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*Simultaneity, Conventionality and Existence**

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ABSTRACT

The present paper pursues two aims. First to show that the experiment proposed by Stolakis [1986] does not lead to absolute synchronization in a single frame of reference and therefore also to the measurement of one-way velocity of light. Second, by consecutively considering the problems of the conventionality of simultaneity and of existence to show that the simultaneity of distant events can be a matter of convention only in a four-dimensional world.

1 INTRODUCTION

There have been three changes in the history of the idea of simultaneity. It has changed for the first time in the 17th century after Rømer had shown that light propagated with extreme velocity. It was then clearly realized that the events we observe simultaneously at a given moment of time have in actual fact taken place at different previous moments. The idea of simultaneity was changed for the second time when the theory of relativity showed that simultaneity was not absolute, that there is meaning in speaking of the simultaneity of any events only as regards a given reference frame (or observer). The third change of view on simultaneity is connected with the elucidation of the fact that even as regards a single reference system the definition of the simultaneity of events is not absolute but is a matter of convention. The present paper is devoted precisely to elucidating the essence of the conventionality of simultaneity.

The problem of the conventionality of simultaneity already stemmed from Einstein and Reichenbach and chiefly boils down to the following. Two distant clocks at the respective points A and B in a single frame of reference must be synchronized. At moment t_1^A a light signal is emitted from point A, is reflected

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on point B at moment t_2^B and returns to point A at moment t_3^A. The times t_1^A and t_3^A are measured by the clock at point A, while the time t_2^B is measured at point B. The question is: is there an *objective* criterion on the basis of which it can be determined which moment t_2^A of the interval (t_1^A, t_3^A) is simultaneous with the moment of reflection of the light signal at point B, *i.e.* with the moment t_2^A? The different possibilities of this are expressed in the formula:

$$t_2^A = t_1^A + \varepsilon(t_3^A - t_1^A),$$

in which $0<\varepsilon<1$. However, it appears that in the attempt to establish this moment, *i.e.* in the attempt to determine the '*real*' value of ε, a logical circle is obtained (Reichenbach [1958]): if we try to synchronize the clocks at points A and B by light signals we must know the one-way velocity of light; but in order to measure it the clocks should have been synchronized *beforehand*. The situation in the attempt to synchronize the clocks by slow transport of a third clock is analogous.

This situation shows that it is not possible to determine the value of ε by means of a physical experiment, *i.e.* it is impossible to establish which events are simultaneous at a given moment of time even as regards a single system of reference. From this the conclusion is drawn that determining simultaneous events is a matter of *convention*, from which it follows in particular that the answer to the question: are the back and forth velocities of light one and the same, also proves to be conventional. The latter conclusion appears to arouse the strongest instinctive resistance, because it contradicts the statement considered as an obvious one that *in reality* light travels at an *exactly determined* velocity. If this is so, we should be able to measure its velocity in one way. This dissatisfaction with the conventionality of simultaneity probably explains why ideas on measuring one-way velocity of light are persistently suggested.

2 HAS THE CONVENTIONALITY OF SIMULTANEITY BEEN REFUTED?

One of the most recent suggestions for an experimental solution of the problem of the conventionality of simultaneity was made by Stolakis [1986]. The aim pursued crossed the one factually achieved. The author's efforts were directed to proposing an experimental way of measuring one-way velocity of light, thus showing the inconsistency of the conventionality thesis. Actually, however, he proposes an experiment which had no relation to the conventionality of simultaneity but could serve to discover a possible anisotropy of spacetime in a space-like direction.

The essence of the experiment proposed by Stolakis would be revealed by a more thorough analysis of the standard schema of synchronizing the clocks A and B, distant in space, set forth in Part 1. Figure 1–a shows the world lines A and B of the two clocks (at rest as regards one another) and the world line of the

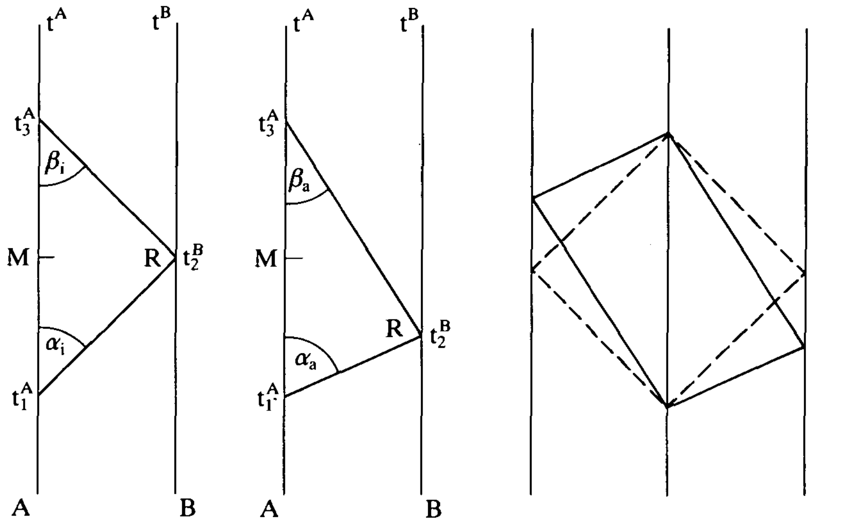

Figure 1

light ray propagating between them. In standard synchronization ($\varepsilon=1/2$) event *R* (reflecting the light ray from clock B) is simultaneous with event *M*. In this case space is *orthogonal* to the world lines of the clocks and the velocity of the back and forth light signal is one and the same. In any other choice of ε (in the limits $0<\varepsilon<1$) space is not orthogonal to the world lines of clocks A and B and the velocity of the back and forth light ray is different. Therefore velocity of light in a straight direction is different from velocity in the opposite direction, owing to the fact that space is not orthogonal to A and B. This conclusion is only correct, however, if a premise (usually understood) is fulfilled, namely that space-time is isotropic. In this case (depicted in Figure 1–a) the slant (in relation to A and B) of the world line of the light ray propagating from clock A to B is equal to the slant of the world line of the light ray from B to A, *i.e.* the angle α_i is equal to the angle β_i. But if space-time is anisotropic in a space-like direction (see Figure 1-b) the slant (in relation to A and B) of the world line of the light ray, propagating from clock A to clock B can be larger than the slant of the world line of the light ray, propagating from B to A, *i.e.* the angle α_a can be larger than the angle β_a (this anisotropy of space-time would appear as a deformation of the light cone). In this case the orthogony of space in relation to A and B does not ensure equality of light velocity in a back and forth direction. Therefore there is no simple connection between the equation of light velocity in a back and forth direction and the orthogony of space in relation to the world lines of the clocks, *i.e.* in relation to the time axis of the system of reference, in relation to which clocks A and B are at rest.

In both cases depicted in Figures 1–a and 1–b, we can *arbitrarily* choose the value of ε (of course in the limits of $0<\varepsilon<1$), *i.e.* we can arbitrarily define which moment of the interval (t_1^A, t_3^A) is simultaneous with t_2^B. Thus, in both cases we would obtain arbitrary values of back and forth velocity of light (as Winnie [1970] showed and all relative velocities will also prove to be arbitrary). In other words, we can arbitrarily (but nevertheless within definite limits, ensuing from the restriction $0<\varepsilon<1$) choose the angle between space and the world lines A and B. This arbitrariness shows that defining the simultaneity of events M and R is a matter of convention and ensues from the fact that not a single moment in the interval (t_1^A, t_3^A) is *objectively* priviledged so that it can be considered simultaneous with the moment t_2^B. The matter of the essence of this objective privilege will be discussed in Part 3. But even if we accept that any moment of the interval (t_1^A, t_3^A) is simultaneous with the moment t_2^B, the question of the orthogony of space in relation to the world lines A and B (*i.e.* the matter of the isotropy of space-time in a space-like direction) remains open. Let us suppose that event M is simultaneous with event R, *i.e.* with the moment t_2^B. Then in both cases depicted on Figures 1–a and 1–b it appears that back and forth velocity of light is one and the same, but owing to the isotropy of space-time, on Figure 1–a space is orthogonal to the world lines A and B, while, owing to the anisotropy of space-time in a space-like direction, on Figure 1–b space is not orthogonal to A and B. These two cases are indiscernible experimentally. The matter of the isotropy of space-time cannot be solved by a more complicated experiment (shown on Figure 1–c) in which light signals are emitted from a clock in opposite directions to two other equally distant clocks. After being reflected from the endmost clocks the light signals return to the central clock. Regardless of whether the light signals propagate in isotropic spacetime (in this case their world lines are depicted with dotted lines) or in anisotropic space-time, they arrive *simultaneously* at the central clock.

Nevertheless, the question might be asked: is there any way of delimiting the cases of isotropic and anisotropic space-time experimentally? The value of the Stolakis experiment proposed consists namely in the fact that it attempts to answer this question. The experiment is depicted in Figure 2. Figure 2–a shows the case when space-time is isotropic, while on Figure 2–b we see the case of anisotropic space-time. The smaller slant of the world lines of the light signals to events M and N (lying on the world lines of the points at which the light rays have been reflected) in Figure 2–a, compared with the slant of their world lines after M and N, reflects the fact that up to the moment when the light signals are reflected they have moved at a lesser velocity (owing to their propagation in a medium with a refractive index of $n>1$). In this case, owing to the isotrophy of space-time, the light signals arrive *simultaneously* with event C_2. However, this is no proof that back and forth velocity of light is one and the same, because we

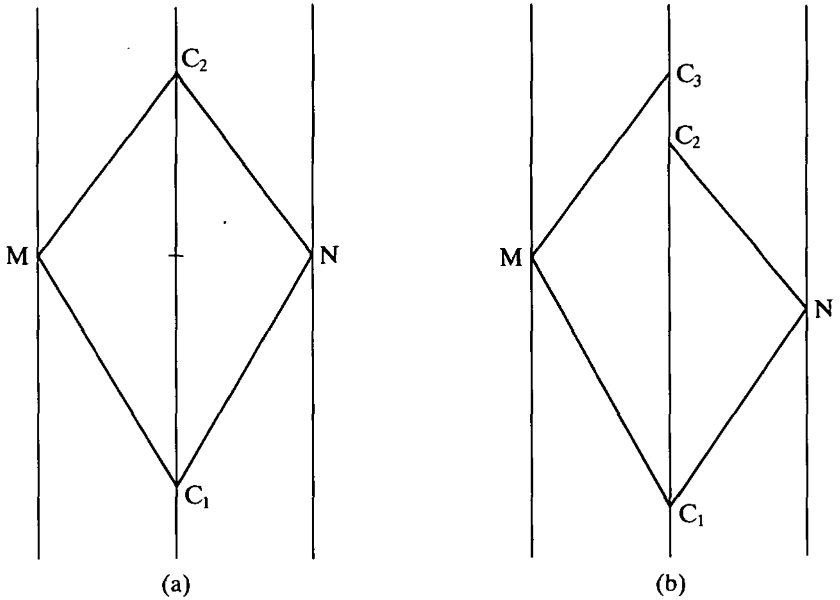

Figure 2

can again choose to have space not orthogonal to the time axis which will lead to different values of back and forth velocity. We have no criterion (and the Stolakis experiment does not give us one) which would force us to choose space in such a way as to have events *M* and *N* occur simultaneously in it. Only if we consider events *M* and *N* as simultaneous (*i.e.* as being *privileged* in comparison with the remaining events on the world lines on which events *M* and *N* lie) could it be asserted that the one-way velocity of light has been found. The simultaneous arrival of light rays at the initial point from which they were emitted is proof alone of the fact that space-time is isotropic in a space-like direction.

Figure 2–b depicts the Stolakis experiment in a case of anisotropic space-time in a space-like direction. In the case, the light signals emitted at event C_1 and respectively reflected in events *M* and *N* will not arrive simultaneously at their point of emission. The reason for the non-simultaneous arrival of the light signals (*i.e.* the appearance of the time difference $t_{C_2C_3}$) is, however, due *solely* to the anisotrophy of space-time. Even now the definition of back and forth velocity of light is a matter of convention, because once again the criterion for the simultaneity of events *M* and *N* has not been discovered. The only fact which can be established by the Stolakis experiment is whether space-time is anisotropic in a space-like direction.

Yet even if the problem of the isotropy of space-time is solved, the problem of the conventionality of simultaneity remains untouched. Thus the Stolakis experiment has no relation to the problem of the conventionality of simultaneity. The analysis of this experiment shows once again *the impossibility in principle* of measuring one-way velocity of light and therefore of rejecting the thesis of the conventionality of simultaneity.

3 ON THE ESSENCE OF THE CONVENTIONALITY OF SIMULTANEITY

The discussion on the problem of the conventionality of simultaneity would hardly have continued so long if it had been considered in close connection with the problem of existence. The joint consideration of both problems makes it possible (1) categorically to establish that the definition of simultaneous events is a matter of convention, and (2) to elucidate the essence of this convention. So that this joint consideration may be realized, from now onwards *simultaneously at the present moment of time* will be implicit in the use of the term simultaneity.

According to the classical (pre-relativistic) view of reality only the present exists, *i.e.* only the constantly changing three-dimensional world at the moment 'now'. But bearing in mind the fact that the present (the three-dimensional world) is a set of *simultaneous* events at the present moment (*i.e.* the set of material objects existing *simultaneously* at the moment 'now') it follows that the simultaneity of events is an *objective* fact.

Therefore, the objectivity of simultaneity is expressed in the circumstance that simultaneous events *occur* simultaneously, *i.e.* that the objects with which these events take place *exist* simultaneously. It is precisely the existence at the moment 'now' which objectively privileges one class of events. As is apparent a conventionality of simultaneity in this case obviously leads to an unacceptable conclusion regarding a conventionality also connected with what exists (R. Weingard [1972] says that if two events are real, their simultaneity cannot be a matter of convention). Therefore, according to the classical view of reality, simultaneous events at the present moment of time (*i.e.* present events) are *objectively* privileged in comparison with past and future events (since only present events are considered as existing), which means that simultaneity is not conventional.

However, things look quite different from the point of view of the theory of relativity. The problem is additionally complicated by the fact that the problem of the *dimensionality* of the world has not been convincingly solved to this day. If we allow that even according to the special theory of relativity reality is a three-dimensional world (a three-dimensional space-like slice of the Minkowski world—the present), the above-mentioned unacceptable conventionality as regards what exists follows from the conventionality of simultaneity. Therefore *reality cannot be a three-dimensional world if the definition of* *simultaneity is a matter of convention*, because if it could, it follows that it will depend on our own will *which* three-dimensional space-like slice of the Minkowski world we are to consider as reality. This unacceptable conclusion is reached on the basis of the premises of the conventionality of simultaneity and the three-dimensionality of reality. It can only be avoided if we give up one of the premises. The impossibility of demonstrating by means of a physical experiment the privileged state (existence) of only one set of events which are to be considered as *simultaneous* at the present moment (*i.e.* the impossibility of refuting the conventionality thesis of simultaneity), shows that the premise of the three-dimensionality of the world should be abandoned. This conclusion also follows directly from the relativity of simultaneity. The fact that the observers in relative motion have *different* classes of simultaneous events shows that not a single class *is objectively privileged*. Therefore all events are *equally* real (Putnam [1967]), which means that it really is a question of convention which events should be considered as *simultaneous* for a given observer. In the contrary case—if any observer has *objective* grounds to examine as simultaneous exactly defined events—this would mean that, being *objectively* privileged, these events would be simultaneous *for all* observers in relative motion. In such a case, however, the relativity of simultaneity proves to be impossible. That is why it (the relativity of simultaneity) unambiguously shows that the simultaneity of distant events is conventional (from which it follows that the world cannot be three-dimensional). If we deny the view that the world is three-dimensional and consider the Minkowski world as a mathematical model of a *real* four-dimensional world, conventionality in the choice of a three-dimensional space-like slice of this world becomes trivial, because all slices are *equally existent* and the matter only concerns the convenience of which slice is to be examined as the present. In other words, since all events in a four-dimensional world exist in the *same* way the conventionality of simultaneity does not also lead to conventionality of existence, but is connected only with the *description* of the four-dimensional world in our habitual 'three-dimensional language'. The elucidation of this situation reveals the profound essence of the conventionality of simultaneity: we cannot choose one class of events among the events of the Minkowski world simply because *there is no* such a class of *objectively* priviledged events (owing to the *equal existence* of all events), which we might examine as *simultaneous* at the moment 'now'.

It can now be said that the logical circle obtained in an attempt to imagine an experiment enabling us to define which events are simultaneous at a given moment of time, or to establish the one-way velocity of light, convincingly shows that we have tried, on the basis of an *erroneous* view of the dimensionality of the world to discover the *objective* content of concepts (as simultaneity and velocity), for which it appears that they have no such content according to a more adequate view of reality. This explains why the conventionality of simultaneity does not presuppose some kind of 'agreements' concerning physical magnitudes as to which we have been intuitively convinced that they have an exactly defined *objective* content. And, indeed, the concepts simultaneity and velocity have no adequate content, because among the *equally* existing events of the four-dimensional world *there is no* set of events which are privileged as being simultaneous (at the present moment). We can speak of simultaneity and velocity only *after* the stratification of the four-dimensional world, *i.e.* of space-time, into space and time. However, this stratification has no objective basis (space-time is not really divided into space and time precisely because of the equal existence of all events), but is the result *solely* of a *description* of the four-dimensional world in 'three-dimensional language'. Owing to this reason it is obvious that it is indeed a matter of convention as to how to stratify space-time into space and time (of course, within the framework of the requirement $0 < \varepsilon < 1$). Only in this case, when we have chosen that space should be orthogonal to the time axis (*i.e.* with $\varepsilon = 1/2$ and with isotropic space-time) the back and forth velocity of light is one and the same. Depending on the manner in which we shall stratify space-time into space and time (*i.e.* depending on the choice of ε) different values of back and forth velocity of light will be obtained and the experiment will always confirm (in the supposed isotropy of space-time) the theoretically foretold result, simply because in processing the experimental data *the premise* on the choice of ε is essentially made use of. That is why all attempts to measure one-way velocity of light are doomed to failure beforehand.

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