Philosophical Model of Special Relativity

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Abstract

The model of special relativity is built in the article. Within the framework of the model, formulas of special relativity are obtained and their philosophical and physical meaning is revealed.

1 To special relativity

1.1 Model of special relativity

Create different kinds of models plays an important role in scientific knowledge . Therefore, the construction of a visual model of the special relativity is of great importance for the explanation of the phenomena (length contraction, time dilation processes) inaccessible to direct perception of human senses.

Model of special relativity is a system of two observers and two rods (Fig.1a). Here AB and $A'B'$ are rods with a length l_0. At points D and D' are observers. R is a constant distance, R_1 is a variable distance. Thus, each observer associated with a respective rod (own reference system indicated in red or blue).

From Fig.1a is easy to obtain equations that are valid with respect to both observers

$$l' = l_0 \left(1 - \frac{R_1}{R}\right) \tag{1.1}$$

$$\tan\alpha' = \frac{\tan\alpha}{1 - R_1/R} \tag{1.2}$$

$$R\tan\alpha = \tan\alpha'(R - R_1) = invariant \tag{1.3}$$

The equation (1.1) characterizes the apparent decrease in the length of one rod with respect to the other rod as a function of the distance R_1. The equations (1.2) and (1.3) characterize the invariance of the lengths of both rods as the distance R_1 changes, that is, the length l_0 is an invariant of the transformations. We note that in (1.1), the decrease in the length l' is not the result of the action of some internal molecular forces in the rods. This is analogous to special relativity (SR) where, according to Einstein, the "compression" of rods is an inevitable consequence of kinematics, and not the result of a change in the balance of forces between solid-state molecules during motion, according to Lorentz and Poincare.

If we consider the motion of the light signal from the point A to the point B and back to the point A in the indicated model, then it is not difficult to show that for the light signal of the formula (1.1), (1.2), (1.3) take the following form

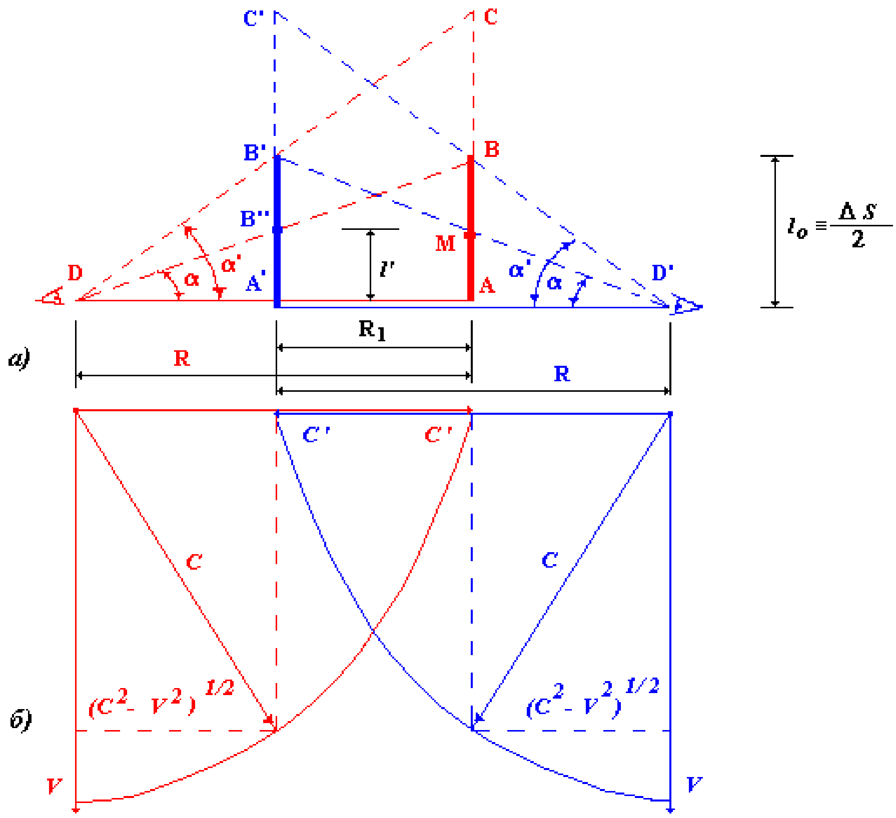

Figure 1: Model of special relativity

$$l' = l_0\sqrt{1 - \frac{v^2}{c^2}} \tag{1.4}$$

$$\Delta t' = \frac{\Delta t_0}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{1.5}$$

$$c\Delta t_0 = c'\Delta t' = \left(c^2 - v^2\right)^{1/2}\Delta t' = \left(c^2\Delta t'^2 - \Delta x'^2\right)^{1/2} = \Delta S = inv \tag{1.6}$$

Here l' is the distance that the light signal travels during the time $\Delta t_0/2$ with respect to the rod $A'B'$ and is the *projection* of the light beam on this system; $\Delta t_0 = 2\tan\alpha\,(R/c)$ and $\Delta t' = 2\tan\alpha'\,(R/c)$ are the total times of the light signal's movement back and forth with respect to its own and other frames of reference; c is the speed of light; v is a quantity with the speed dimension (the so-called spatial component of the speed of light, (see Fig.1b); $c' = \sqrt{c^2 - v^2}$ is the so-called "transverse", time component of the speed of light; $\Delta S = 2\,l_0$ is an invariant quantity characterizing the unchanged length of the rods and expressed in terms of the spacetime characteristics of the light signal, which runs through the length l_0 of the rod twice, from A to B and back to A.

Since the formulas (1.4), (1.5), (1.6) are completely analogous to the formulas in SR, then all the conclusions of special relativity are visually and easily displayed in the constructed model of SR.

In Fig.1, we can explicitly show the value of the velocity v. Since $c' = \sqrt{c^2 - v^2}$ or $c^2 = c'^2 + v^2$, which is the equation of the circle, we get Fig.1b. Figure 1b shows that for $v \ll c$ we obtain $l'/l_0 \approx 1$ and $\Delta t'/\Delta t_0 \approx 1$, which is a transition from Lorentz transformations to Galileo transformations. For $v > c$, the SR-model becomes meaningless. The constancy of the speed of light c in the model is shown by the constancy of the radius of circles in Fig.1b, regardless of the value of the velocity v (that is, regardless of the mutual arrangement of the two frames of reference). The form for the velocity $c' = \sqrt{c^2 - v^2}$ is due to the fact that the signal transmission rate has a limit and the speed of light in vacuum is the highest signal transmission rate.

In the SR-model, you can define the so-called "event space". It is a half-plane over the line DD', where each point can be characterized by time and place. Let us consider how the problem of simultaneity of two events is displayed in the model. Let light signals be emitted from the point M lying in the middle between the points A and B to the points A and B. An observer at point D will find out that these signals will come to points A and B simultaneously. However, at the points A' and B' from the point of view of the observer in D these signals will not come simultaneously. Thus, the concept of simultaneity becomes relative, depending on which frame of reference this process is being examined. An observer will arrive at similar conclusions at the point D'.

From the SR-model it is also seen that the "shortening" of the length of the rod l' is closely related to the concept of the simultaneous arrival of light signals to the ends of the rods. Indeed, if we send light signals from the point M (Fig.1) to the points A and B, then the observer in D will find out that these signals will come to the points A and B simultaneously. In relation to the rod $A'B'$, the light signals will come simultaneously to the points A' and B''. But the distance $A'B''$ is the "reduced" length l'. Thus, with respect to the rod $A'B'$, the SR-model adequately reflects the "contraction" of the original length. And, as in SR, in the SR-model (Fig.1a), this "reduction" is also connected with the concept of simultaneity.

Note that the length of the rod can also be determined in such a way that the positions of the ends of the rod $A'B'$ that are simultaneous in the improper reference system are measured. That is, here the light signals must be sent from the middle of the rod $A'B'$ to points A' and B'. In this case, the Lorentz transformations will be followed not by a "reduction" but by an "increase" in the length of the rod. In the SR-model in Fig.1, this is reflected in the fact that, relative to the rod AB from the point of view of the observer in D, the light signals will come simultaneously to the points A and C, and the initial length of the rod $A'B'$ will appear "increased" and equal to AC. In this case, instead of the previous relation, we would have the following equation

$$l' = \frac{l_0}{\sqrt{1 - \frac{v^2}{c^2}}} \qquad (1.7)$$

However, relativistic physics prescribes, when measuring the length, to make a simultaneous reading in the system in which the measurement is made, and thus eliminates the ambiguity of the results. The considered example of the length relativity clearly indicates that the length of the object is not some absolute property associated with the very existence of the object, but, on the contrary, the numerical value to be compared with the length depends on the conditions of the measurement.

As noted by Pauli, Lorentz reduction is not a property of one scale, but represents a fundamentally observed mutual property of two scales that move relative to each other. It is satisfactory to regard the relative motion as the cause of the Lorentz contraction, since this latter is not a property of one scale, but a ratio between two scales.[1] The above remark of W.Pauli is reflected in our model in Fig.1a by the presence of two rods AB and $A'B'$.

What does it mean to reduce the length of the ruler? First of all, it is clear that no compression of the ruler can occur. This follows from the basic principle underlying the SR, the principle of the equality of all inertial reference frames (IRF). In all IRF, the physical state of the ruler is the same. Therefore, there can be no question of the occurrence of any stresses leading to deformation of the ruler. The "shortening" of the ruler occurs solely due to various methods of measuring the length in two frames of reference. On the other hand, the detectable relativity of the length of the ruler is not an illusion of the observer. This result is obtained for any reasonable method of measuring the length of a moving body. Moreover, considering the physical phenomena in a given frame of reference, it is necessary to take the length $l\,'$ for the length of the body, and not the length l_0. [2]

In SR, the speed of light is determined from the expression $\Delta\,S = 2\,l_{\,0} = 0$. How this situation is displayed in the SR-model. In this case, for an observer in D, the length of the rod AB is 0, i.e. own reference system no longer exists. There remains only a light signal and there is nothing to correlate with. That is, the light signal can not be a reference system. For light there is no own frame of reference. If light signals are taken as clocks, then these clocks do not go, they cost. The counting of the time process (movement of the light beam) can occur only with respect to the rods AB or $A'B'$, but not with respect to itself.

It is seen from the model that the invariant interval $\Delta\,S$ maps the immutable extent of the moving body $l_{\,0}$, which the light signal passes twice (back and forth). This interval is expressed in terms of the characteristics of the light signal r and $c\Delta\,t\,'$.

In the model, one can display the situation when one of the reference frames moves uniformly-accelerated (Fig.2).

In this case, the quantity $c\,'$ (in Fig.2 on the left) will have the form

$$c\,' = c(1 + \gamma x/c^2) \tag{1.8}$$

where γ is the uniform acceleration. On the right as before, $c\,'$ has the form $c\,' = \sqrt{c^2 - v^2}$. As can be seen from Fig.2, the symmetry of two frames of reference (their equality) is already lost. The change in speed $c\,'$ under the influence of acceleration naturally changes the speed of the remaining time processes in the accelerated frame of reference. Such a change in the velocity $c\,'$ in the accelerated frame of reference and solves the so-called "twin paradox".

Thus, the SR-model constructed adequately reflects the spacetime relations in the SR and, by studying the model, we can better understand the essence of the special of relativity.

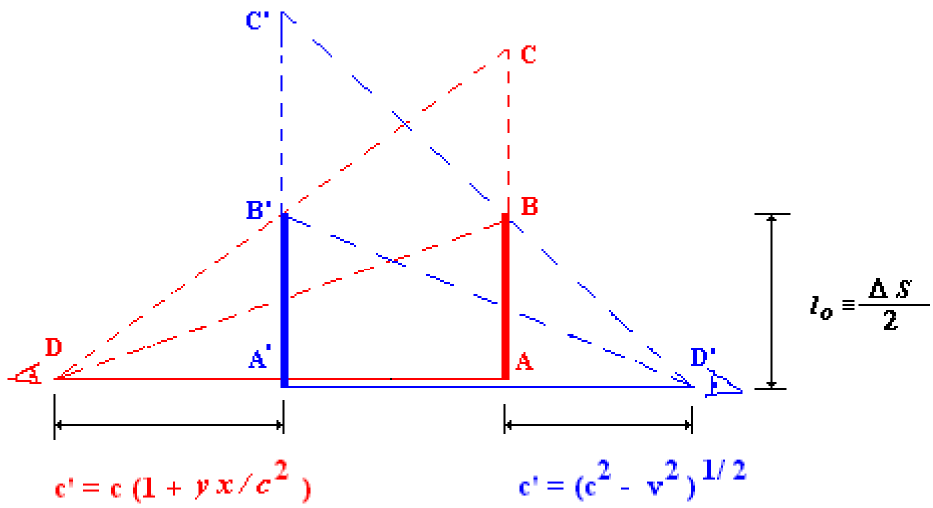

Figure 2: Model of special relativity

Physics is unthinkable without mathematics and mathematical concepts, but cannot be reduced to them. Indeed, in the SRT model, formulas (1.1), (1.2), (1.3) can be interpreted in two ways. Either assume that the compression of rods is the result of a change in the balance of forces between the molecules of a solid when the distance R_1 changes, or assume that the reduction in the length of the rods is a result of a change in the magnitude of their projections onto a particular reference system. Fig. 1 clearly shows that we are talking about changing the magnitude of the projections of the rods. Thus, we see that the main thing in physics is not formulas, but their interpretation is understanding. That it nourishes intuition. Physics develops not with the help of mathematical logic, but with the help of physical intuition. This statement is difficult to accept the physics of the mathematical warehouse, which considers physics as a section of applied mathematics. And he is surprised: "Why do you attribute the main merit in creating the theory of relativity to Einstein, whereas the Lorentz transformations were obtained earlier?" or "Why do you attribute Bohr the main role in understanding quantum mechanics, whereas the basic equation of this theory was obtained by Schrodinger (or in Heisenberg matrix form)?"[3]

1.2 On the philosophy of special relativity

In support of all of the above, we point out an article by the well-known physicist and close friend of Einstein, Nobel laureate Max Born, "Physical reality"[4] in which he emphasizes that the essence of the special theory of relativity lies in the logical distinction between the fact that often the measured quantity is not a property of the object, but the property of his attitude to other subjects and shows examples of this. As an example, he shows a figure from a cardboard circle and shadows, which he throws from a remote lamp on a flat wall. Rotating this cardboard shape, you can get any value of the length of the axis of elliptical shadows from zero to maximum. This is an exact analogy with the behavior of length in the theory of relativity, which in any state of motion can have any value between zero and maximum. A similar example Max Born also shows with respect to mass behavior in the theory of relativity.

Max Born shows that the majority of dimensions in physics do not refer to the things that interest us, but to some kind of their *projections* in the broadest sense of the word. *Projection* is defined relative to the reference frame. In the general case, there are many equivalent frames of reference. In any physical theory, a rule is given that links the *projection* of one and the same object to different frames of reference. This rule is called the law of transformations (in the special of relativity it is Lorentz transformations); all these transformations have the property that they form a group, that is, the result of the two subsequent transformations is a transformation of the same kind. Invariants are quantities that have the same meaning for any frame of reference and are therefore independent of the transformations. And the main progress in the structure of concepts in physics is to discover that a certain quantity that was considered as a property of an object is in reality only a property of *projection*. And it turns out that in the relativistic theory the maximum length (length l_0) and the minimum mass (rest mass m) are relativistic invariants. The idea of invariants is the key to the rational concept of reality.

Some physicists consider (Max Born attributed to them the well-known physicist Paul Dirac) that there is no need to be interested in the question of whether there is anything behind the projections. Max Born states that behind projections is physical reality, which is displayed through *projections*. We observe only *projections*, which are variable and dependent on devices (frames of reference). But their combination makes it possible to find the properties of reality itself, no longer dependent on instruments. These ways of transition from *projections* to the reality itself are developed by the theory of invariants. At the same time, *projections* can not be denied in reality only because they are not invariant. *Projection* is the result of the actual interaction of an object with a reference system. Example: the thermal effect of the solar disk (the projection of the Sun) on the observer depends on the distance between the observer and the Sun. But the physical reality is only the Sun itself, and not its *projection*.

We quote a quote from another author confirming this point of view. Spatial-temporal relations and properties of bodies do not depend on the frame of reference, but only differ in different systems. In general, physical quantities that depend on the reference frame and in this sense are relative, are a kind of *projection* of more general quantities that do not depend on the reference frame. In accordance with this, Minkowski gave a four-dimensional formulation of the laws of relativistic mechanics and electrodynamics. Nevertheless, Minkowski's view of the theory of relativity was not accepted by physicists in all its depths. The point of view of relativity, taking any phenomenon in relation to one or another frame of reference, was more familiar, firstly, because this is the real position of the experimenter, the observer, and secondly, because the theorist also considers phenomena using this or that coordinate system. But there was also a third point - positivist philosophy, which essentially attached importance to reality only to what was given in direct observation; all the rest that is contained in the theories of physics is interpreted by it not as an image of reality, but as a construction that only links the observational data. From this point of view, Minkowski's four-dimensional world is nothing more than a scheme that does not reflect any reality beyond what is already expressed in the original exposition of the theory of relativity. Thus, two different approaches to the theory of relativity were defined. The first is Minkowski's approach, which is based on the idea of spacetime as a real absolute form of the existence of the material world. The second is a purely relativistic approach; the main thing in it is one or another frame of reference. It is clear that the first approach is of a materialistic nature and corresponds to the natural logic of the object: "its form determines its relative manifestations." The second approach turns out to be positivistic, denying that the relative is only a facet of the manifestation of the absolute. [5]

For those who do not like formulas, as a *close* illustrative example, let us cite a plane flying high in the sky. Its dimensions are reduced, and the speed of movement (time process) is slowed down. For passengers of an aircraft, the same phenomena on the earth's surface (for example, moving cars) also look like this. Who flew on an airplane, probably remembers that feeling of unreality when viewed from a high altitude on the tape of an automobile road, where cars moving at high speed seem almost frozen in one place. Time for them seemed to stop. There is an equality between the observer on the earth's surface and the observer in the plane (mutual "contraction" of lengths and mutual "slowing down" of temporal processes - velocities of motion), similar to how it occurs in the special of relativity. The only difference is that in our model the variable is the *relative distance* between two observers (geometric relativity), whereas in the special of relativity the variable is the *relative speed* between the two reference frames (kinematic relativity).

References

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