Arguing the Concept of Relative Simultaneity

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Abstract

By applying Einstein's procedure to determine whether or not two spatially separated events occur at the same time, it is shown that simultaneity does not depend on the observer's reference frame, but the way how to recognize/assess simultaneity definitely does. Thus Einstein's claim of relative simultaneity, *i.e.* the frame-dependence of simultaneity, is simply unsubstantiated and, as also shown here, is in conflict with the relativity principle.

Keywords: simultaneity, relative simultaneity, special relativity, relativity principle

1. Introduction – Einstein's argument

According to the widely accepted concept of the *relativity of simultaneity*, whether or not two spatially separated events are observed to be simultaneous depends on the observer's reference frame. Einstein seemingly verbalized this concept of relative simultaneity (1) to substantiate his claim that "e*very* [...] *coordinate system has its own particular time*", *i.e.* to make time and, consequently, space relative, which then culminated in the formulation of his *Special Theory of Relativity* (1, 2).

To demonstrate his concept of relative simultaneity, he presented (1) his famous moving train *vs.* embankment example depicted in Fig. 1. In this example, a single lightning strikes at point A and at point B (on the embankment) at the same time (according to a clock registering the embankment's time). Then, light is reflected from both points (A and B) towards the point M, which is halfway from both A and B. The observer standing on the embankment at location M registers light incoming from A and from B at the same time. Thus, the observer concludes that lighting strikes at A and B occurred simultaneously (relative to the embankment). Then, Einstein asks: "*Are two events (e.g. the two strokes of lightning points A and B) which are simultaneous with reference to the railway embankment also simultaneous relatively to the train?*". Next, his somewhat surprising answer reads: "*We shall show directly that the answer must be in the negative*".

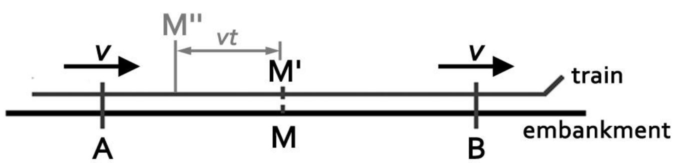

Fig. 1: Train travels with speed *v* relative to the embankment. Redrawn from ref. 2 with some modifications shown in grey. (For details, see text.)

Then, he (correctly) argues that, since M' on the train, which is aligned with M at the very instant of the lighting strike, moves with speed ***v*** (away from M) during the time light travels from A (or B) towards M (or M'), the observer standing at M' (on the train) will not see the light signals from A and from B arriving simultaneously. Einstein thus concludes: "*Events which are simultaneous with reference to the embankment are not simultaneous with respect to the train, and vice versa (relativity of simultaneity)*". It is shown here that this conclusion is simply unsubstantiated even by his own argument above and also that his concept of relative simultaneity is in conflict with the relativity principle.

2. A counter argument to Einstein's above argument

First, it is immediately noticeable that, if Einstein's above procedure is followed to assess simultaneity, there is only one single location on the embankment (at M; see Fig. 1), where an observer in fact registers simultaneity. Second, although Einstein either ignored or failed to notice it, there is such single identifiable location on the train as well. Let ***t*** be the time required for light to travel from A to M. Then, it follows that an observer standing on the train at the ***vt*** distance from M towards A (at location M'' drawn in grey in Fig. 1) will also detect light from A and from B arriving at the same time. Therefore, the observer standing on the train at location M'' would also safely conclude that the events at A and B did occur simultaneously. Thus, whether or not simultaneity is successfully detected simply depends on the 'proper location' of the observer in both the stationary reference frame (the embankment) and the moving frame (the train). In other words, simultaneity (as determined by the Einstein method) is not frame-dependent at all, but location-dependent in both frames.

However, what is definitely frame-dependent is the method how to detect simultaneity. *i.e.* how to find the 'proper locations' of the observers in the stationary frame and in the moving one, respectively. In the case of the moving frame, the 'methodology' simply requires the knowledge of its speed (***v***) relative to the stationary frame.

Since it is not known when and where the lightning strikes, the above 'proper location' method is, of course, not meant to be a practical approach to determine such event of simultaneity. As a useful alternative, the observers both on the train and the embankment are equipped with clocks to register the times, at which light arrives from points A and B. Then, the observer standing at any known location either on the embankment or on the train can successfully detect simultaneity occurring. (Of course, the observer on the train is again required to know the speed (***v***) of the train.) This second 'methodology' again demonstrates that the successful detection of events occurring simultaneously is not reference frame-dependent.

3. Discussion

It is thus safe to conclude that Einstein's above procedure can determine simultaneity in both frames, if ***v*** and the A-B distance are known. Thereby, one must also conclude that simultaneity is not frame-dependent. However, the location where an observer should stand in order to detect whether or not some events occur simultaneously definitely is (if one wants to follows Einstein's procedure). This also means that detecting/observing simultaneous events is clearly not a theoretical, but rather a methodological problem. Consequently, Einstein's argument for the concept of relative simultaneity is flawed and thereby cannot substantiate his claim (2), according to which the relativity of simultaneity is required to establish a need to make time (and space) relative.

Furthermore, relativity of simultaneity also seems to be in conflict with the principle of relativity, which – as phrased by Einstein (2) – states: "*The laws by which the states of physical systems undergo change are not affected, whether these changes of state be referred to the one or the other of two systems of co-ordinates in uniform translatory motion*". Simultaneity is either detected a result of a coincidence or that of the manifestation of some causation, which must be governed by a relevant law of nature[1]. Thus (if the case of coincidence is not considered), the acceptance of the concept of relative simultaneity would be equal to the acceptance of a statement that some cause-and-effect relationship, *i.e.* the manifestation of some natural law, is frame-dependent, which would evidently contradict the relativity principle.

In summary, the concept of relative simultaneity, as proposed by Einstein (2), is fallacious and, thereby, cannot support his claim that "[E]*very* [...] *coordinate system has its own particular time*".

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[1] Consider the following example: the molecule AB is known to decompose to yield molecules A and B upon some effect, by raising the temperature, for instance. Then, the simultaneous detection of molecules A and B are expected. However, according to the relativity of simultaneity, such detection is bound to a given reference frame.

References

1. Einstein, A.: *On the electrodynamics of moving bodies* (English translation, ed. John Walker), Ann. der Physik. 17:891 (1905)
2. Einstein, A.: *Relativity: The Special and the General Theory*, Reprint of 1920 translation by Robert W. Lawson ed. (2001)