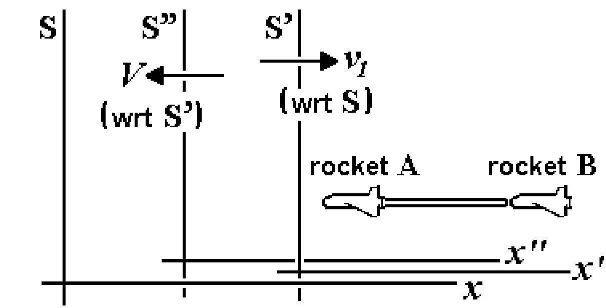

Figure 1. Ideal experiment

Lengths for the different frames

a) In the measurements of S':

The initial values for the rod length and for the distance between the rockets, all of them at rest in this frame, are

$$l'_0 = d'_0 = D \tag{1}$$

The final length of the rod firmly attached to rocket A is shortened, if the acceleration process did not originate permanent deformations, according to length contraction formula:

$$l' = D\sqrt{1-(V/c)^2} \tag{2}$$

The same happens with the rockets length, but not with the separation between them. This distance remains as *D*, due to the way in which they were accelerated:

$$d' = D > l' \tag{3}$$

b) In the measurements of S'':

Initially, the rockets and the rod move with velocity *V* in the direction of *x''*-axis and the values for the rod length and the distance between rockets are, now:

$$l''_0 = d''_0 = D\sqrt{1-(V/c)^2} \tag{4}$$

The final length of the rod is its proper length:

$$l'' = D \tag{5}$$

Due to length contraction of measuring standards in S'', the final distance between the rockets is enlarged by the same factor. Since it is *D* for S', it will be for S'':

$$d'' = \frac{D}{\sqrt{1-(V/c)^2}} > l'' \tag{6}$$

This enlargement can also be explained by the desynchronization of time. From fourth formula in Lorentz transformation:

$$t' = \gamma_{(-V)}\left(t'' + [-V]x''/c^2\right) = \gamma_V\left(t'' - Vx''/c^2\right) = \frac{t'' - Vx''/c^2}{\sqrt{1-(V/c)^2}} \tag{7}$$

we know that events simultaneous for S' (*Δt'=0*) happen for S'' with a difference of time:

$$\Delta t'' = \frac{V}{c^2}\Delta x'' \tag{8}$$

being the underlying reasons both the defective synchronization method used by inertial observers [2, 3] when they ignore their real movement, and the different time dilation factors for S'' of objects and persons moving slowly within S' in opposite directions [4].

Consequently, for S'' the successive acceleration impulses are given to rocket A before than rocket B (*Δt''<0* if *Δx''<0*), increasing the distance between them. It must be noticed, nevertheless, that when the rockets begin their movement for S', their velocity (for S'') diminishes and the impulses are, precisely, impulses of deceleration from the initial velocity *V* until the final velocity zero. For S'', the rockets move towards their sterns, rocket A travelling into the direction where rocket B is.

c) In the measurements of S:

The initial values for the rod length and the separation between rockets, being at rest in S', are

$$l_0 = d_0 = D\sqrt{1-\left(v_1/c\right)^2} \tag{9}$$

To obtain the final velocity of the rockets and the rod (now at rest in S''), we must firstly use Poincaré's formula for the transformation of velocities:

$$v_2 = \frac{-V+v_1}{1+\left(-V\right)v_1/c^2} = \frac{v_1 - V}{1-v_1V/c^2} \tag{10}$$

Therefore, the final rod length is

$$l = l''\sqrt{1-\left(v_2/c\right)^2} = D\sqrt{1-\left(v_2/c\right)^2} \tag{11}$$

If $v_1=V$, the final velocity v_2 results zero and l is larger than l' and equal to l''. This is obvious, since S and S'' coincide in such a case, being the rod finally at rest in the privileged frame. In fact, this ideal experiment would be simpler (involving the same physical concepts) with only two inertial reference frames, but we keep the experiment just as is described in reference [1].

The final distance between the two rockets for S is

$$d = d''\sqrt{1-\left(v_2/c\right)^2} = D\frac{\sqrt{1-\left(v_2/c\right)^2}}{\sqrt{1-\left(V/c\right)^2}} > l \tag{12}$$

and the results obtained are coherent for all inertial reference frames: there is a gap between the right end of the rod and rocket B, and this gap corresponds to the same fraction of the complete distance between both rockets.

We can also express equations (11) and (12) as explicit functions of v_1 and V:

$$l = D\sqrt{1-\frac{\left(v_1-V\right)^2}{c^2\left(1-\frac{v_1V}{c^2}\right)^2}} = D\frac{\sqrt{\left(1-\frac{2v_1V}{c^2}+\frac{v_1^2V^2}{c^4}\right)-\left(\frac{v_1^2}{c^2}-\frac{2v_1V}{c^2}+\frac{V^2}{c^2}\right)}}{1-\frac{v_1V}{c^2}}$$

$$= D\frac{\sqrt{\left(1-v_1^2/c^2\right)\left(1-V^2/c^2\right)}}{1-v_1V/c^2} \tag{13}$$

$$d = \frac{l}{\sqrt{1-V^2/c^2}} = D\frac{\sqrt{1-(v_1/c)^2}}{1-v_1V/c^2} \tag{14}$$

Special analysis in the privileged frame

The author of reference [1] accepts equation (12) as a result of special relativity theory, but denies it as a result of Lorentz-Poincaré's theory. In [1] it is said that the true final distance (*i.e.*: the final separation for S) between the rockets remains as (9) –being, then, shorter than the final rod length– arguing that the rockets accelerate identically.

But if the rockets accelerate identically for S', they cannot accelerate identically for S (unless S' knows previously its absolute velocity and uses the absolute synchronization criterion, but in such a case *all equations* (1)-(14) would be wrong for both theories, because those equations have been deduced assuming that S' accepts Poincaré's criterion for synchronization).

We will confirm now the results deduced for S, reasoning directly in this privileged frame.

a) Calculation of the rod length:

When rocket A accelerates, the rod length has to enlarge because the transmission of the acceleration cannot be instantaneous for all rod points. The rod does not reach its equilibrium length until the acceleration has ceased. To avoid this problem, we will use a reversible acceleration process: that in which the acceleration is provided by the engines of the rockets through successive separated small impulses, in such a way that there is enough time for the accelerated body to reach its equilibrium length between two consecutive impulses. The final result will be the same as that obtained with any acceleration which does not produce permanent deformations. It is also convenient to remember that, as it happened for frame S'', the acceleration of the rod is negative and the impulses are deceleration impulses.

By using a reversible acceleration, the rod will keep its (variable) equilibrium length practically during the whole process, in such a way that *its changes in length for S will be the same* as those produced by acceleration impulses given to both ends of the rod simultaneously for the successive inertial reference frames which coincide instantly with the rod, in spite of the fact that it is not true (as it has been said, all impulses are really given before to the left end by means of rocket A).

According to time desynchronization formula, clocks in an inertial frame moving with velocity v show a difference in readings, at a given instant of S:

$$\Delta t' = -\frac{v}{c^2}\Delta x' \tag{15}$$

so that two clocks synchronized in the moving frame are really (for S) desynchronized, being ahead the clock that moves towards the other ($\Delta t'>0$ if $\Delta x'<0$), but it must be noticed that, in this general equation (15), the primed letters represent coordinates in any frame with velocity v (and not in our previous S', whose velocity is v_1).

Let us suppose, according to what has been said, that the deceleration impulses are given to the ends of the rod when the readings of two clocks placed next to each end, in the successive inertial frames where the rod is at rest at every time, are the same. Since these clocks are always at rest in their respective inertial frames, equation (15) with $\Delta x'=D$ applies to them; in such a way that, for the privileged frame S, each impulse is given firstly to the left end of the rod and will not be given to the right end until the clock next to it shows the same reading.

Due to time dilation of moving clocks, the true time interval (for S) needed for the clock next to the right end of the rod to cancel out its difference with the simultaneous reading of the clock next to the left end is larger than their difference of readings by γ-factor:

$$\Delta t = -\gamma \Delta t' = \frac{vD}{c^2 \sqrt{1-(v/c)^2}} \tag{16}$$

and during the time interval (16) the velocity of the left end of the rod is smaller than that of the right end in an absolute infinitesimal difference *dv*.

As a consequence, in the whole acceleration process, the rod length has enlarged ($v_2<v_1$) in

$$\Delta l = -\int_{v_1}^{v_2} \frac{Dvdv}{c^2 \sqrt{1-(v/c)^2}} = D\sqrt{1-(v_2/c)^2} - D\sqrt{1-(v_1/c)^2} \tag{17}$$

what confirms, by adding (17) to (9), that the final rod length is given by equation (11), result in which there is no disagreement.

In this way we have deduced length contraction from time desynchronization and time dilation, showing the strong interdependence of the relativistic effects: each of them is implied by the others.

A precision is convenient at this point: equation (15) comes from the synchronization criteria of different inertial frames and has nothing to see with the real order in which the deceleration impulses are given. The clock next to the left end of the rod would also be ahead if the rod were firmly attached to rocket B and, consequently, pushed along by its right end.

b) Calculation of the distance between the two rockets:

The rockets are accelerated in a different way than rod points: simultaneously for S’, what is, precisely, the easiest way of carrying it out. This could be achieved even without further manoeuvres if the propellant stock is the same for both rockets, their engines are synchronized and programmed previously in S’ and rocket B has an identical rod attached behind it (to keep both rockets identical).

Clocks in the rockets will have different readings than clocks in S', due to time dilation, as soon as the rockets begin to move; but, since they move in the same way and at the same time from the beginning, clocks of computers on board of both rockets will read always the same for S'; and the successive acceleration impulses will be given synchronized for this frame.

Let us suppose that there is a wide set of clocks at rest in S' along the path of the rockets. As each deceleration impulse is provided to both rockets simultaneously for S', it will be given to the rockets when two of these clocks at rest in S' (placed next to each rocket) show the same reading.

Since these clocks are synchronized for S', they will be desynchronized for S according to equation (15) with $v=v_1$:

$$\Delta t' = -\frac{v_1}{c^2}\Delta x' \tag{18}$$

being now the primed letters coordinates in S', where $\Delta x'$ is always *D*.

Due to time dilation of moving clocks, the true time interval (for S) needed for the clock in S' next to rocket B to cancel out its difference with the simultaneous reading of the clock next to rocket A is larger than their difference of readings by γ_1-factor:

$$\Delta t = -\gamma_1 \Delta t' = \frac{v_1 D}{c^2\sqrt{1-(v_1/c)^2}} \tag{19}$$

and during the time interval (19) the velocity of rocket A is smaller than that of rocket B in an absolute infinitesimal difference *dv*.

As a consequence, in the whole acceleration process the separation between both rockets has enlarged in

$$\Delta d = -\int_{v_1}^{v_2} \frac{Dv_1 dv}{c^2\sqrt{1-(v_1/c)^2}} = \frac{Dv_1}{c^2\sqrt{1-(v_1/c)^2}}(v_1 - v_2)$$

$$= \frac{Dv_1}{c^2\sqrt{1-(v_1/c)^2}}\left(v_1 - \frac{v_1 - V}{1-\frac{v_1V}{c^2}}\right) = \frac{Dv_1}{c^2\sqrt{1-(v_1/c)^2}} \frac{\left(-\frac{v_1^2V}{c^2}+V\right)}{1-\frac{v_1V}{c^2}}$$

$$= D\frac{v_1V}{c^2}\frac{\sqrt{1-(v_1/c)^2}}{1-v_1V/c^2} \tag{20}$$

Thus, the final distance is

$$d = d_0 + \Delta d = D\sqrt{1-(v_1/c)^2}\left(1+\frac{v_1V/c^2}{1-\frac{v_1V}{c^2}}\right) = D\frac{\sqrt{1-(v_1/c)^2}}{1-v_1V/c^2} \tag{21}$$

which coincides with equation (14), as it must be.

Since this is the result in which there is no agreement, we will insist about it. Now we will apply equation (19) only to the beginning of the process, but in this occasion we will assume that S’’ is the privileged frame (being the rockets finally at absolute rest) to remark the simplicity of the reasoning.

Due both to time desynchronization and time dilation, the true (now for S’’) time interval between the departures of rockets A and B is given by equation (19) with $v_1 = V$:

$$\Delta t'' = -\gamma_V \Delta t' = \frac{VD}{c^2\sqrt{1-(V/c)^2}} \tag{22}$$

being rocket A the first in starting its travel.

During the time interval (22) after the departure of rocket A, rocket B remains motionless in S' at its departure position, therefore moving together with S' at a velocity *V*. When rocket B starts its travel, its departure position has advanced in *x''*-axis of S'':

$$\Delta d'' = V\Delta t'' = \frac{V^2 D}{c^2\sqrt{1-(V/c)^2}} \tag{23}$$

and the true (absolute) distance between the departure positions of rockets A and B has increased to

$$d'' = d''_0 + \Delta d'' = D\sqrt{1-(V/c)^2} + D\frac{V^2/c^2}{\sqrt{1-(V/c)^2}}$$

$$= D\frac{1-V^2/c^2+V^2/c^2}{\sqrt{1-(V/c)^2}} = \frac{D}{\sqrt{1-(V/c)^2}} \tag{24}$$

Meanwhile rocket A is also moving for S'' along the direction of *x''*-axis, (although its velocity is less than *V*) and the distance between the rockets at the departure of rocket B is much shorter than (24). But we can reason that, after its departure, rocket B repeats for the privileged frame exactly the same travel that rocket A is doing previously, in such a way that the trajectory (although corresponding different instants to homologous points) of rocket B is that of rocket A displaced a distance (24). Thus, this will be the final separation between both rockets, which coincides with (6). On the other hand, if the final velocity is not zero, and rocket A moves at uniform velocity while rocket B is still under the acceleration process, another difference in length must be taken into account.

All these calculations show that it is possible to assume any of the inertial reference frames as being the privileged frame. At the beginning we worked as if S' were really at rest. In this section we have firstly assumed S as the privileged frame, and finally we assumed S'' as that. In all cases the results have been the same. Of course, *this is necessary for the coherence* of the relativity principle: all observers must agree about the results of the measurements made by all of them.

Distinguishability of relativistic theories

Since every physical result can be explained choosing only one particular inertial observer as being at rest in the privileged frame, the possibility of this assumption being true cannot be avoided: an inertial observer among all of them *could be really the only one at absolute rest*, while the other observers get wrong (but coherent) values when measuring, due to the effects generated by their absolute movement in their measuring devices. The principle of relativity, as any other coherent physical theory, cannot be incompatible with the existence of a privileged frame.

Moreover, only when there are real effects of the movement with respect to a privileged frame, the apparent effects of the movement with regard to other frames can also appear. Therefore, Lorentz-Poincaré's theory assumes the existence of a real privileged frame even if it cannot be identified.

On the contrary, the so-called special relativity theory, which denies the existence of such frame, consists only of a misunderstanding between the physical reality and the results of measurements and can hardly be considered a physical theory.

Lorentz-Poincaré's principle of relativity says that an inertial observer cannot discover his real velocity with experiments made in his reference frame. For instance, he cannot realize of his own motion because the velocity of light is *apparently* isotropic for him and the measured (*not real*) values of physical entities satisfy exactly the same equations as those obtained with real values by an observer at absolute rest.

The last two results in the previous paragraph are chosen by special relativity theory as postulates, but in such a way that the conclusions (about measurements) of one theory are converted into the start point (about the physical reality) by the other theory, which leads, in different order and with different interpretation, to the same mathematical development. Therefore, the postulates of special relativity can be simplified into only one: “the measurable results of Lorentz-Poincaré’s theory represent the physical reality”. As a consequence, the measurable results of both theories are the same *by the definition itself* of special relativity theory.

Another consequence, frequently forgotten, is that Lorentz-Poincaré’s principle of relativity says that all measurable results (but not physical reality) can be obtained assuming any inertial observer at rest. In practical words: all calculations about measurable results made with special relativity theory are also calculations made with Lorentz-Poincaré’s theory. Calculations made in the preceding section have certain difficulty, and it is simpler to use equations (11) and (12), derived from the measurements made by observers in S’.

If it is obtained that the result of an experiment is different according to special relativity or to Lorentz-Poincaré’s theory, it must be due to a mistake in the calculations made when using one of both theories. And it can be added that, as it is usually more difficult reasoning directly in the privileged frame, many experiments that had been claimed as crucial tests to distinguish between both relativistic theories rely on an erroneous derivation of the result corresponding to Lorentz-Poincaré’s theory; contributing, incidentally, to discredit this last theory. A well-known example is Cedarholm-Townes experiment, which was regarded by a textbook [5] on special relativity as delivering the “coup de grâce” to the fixed-ether hypothesis, while the authors themselves of the experiment [6] had explicitly admitted that it could also be explained by that ether theory.

A different issue is that the result of an experiment could contradict the principle of relativity, but in such a case both relativistic theories would be refuted. Of course, this would not affect non-relativistic ether theories; however these theories must not be called Lorentz theories.

On the other hand, no experiment is needed to decide if there is a privileged reference frame, since this frame has already been identified.

The relativity principle has nowadays the same meaning as it had with Galileo: an inertial observer can only measure relative velocities and cannot discover his own movement *without looking outside* and finding a privileged reference frame. The passenger in the cabin of Galileo's ship have the possibility of discovering if the ship moves by going up to the ship deck and looking for the coast. The coast is an adequate privileged frame for a ship, but of course, not for the universe.

Nevertheless, an adequate privileged frame for the universe has also been discovered. The cosmic background radiation, coming from all directions of the space, is isotropic for one inertial reference frame. This unexpected experimental fact can be explained if such frame is the only one in which the velocity of light is really isotropic. So, it is possible to say that, at last, the absolute velocity of the Earth has been measured. Accurate experimental data obtained from Doppler shifts in the background radiation with the COBE satellite show that, in the privileged reference frame, the Sun has a velocity of 370 ± 3 Km/s in a direction that crosses the celestial sphere on a point placed next to the limit between Leo and Crater constellations. It can be added that the privileged frames supported by different authors (as Newton's absolute space in reference [7], Lorentz ether in [8], Machian preferred frame in [9, 10]) are compatible and can be the same frame as that obtained from the background radiation.

Moreover, it would not even be necessary to find the privileged frame for rejecting the special theory of relativity. Occam's razor argument supports Lorentz-Poincaré's theory as far as special relativity needs the physical reality of the four-dimensional Poincaré's space-time of measurements (reality later supported by Minkowski and denied by Poincaré himself) to avoid the simultaneous physical reality of a multiplicity of different three-dimensional spaces. But what could be definitive is that, although special relativity fits in well when used in inertial reference frames, it leads to implausibilities in accelerated frames. For instance, as some authors remark [11, 12], when an observer increases his velocity with respect to others, special relativity theory leads to reversals in time; which, besides, happen almost instantaneously at remote locations.

Conclusions

a) Two different theories account for the principle of relativity: Lorentz-Poincaré's theory and special relativity theory (with and without the existence of a privileged frame, respectively). Therefore, the invariance of the laws of nature or the indistinguishability of uniform movement *cannot be argued for supporting one of these theories in particular*. Of course, the violation of the relativity principle would refute both of them.

b) It is not possible to distinguish experimentally between Lorentz-Poincaré's theory and special relativity, because the measurable results of both theories are identical.

c) These theories differ in theoretical (non-measurable) results, of which those of special relativity theory are implausible.

d) Nevertheless, special relativity was supported by an important argument: it does not seem reasonable that, if the absolute space exists, nature prevents us for finding it. Therefore, the discovering of a background radiation in the universe that is symmetric for only one privileged reference frame may be regarded as delivering the "*coup de grâce*" to special relativity theory.

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