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SPONTANEOUS REASONING OF SECONDARY SCHOOL TEACHERS ABOUT THE RELATIVITY OF MECHANICAL MAGNITUDES

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Abstract

Some characteristics of spontaneous thinking in physics students, in relation to kinematics, were reported by Saltiel and Malgrange in 1980. One of them is this: ***speed, the distance which has been traversed in a motion, and the trajectory of a moving object are viewed as independent of a frame of reference.***

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Introduction

We think in concepts establishing complex relationships with them. As a consequence of the experiences that we have, the network of conceptual relationships that we establish in our minds can imply scientifically incorrect reasonings, because of deficient construction of concepts and/or by insufficient or incorrect relationships. When this happens, those scientifically incorrect reasonings last much more time than we would hope.

The history of science is rich in incorrect conceptual relationships that have lasted many centuries (see, for example, the relationships between weight and velocity or between microbe and spontaneous creation); on the other hand, thousands of classroom investigations have revealed an enormous persistence of ingrained thinking of students more or less separated from those that are accepted by current science. These ingrained ideas have empirical foundations, being supported by their living experiences. For instance, the idea that a body is forced to maintain its velocity is supported in experiences with bodies being pushed on tables and on floors (and many other experiences in which friction stops the bodies). These experiences imply, in the students' cognitive structures, incorrect relationships between force and velocity, for example.

Some kinds of Physics students' reasonings have revealed such uniformity, with respect to countries, schools, methodologies of learning and students' ages, so that we suppose those reasonings are supported in conceptual frameworks that are well defined and clearly opposite to the scientific frameworks. For instance, Saltiel and Malgrange (1980, p. 73) concluded about the existence of some universal structures in the students' spontaneous thinkings in kinematics, and pointed out some rules about that *spontaneous kinematics*. One of them is this: *the speed of a body, the distance it travels and the trajectory it describes are viewd as independent of a frame of reference*.

At first glance it looks superfluous to investigate to what degree this spontaneous thinking of students is extended to teachers. It seems evident that teachers, being used to solving problems about galilean relativity, must consider the velocity as a relative magnitude, consequently admitting different distances in different inertial frames. But the research that has been made with students that have studied Physics for many years, and the research with teachers that are involved in their initial training, has taught us not to be confident about such "evidence". As a matter of fact, these students and teachers construct their thinkings very well, using only scientifically correct ideas, when they are confronted with *routine situations*.
Nevertheless, when they have to solve *new situations*, they often use ingrained ideas that are clearly *misconceptions*.

For instance, A. Villani and J. Pacca (1987, pp. 55-66) made a study in Brazil with graduate students in Physics involved in post-graduate courses, and they detected the persistence of spontaneous conceptions that were analogous to those ones that were manifested by secondary school students, and whose characteristics were pointed out by Saltiel and Malgrange.
So, why not investigate if the same kinds (or other kinds) of conceptions are spontaneously used by the teachers in secondary schools (with more or less experience about Physics teaching) when they analyze unfamiliar situations?

In 1992 we gave two short courses (twelve hours) on special relativity that were designed for the preparation of Physics (and Chemistry) secondary school teachers. In the first course (in a town south of Lisbon) 23 teachers participated, and in the second (in the city of Lisbon) there were 30 teachers present.

At the end of these two formative courses, we had the opportunity to administer the two Villani and Pacca' problems and another question about the relativity of motion. The answers of the 53 secondary school teachers with a great range of experience in teaching (varying from 39 years of teaching to 1 year, and from one level to all the five levels of basic and secondary school Physics) were analyzed and we found the same kind of spontaneous thinking observed in the Brazilian students.

Almada: **23** teachers ; *Lisbon*: 30 teachers

	1-5 years	**5-10 years**	**10-15 years**	**15-20 years**	**20-30 years**	**30-40 years**
1 level						
2 levels	**1**	**1**		**1**	1	
3 levels	**2**		**1**	**1**		
4 levels		2	**2** 3	**1** 7	1	
5 levels		**2** 4	**3** 1	**6** 2	**2** 7	2

This communication intends to report this research involving Portuguese physics teachers, to divulge its results, and to make some suggestions about the teaching of relativity of mechanical magnitudes.

Methodology of the research

The *program* of the course was this:
1. The crisis of ether in classic Physics and the theory of relativity as the only possible way out (3 hours).
2. Some fundamental notions of relativistic kinematics (3 hours).
3. The relativistic dynamics and the notions of mass and energy (3 hours).
4. Alternative conceptions in relativity (3 hours).
The first three points were discussed (with questions and little dialogues). In the last point it was administered a written instrument of research that was kindly and responsibly responded to by all the teachers. At the end there was a profitable collective dialogue about all the questions. The instrument had 8 questions (transcript in appendices) on the speed of light and the change of frame of reference: the first seven questions were created by J. Villani and J. Pacca and they belong to their research instrument which was administered by them in Brazil; the last question was written by us and designed to reinforce, if possible, the investigation of an answer for this focus-question:

To what degree do Portuguese Physics teachers have the same kinds of spontaneous reasonings revealed by Brazilian graduate students?

The answers were carefully analyzed so as to try to discover the kind of reasoning used. If there is a reasoning based on *einsteinean relativity*, then some characteristics will be present, say:
- choice of the convenient inertial frame without any kind of bias to earth frames or other frames;
- constancy of light speed in all inertial frames and the assumption of its finite character;
- relativity of all the other velocities, times, and distances traversed by bodies;
- adequate use of Lorentz equations.

When we are in the presence of a reasoning supported by *galilean relativity*, the characteristics will be:
- choice of an inertial frame but the assumption of an absolute frame, the only one where light travels at the same speed in all directions;
- variability of the speed of light in all inertial frames, except in the absolute frame, and no assumption of the finite character of light;
- relativity of the velocities of bodies and the distances which they traverse in motion; no relativity of spatial distances and time;
- adequate use of galilean equations.

Finally, the reasoning supported in "*spontaneous kinematics*" will be evident when we can verify some characteristics:
- no choice of frames, and a tacit adoption of earth frames, or a space absolute frame, where the biased observer of real, proper or truth values is situated;
- no assumption of the finite character of light speed;
- privileged velocity in the earth frames, or in other frames assumed as absolutes; no relativity of time, spatial distances and distances traversed by bodies;
- inadequate use of transformation equations.

We tried very hard to discover a predominance of some of these characteristics.
As we had teachers who graduated in different subjects (Physics, Chemistry, Physics and Chemistry, Chemical Engineering and Pharmacology), we began making separated analyses considering the different variables: geographical area, experience, and kind of academic education, say, the subjects of the degrees teachers held. This detailed work led us to many separate annotations and many tables like this one (with the values in percentages, except the ones in the last column):

Almada: 23 teachers

	SR	GR	S_pK	1_{PC}	4_P	6_C	11_{CE}	1_{Ph}	N
$\Delta t'_f > \Delta t'_b$	R	NR	NR	0	0	0	9	0	1
$\Delta t'_f = \Delta t'_b$	A	NR	NR	100	75	100	82	100	20
$\Delta t'_f < \Delta t'_b$	R	R	NR	0	0	0	9	0	1

The *legend* is:
SR- special relativity
GR- galilean relativity
S_pK- "spontaneous Kinematics"
A- in accordance with
R- refuted by
NR- not refuted by
N_x- number of teachers with a degree X
N - total number of teachers with correct answers
PC- Physics and Chemistry, etc

A careful comparison of all the tables and annotations, and the fruitful discussion that happened at the end of the course, permitted us to infer this first and important conclusion:
The geographical area, the experience, and the kind of academic education did not reveal any significance in respect to this work. Independent of the self confidence shown (or not) in some teachers' replies, and the more or less formal correction of this or that answer, the kinds of responses were quite similar and revealed the same kind of omissions and misconceptions.

Regarding this conclusion, it is important to remember that all these teachers had no practice on special relativity teaching, because this theme is not included in our programmes.

Consequently, we are now presenting the partial results all included in the same tables, and doing an over-all analysis.

The results of research

First physical situation

In the first situation (Appendices) two luminous signals (light pulses), B and D, and two spatial vehicles were sent from the same point. Simultaneously, the signals and the vehicles traveled in opposite directions. This situation is completely symmetric.

First question- comparing distances traversed by signals and vehicles

Obviously, the conclusions that the distances traversed by light are equal, and that the distances travelled by the trains are also equal, are in agreement with any relativistic model: einsteinean or galilean. A correct spontaneous reasoning, although it is not supported in any relativistic theory, can also lead to a correct conclusion. Consequently, this question is not very discriminating.

The results that we have obtained from the Portuguese teachers and the corresponding results which had been obtained by Villani and Pacca with Brazilian graduate students are these:

Almada: 23 teachers ; *Lisbon*: 30 teachers

	SR	**GR**	**S_pK**	N_A	N_L	N_P	N_B
AB=AD	A	A	A	19	24	43	24
$T_BA=T_DA$	A	A	A	16	26	42	24

One teacher (with more than 15 years experience) concluded that T_B *moves* $L/2$ and T_D *moves* L . Another teacher obtained $T_DA = L+L/2$.
What kind of reasonings can be behind these answers that correspond to velocities of vehicles equal or greater than the velocity of light? Won't they be supported by a strange transformation of coordinates? This hypothesis is plausible. As a matter of fact, there were two other answers where the equation of Lorentz was used. In one of them, the conclusion was that the distances traversed by the trains were different and given by

$$\frac{L+\frac{c}{2}t'}{\sqrt{1-\frac{1}{4}}} \quad e \quad \frac{L-\frac{c}{2}t'}{\sqrt{1-\frac{1}{4}}}$$

In the other answer, the *distances* obtained are *equal*, *but* are *wrong*.
All these teachers responded incorrectly to the next two questions.
One answer was abandoned in the middle, but it revealed a formal reasoning, that if it had been completed, would have implied a *distance traversed by* T_D also *greater than L.*

Finally, another teacher used explicitly the galilean relativity, concluding that *the velocity of signal B, in relation to* T_B *, is c/2* .

Comparing these results with the ones obtained by Villani and Pacca, we can conclude that *the experience of teaching had a negative effect*, producing a result contrary to the one many people would expect. Sometimes, they revealed a tendency to use formal reasoning, as opposed to good intuitive reasoning. If they had used intuition, instead of trying to formalize the answer, they all would have answered correctly.

It is worth emphasizing (as did Villani and Pacca) that some teachers presented in their answers an explicit reference to the frame where the situation is happening. These teachers manifested a significant characteristic of relativistic thinking, yet this does not exclude the possibility of spontaneous reasoning. But these cases are less than one fifth of the total:

Indications of the frame of reference

	N_A	N_L	N_P	N_B
yes	4	6	10	3
no	19	24	43	21

Comparing these results with the ones that were obtained in Brazil, we can conclude that they are very similar. Also the great majority of Brazilian students did not indicate the frame of reference. This, by itself, does not mean that their reasoning, regarding relativity, is not correct, since the adoption of a frame may have been implicit.

<u>Second question- comparing distances traveled by photons as seen from train T_B</u>

This question already needs a change to frame T_B . In the same way as happened with the Brazilian students, almost all the answers of Portuguese teachers were incompatible with einsteinean relativity. In fact, *48 of the 53 teachers concluded that signal B was nearer.*
This answer, by itself, could mean either an unacceptable reasoning based on the galilean relativity , or based on a deeply empirical and spontaneous reasoning.

	SR	**GR**	**S_pK**	N_A	N_L	N_P	N_B
$T_BB<T_BD$	R	A	A	19	29	48	20
$T_BB=T_BD$	A	R	R	4	0	4	4
$T_BB>T_BD$	R	R	R	0	0	0	0

Some of the reasons presented that signal B was nearer revealed that most of the teachers maintained the relativity of the speed of light, and not only believed but promoted the earth frame as an absolute frame. One of the answers, for example, was this:
"*Signal B is nearer because its direction is the same as the vehicle T_B's direction, in which I travel.*"

To what degree is «spontaneous kinematics» (with the characteristics we refered to before) behind these wrong answers? In our opinion, this question does not permit a definitive response. After all, the question is quite similar to many others of the «car pursuit» type that teachers are used to solving in classrooms. These typical problems of earth related velocities enforce the natural tendency for geocentric reasonings. In this respect, it is very significant that the few correct answers belonged to Almada teachers (with less experience of teaching galilean relativity, on average).

But, in fact, *only a few answers revealed clear galilean reasoning* (in one of them the velocity c/2 was computed , as being the velocity of light, with the application of the galilean rule for composition of velocities). *The majority of teachers only presented the idea that T_B pursued the luminous signal,* and this could mean a spontaneous and not a relativistic reasoning, based on the composition of absolute distances traversed by particles (including photons). A teacher, for instance, presented a scheme of trajectories from which he concluded "*the distance between signal B and T_B is l/2*".

In spite of the fact that this question is very easy, there were many reasonings that revealed the difficulty teachers had to transfer their knowledge to the conceptual network of special relativity. For example, the reasoning contained in this answer:

"*The distance of T_B shortens but T_B moves with time dilation*".

In fact T_B moves on the earth, but does not move in the frame connected to T_B . There is a «contamination» of frames resulting in a bias towards the earth frame. To speak in a time dilation, we have to think as an earth observer, and about the events that happen in the frame T_B . Therefore, the observer is in frame T_B (and not on earth) and the motion occurs on the earth (and not in T_B).

This «contamination» of frames , with unconscious sliding from the frames in motion to the frames on the earth, occurred many times in the resolution of the problems, and also happened in the final discussion, at the end of the course.

Third question - comparing distances traveled by photons as seen from train T_D

The answers to this question were compatible with the answers to the previous question:

	SR	**GR**	**S_pK**	**N_A**	**N_L**	**N_P**	**N_B**
$T_DB>T_DD$	R	A	A	19	27	46	20
$T_DB=T_DD$	A	R	R	4	0	4	4
$T_DB<T_DD$	R	R	R	0	0	0	0

The few differences between the answers to these questions, Q_2 and Q_3, were these:
The teacher that had responded "*The distance of T_B shortens...*" did not now present any answer.
There were three teachers that did not respond to this question, whereas there had been only one that had not presented any answer to the previous question.
The analyses we made about the previous question are valid for this question.

Second physical situation

In this situation there is a rocket that flies over an earth station with the velocity c/2. A luminous signal is emitted by an antenna situated at the rear extreme of the rocket, it is reflected on a mirror situated at the front extreme of the rocket, and finally it returns to the antenna.

Fourth question - comparing the forward time ($\Delta t'_f$) and the backward time ($\Delta t'_b$) of the signal in the rocket frame

In a large majority of answers the idea was this: the forward time and the backward time are equal because the speed of light is constant and the distance is the same in the two trajects.
Nevertheless, this fact does not mean that the reasoning had been in accordance with einsteinean relativity. In fact, it is possible to answer the question correctly, whether you have correct or incorrect ideas about the distances traversed by light forwards or backwards. It is enough to admit that the distances are equal.

	SR	GR	S_pK	N_A	N_L	N_P	N_B
$\Delta t'_f > \Delta t'_b$	R	NR	NR	1	5	6	7
$\Delta t'_f = \Delta t'_b$	A	NR	NR	20	22	42	21
$\Delta t'_f < \Delta t'_b$	R	R	NR	1	3	4	2

Only a few teachers referred to the fact that motion occurs in the frame where the observer is situated. But, as a matter of fact, the frame is clearly established in the question, and maybe this was the reason why they did not refer to the frame.

Although the question is very simple, there were some answers that revealed spontaneous reasoning. There was a clear bias towards the earth frame, and velocities and distances traversed were thought of as being absolute distances. For example, this answer:

"*The luminous signal takes more time to go from antenna to mirror, than from mirror to antenna, because, in the traject* $\vec{AM}$, *the signal has to cover the length of rocket plus the distance it moves*".

We must register that the fact this teacher presented a vector is an indication (amongst others) that he was using a reasoning based on a composition of absolute displacements (as they refer to the earth, assumed as an absolute frame, as opposed to the fact the observer is in the rocket).

Another teacher formulated an analogous answer, and this reasoning also was detected in the Brazilian students. (Villani and Pacca, p. 61).

Two teachers responded $\Delta t'_f > \Delta t'_b$ because "*the velocity of luminous signal is c/2, and it is 3c/2 from M to A*". This answer involved a calculus based on an inadequate utilization of the rule of galilean composition of velocities. It manifests a hybrid reasoning where galilean and spontaneous ideas are mixed.

The most curious and strange answers were the ones belonging to teachers who affirmed *time forward is less than time backward*. The justification of one of them was this: "*on the going, antenna A moves in the same direction as the photons, whereas the mirror moves in the opposite direction of the photons on the return.*" Another teacher said that the result was the consequence of the "*Doppler effect*". Two of these teachers did not present any justification, but their answers must have been based on analogous reasonings that admited the motion of the antenna. As this object does not move in the rocket frame, we are in the presence of a misunderstanding based on the assumption of an absolute frame. But these kind of reasonings have a curious characteristic: they are based on an *emission theory*.

These emission theories of light have their history in a period when scientists tried to solve the problem of the negative result of the Michelson-Morley

experiment, without abandoning the conceptual framework of classic mechanics. These theories failed as a consequence of the observation of binary stars, and as a result of the experiments of interferometry with extra-earth light. Then, in this situation, the forward velocity of light would be $c+v_A$, as photons and antenna A move in the same direction, and the backward velocity of light would be $c-v_M$, as photons and mirror M move in opposite directions.
We think this is an interesting example of the existence of some similarities between the spontaneous reasoning of students and teachers, and the scientific ideas throughout the history of science.

Fifth question- comparing the forward time (Δt_f) and the backward time (Δt_b) of the signal in the earth frame

In this question, the length of the rocket is contracted in the earth frame, but the most important aspect is the fact the forward trajectory traversed by light is greater than the backward.
Then, the result is $\mathbf{\Delta t_f > \Delta t_b}$.

	SR	GR	S_pK	N_A	N_L	N_P	N_B
$\mathbf{\Delta t_f > \Delta t_b}$	A	NR	NR	11	11	22	16
$\mathbf{\Delta t_f = \Delta t_b}$	R	NR	NR	8	2	10	13
$\mathbf{\Delta t_f < \Delta t_b}$	R	R	NR	3	14	17	1

The first aspect to raise is the great number of teachers that responded incorrectly that $\mathbf{\Delta t_f < \Delta t_b}$. The analyses of justifications, and the final dialogue, permited us to conclude that many of them used a composition of velocities based on a *emission theory of light*. For example this answer:
" *It takes more time to go from M to A, because the distance is the same and the velocity is less*". The velocities c+c/2 and c-c/2 were computed by using the classic rule of velocities composition.
Many answers contained, implicitly or explicitly, the idea that the length of the rocket was precisely the distance traversed by light. This was assumed as an absolute distance (one of the main characteristics of spontaneous reasoning pointed out before). We choose these two examples:
"*The justification (for $\Delta t_f = \Delta t_b$) is the same as I presented in the previous answer (that is, the distances traversed by light are equal from A to M ,and from M to A , and the velocity of propagation of signal is the same)*".
"*The same as in the previous question.: the time is equal, as c is constant and the distance traversed also is constant*".

This kind of reasoning was similarly detected by Villani and Pacca in the Brazilian students (1987, p. 62).

Some teachers that responded $\mathbf{\Delta t'_f > \Delta t'_b}$ (Q_4) presented now the same choice, $\mathbf{\Delta t_f > \Delta t_b}$,
and the same kind of justification.

We detected three answers from teachers with very different backgrounds where the justification for $\mathbf{\Delta t_f < \Delta t_b}$ was the same: *the luminous signal is going away from the earth observer.*
Another answer was this:
"*It takes the same time, in accordance with the theory of relativity. Intuitively, I would think the opposite, that is: in the traject from A to M, in accordance with classical mechanics, when the rocket goes forward, the mirror M should go away; then, light should take more time to reach M . Inversely, in the return traject, from M to A, it is the back of the rocket that approaches the reflected luminous signal, and then, it should take less time*."
These answers (and others) showed us how the misconceptions, like this one of absolute distances traversed by things, are. Some teachers can remove themselves from these misconceptions, when they dominate the Newtonian mechanics, but they still fall into them when they penetrate into other, more formal and less known, conceptual fields (as in the case of einsteinean relativity). It happens the same with secondary school students, but for these, quite often it is unnecessary to reach such a formal field.

We detected the same inversion of frames and relativistic effects that Villani and Pacca had verified with Brazilian students (1987, p. 62). For instance:
"*It takes more time to go from A to M because the length of the rocket becomes longer than L for me, as I'm on the station*".
For the observer on the station the length becomes shorter, as a consequence of space contraction.

<u>Sixth question- comparing the rocket time ($\Delta t'_r$) and the earth time (Δt_e) of the signal in the forward motion</u>

This situation contains two opposite effects in relation to the earth observer: one of them implies a decrease in the time the signal takes to cover the distance; the other implies an increase in that time. As a matter of fact, if on one hand, light covers a distance longer than the rocket's length, as the mirror moves, on the other hand, there is a relativistic contraction of the rocket's length. The first effect is more influential, so the result is $t_e > t'_r$.

	SR	GR	S_pK	N_L	N_A	N_P	N_B
$\Delta t'_r < \Delta t_e$	A	R	NR	21	19	40	18
$\Delta t'_r = \Delta t_e$	R	A	NR	0	2	2	9
$\Delta t'_r > \Delta t_e$	R	R	NR	7	1	8	3

A great number of answers ignored the increase of distance traversed by light, caused by the fact that the rocket was in motion, although this increase was predictable by Newtonian mechanics. This fact showed us, once more, the existence of this misconception we have been refering to. In fact, most of the teachers considered only the space contraction, or the time dilation (in the same way the Brazilian students did).
Here are some examples:
"*To someone on the station. To someone that is in this frame, there is a time dilation.*"
"*As the time, measured in the stationary frame (taking earth as a stationary frame), is ever greater- time dilation.*"
"*To someone on the station, because in the rocket there is a time contraction.*"
"*Less time for the observer on earth, because the distance AM is not the same for both observers. The earth observer watches a shortened distance.*"
"*It takes more time for the observer who measures a longer distance between A and M, that is the observer in the rocket.*"

These answers exemplify that, many times, technical language can hide spontaneous ideas. This is more explicit in answers like these:
"*In the station, because to someone in the rocket, this moves in the same direction as the signal.*"
"*The luminous signal takes the same time to travel the distance AM for both observers, because luminous signals move with the same velocity c.*"
Once more, the idea of an absolute distance appeared. And we also could verify the existence of hybrid reasonings in answers like these:
"*The velocity of the signal to someone in the rocket is c. The velocity of the signal to someone on the station is 3/2c . Therefore, the signal takes less time to the observer on the earth station.*"
Some teachers even expressed the two times by L/c and 2L/3c and other similar formulas.
These and other more formal answers hide heterogeneous reasonings, where the ideas on galilean relativity are mixed with spontaneous ideas based on absolute motion, with "proper distances", true velocities, and so on.
Also in this question we detected, once more, the inversion of frames and relativistic effects. For instance:
"*On the station, because the signal has to travel less distance for the observer in the rocket.*"

This teacher considered the space contraction in the proper frame, and not in the laboratory frame where it is valid.

<u>Seventh question- comparing the rocket time ($\Delta t'_r$) and the earth time (Δt_e)of the signal in the backward motion</u>

Now the distance traversed by the luminous signal is clearly less to the station observer, not only because he watches a contraction of the rocket's length, but also because he watches the antenna running into the signal. Nevertheless, in the majority of answers we read that "*time is greater to the earth observer*".

	SR	GR	S_pK	N_L	N_A	N_P	N_B
$\Delta t'_r > \Delta t_e$	A	R	NR	11	6	17	15
$\Delta t'_r = \Delta t_e$	R	A	NR	0	3	3	8
$\Delta t'_r < \Delta t_e$	R	R	NR	12	14	26	7

Why did this great percentage of wrong answers happen? In our opinion, the main reason is the fact that many teachers repeated the same spontaneous reasoning that they had developed in the previous question. So, eight teachers used, once more, only the time dilatation, and three teachers used only the contraction of space. Three teachers used the same justification based on the constancy of light speed, and the same hybrid reasoning with different velocities of light in different frames was used once more .
Furthermore, we think that the fact that many answers had the words "*by the same reason*" is very significant.

Third physical situation

In this last situation there is an earth observer who is situated in the middle of the distance between two antennas that emit two luminous signals.
These signals are observed simultaneously by that observer who measures the distance Δx between the antennas.
Another observer, in a rocket that flies over the earth observer with the velocity $v = \beta c$, registers the arrival of the signals separated by the time $\Delta t'$ (magnitude) and measures the distance $\Delta x'$ between the antennas.

<u>Eighth question- comparing distances as seen by the earth observer (Δx) and the rocket observer ($\Delta x'$)</u>

The teachers had to choose an option from four items that were given to them. These options and the results are in this table:

	SR	GR	S_pK	N_A	N_L	N_P
$\Delta x' = \Delta x$	R	A	A	1	1	2
$\Delta x' = \Delta x\sqrt{1-\beta^2}$	R	R	NR	2	7	9
$\Delta x' = \Delta x\sqrt{1-\beta^2} - v\Delta t'$	A	R	NR	6	9	15
$\Delta x' = \Delta x\sqrt{1-\beta^2} + v\Delta t'$	R	R	NR	5	2	7

The first aspect to register is this: almost 40% of the teachers didn't have any idea which item to choose. Amongst the teachers that answered, three of them did not present any justification, and two of them used the Lorentz equations incorrectly (with these equations we can get the answer immediately). Five teachers vacillated between the two last options.
The most significant answers, according to spontaneous kinematics, are nine answers (most of which came from teachers with great experience of teaching) that opted for the second item

$$\Delta x' = \Delta x\sqrt{1-\beta^2}$$

The idea is this: there is a contraction of space and, as a consequence of it, the distance is shortened by the Lorentz factor. This new distance is now viewed as a new absolute distance, and the interval between the arrival of the signals was not taken into account, although it was explicitly refered to in the question.

Commentaries, conclusions and suggestions in short

The history of science shows us the difficulty scientists have had to get away from a geocentric and homocentric position in the face of the interpretation of events, particularly the motion of celestial bodies. How can we be respected when teachers (in the same manner of students) spontaneously bias the earth frames as opposed to all the others?

The history of special relativity reveals to us that extraordinary scientists (Lorentz, Poincaré and others) were not able to liberate themselves from the conception of absolute space, trying to solve the difficulties built up by the negative result of the Michelson-Morley experiment in the framework of absolute motion. How can we be admired when teachers (in the same manner as students) tend to describe the motion in an absolute space, and to be in favor of one distance, and of one trajectory, against all the others that are involved in the situation?

This research permitted us to conclude that not only do students maintain spontaneous ideas centered in the concepts of absolute motion in a "latent state" (Villani and Pacca, 1990), but so do the secondary school teachers, independent of their experiences. Many times, the teachers end up mixing these spontaneous ideas (whose characteristics are amongst the ones that Saltiel and Malgrange systematized in 1980) with relativistic ideas, sometimes hiding them in a technical language, resulting in unacceptable hybrid reasonings.

This research has depressed the author, who has fought in his country to update the teaching of Physics in secondary schools with the introduction of an approach to special relativity. In consequence of what we could verify in this research, it is our opinion that the introduction of a subject of special relativity (without prejudice of other more basic subjects) requires a previous instruction of teachers, not only in the field of special relativity itself, but also in the field of galilean relativity. The mastering of this theme is a pre-requisite to einsteinean relativity. Moreover, galilean relativity is very good when discussing real and conceptual experiments of relative motion, and when confronting personal, idiosyncratic, spontaneous teachers' ideas with the experimental evidence, trying to liberate the teachers from all kinds of misconceptions related to absolute distances and absolute velocities. Only after that, with a solid penetration in the special relativity field, could they liberate themselves from the spontaneous idea of the infinite light velocity, and the old conception of absolute time, without falling into reasonings outside the proper ground of galilean relativity.

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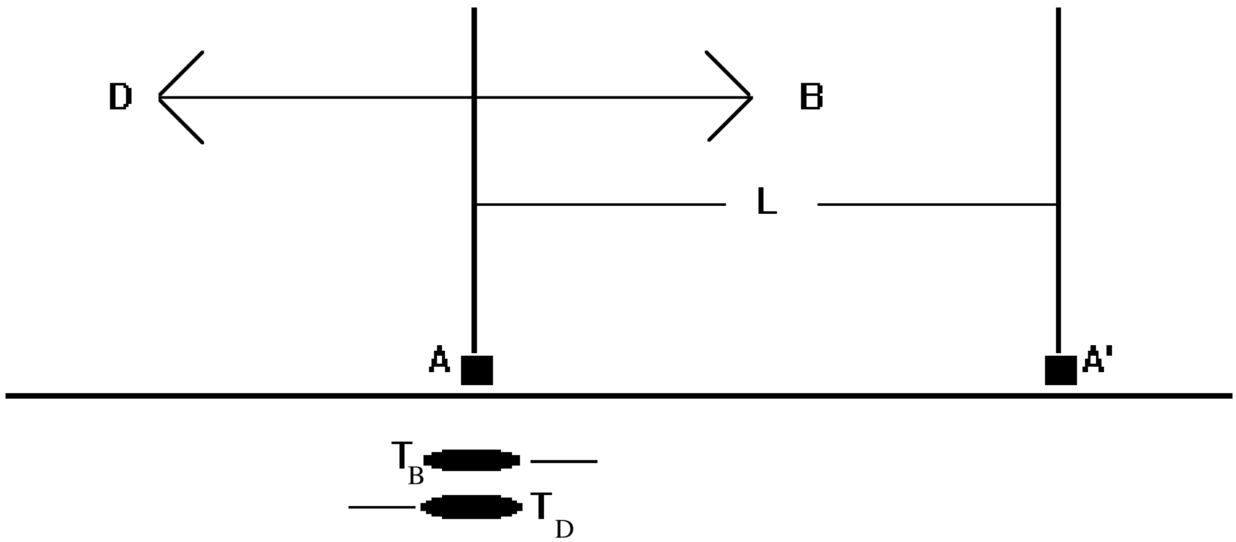
Appendix A- First physical situation

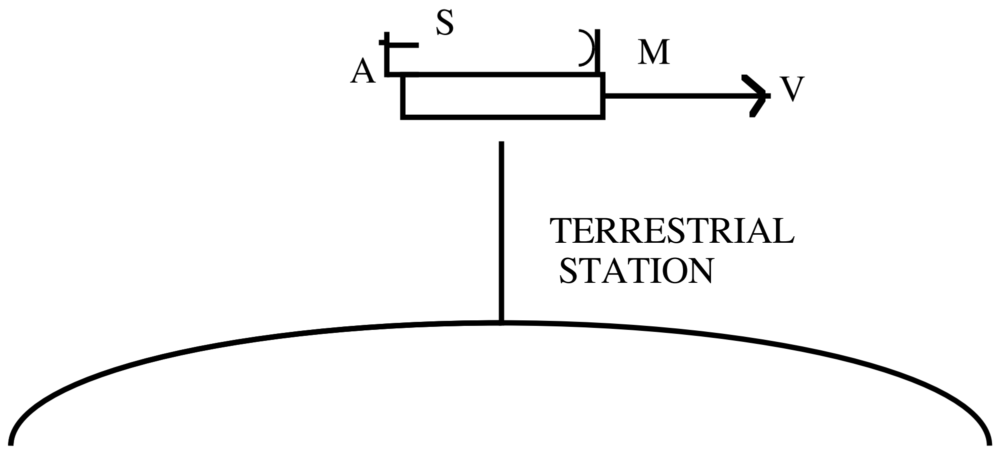
At the moment at which the two trains, T_B and T_D , which travel with speed v = c/2 in opposite directions, cross the antenna A, it emits two light signals, B and D , in opposite directions. Train T_B and the signal B travel in the same direction and so do T_D and D.



Q_1 - At what distance from A , will the two trains T_B and T_D and the signal D be, when B crosses an antenna A' that is at distance L from A? Why?
Q_2 -Suppose you are a passenger in T_B . For you, when B reaches antenna A', which of the two signals will be closer to you? Why?
Q_3 -Suppose you are a passenger in T_D . For you, when B reaches antenna A', which of the two signals will be closer to you? Why?

Appendix B- Second physical situation

A rocket of length L is provided with an antenna, A , in its rear part, and with a mirror, M , in the front part. When the rocket, which travels at a speed which is half the speed of light, passes over a terrestrial station, the antenna emits a light signal, S , which, after reaching the mirror, is reflected and returns to the antenna where it is absorbed.



Q4 - For somebody in the rocket, does the light signal take a longer time to go from the antenna, A , to the mirror, M , or to return from the mirror, M , to the antenna, A ? Why?

Q5 - For somebody at the terrestrial station, does the light signal take a longer time to go from the antenna, A , to the mirror, M , or to return from the mirror, M , to the antenna, A ? Why?

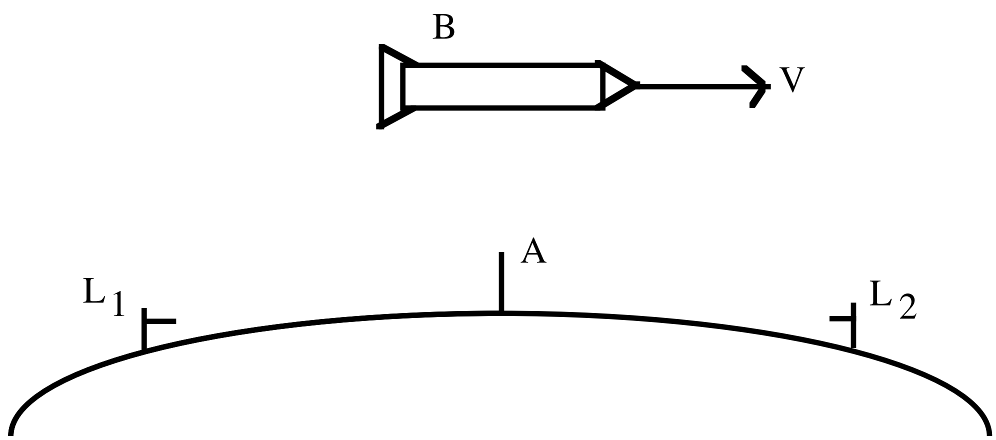
Q6 - Does the light signal take a longer time to traverse the distance AM for somebody in the rocket or for somebody in the station? Why?

Q7 - Does the light signal take a longer time to traverse the return MA for somebody in the rocket or for somebody in the station? Why?

Appendix C- Third physical situation

Two electromagnetic signals are emitted from two antennas, L_1 and L_2, at rest on earth. These emissions are observed simultaneously by a terrestrial observer, A, who measures the distance, Δx, between the two antennas.

Another observer, B, who is travelling in a rocket with a speed $v = \beta c$, reports a time difference between the emissions of signals which has the magnitude $\Delta t'$.



Q8 - Amongst the expressions

- $\Delta x' = \Delta x$
- $\Delta x' = \Delta x \sqrt{1-\beta^2}$
- $\Delta x' = \Delta x \sqrt{1-\beta^2} - v\,\Delta t'$
- $\Delta x' = \Delta x \sqrt{1-\beta^2} + v\,\Delta t'$

choose one that indicates the distance between the antennas which is measured by the observer B in the rocket. Justify your choice.