Observations about a particular clock co-moving with inertial frame K’, by a particular clock co-moving with inertial frame K

Chandru Iyer[1]

[1]Techink Industries, C-42, Phase-II, Noida 201305, India
chandru_i@yahoo.com chandru.iyer@luxoroffice.com

Abstract: The observation that a moving clock runs slow is usually observed by a set of spatially separated, co-moving and synchronized clocks. The synchronization of these co-moving and spatially separated clocks is achieved by the Einsteinian synchronization convention. The universal validity of this convention has been debated by researchers for over a hundred years. In this paper we present the Doppler Effect as a phenomenon to eliminate the issues associated with the synchronization problem. The Doppler Effect involves two objects, the light source and the receptor in relative motion. The ratio of the frequencies expected to be observed by the receptor as estimated by the inertial frames co-moving with the source and the receptor respectively is $(1-v^2/c^2)$, assuming that light travels at speed c in all directions with respect to the source and receptor respectively. The relativistic prediction is the geometric mean of these two estimates. The inertial frame co-moving with the source reconciles this difference by stating that the clock at the location of the moving receptor is running slow by a factor $(1-v^2/c^2)^{1/2}$. A similar explanation is given by the inertial frame co-moving with the receptor – the clocks at the location of the moving source run slow by a factor $(1-v^2/c^2)^{1/2}$, that is the actual emission frequency is less than what the source of light itself observes, due to the slow running of the clock co-moving with the source. Thus the relativistic Doppler Effect is reconciled with the predictions of the individual inertial frames by the slow running of moving clocks. This essentially means that moving clocks run slow – even when we do not use the Einsteinian synchronization convention and use the opportunity presented by the Doppler Effect to observe a ‘moving’ clock by a ‘stationary’ clock, assuming that the speed of light is c in all directions. This essentially means that a moving clock actually runs slow as compared to the usual statement that a ‘moving’ clock is observed to run slow (by ‘stationary’, spatially separated and synchronized (by a convention) clocks). The consequence of the actual slow running of moving clocks is discussed in the conclusion section.

Introduction

The definition of simultaneity within an inertial reference frame and the relative nature of this definition when applied to another inertial frame have been discussed widely in the literature [1]. The so called conventionality of simultaneity or the definition of simultaneity based on the invariant speed of light has been debated for over a century now as indicated in [2, 3, 4, and 5] and the references contained therein.

In general a particular clock of an inertial frame K’ moves past other clocks “Stationary” with respect to inertial frame K as illustrated in Figure-1.

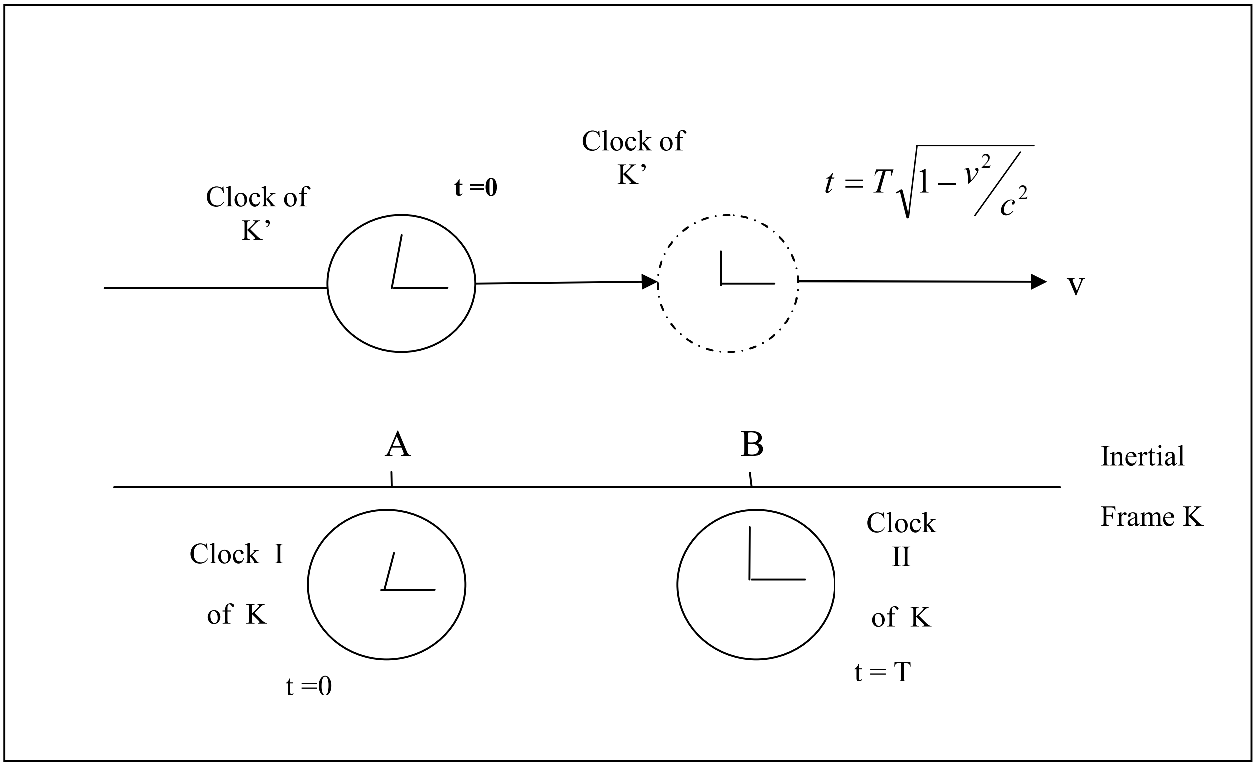

Figure -1

Inertial frame K' is moving with respect to inertial frame K at a velocity v along x –axis, which is the line of relative motion. As illustrated above, a particular clock of K' is timed by clock I and clock II of inertial frame K at two instances t = 0 at location A and t = T at location B. According to the theory of relativity if it is set such that at location A both clock I of K and the moving clock of K' read t=0, and at location B clock II of K reads t = T (when the particular clock of K' passes clock II of K), then at location B the moving clock of K' will read

$$t = T\sqrt{1-\frac{v^2}{c^2}} \ .$$

The above phenomenon is described as the apparent slow running of moving clocks.

Apparent because inertial frame K and K' are equivalent under the special theory of relativity and further this method of determining the rate of running of the moving clock, requires that clock I and II of K have to be synchronized before hand. Clock I and II are spatially separated and their synchronization is a point of discussion [1, 2] for over hundred years.

Thus the observation of the running of a particular "moving" clock by spatially separated clock of another "stationary" inertial frame demands that the stationary clocks be synchronized a priori.

In this contribution we would like to show that a moving source of light can be observed by a particular receptor of a stationary inertial frame, under the assumption that speed of light is a constant, c, with respect to all inertial frames. The observed frequency of light by the receptor can be compared with the emission frequency. The difference in the observed frequency compared to the emitted frequency is known as Doppler Effect after the Austrian Physicist Christian Doppler who explained it in 1842. The Doppler Effect can be estimated by calculations by both the inertial frames. These estimates are then compared with the observed Doppler Effect and this leads to the conclusion, as shown in the following sections, that moving clocks run slow. The significance of this work is that this conclusion has been obtained without utilizing spatially separated clocks of an inertial frame.

Observations by utilizing the Doppler Effect

In an earlier work [6] we have explained the observations of a "Receptor" co-moving with the inertial frame K , measuring the frequency of light emitted from a moving source of light. The source of light is co-moving with the inertial frame K'. Inertial frame K' is moving at speed v along X –axis with respect to inertial frame K.

The unique feature of the Doppler Effect is that it does not utilize spatially separated clocks of an inertial frame thus eliminating the problems associated with synchronizing spatially separated clocks.

In [6] we have shown that classical physics predicts two types of Doppler effects for light. One when the speed of light is **c** with respect to the source and the other when the speed of light is **c** with respect to the receptor. We have further shown that the relativistic Doppler Effect is the geometric mean of the two types of classical Doppler effects both in the longitudinal as well as the transverse (as observed by the receptor) cases [6]. Further we have shown in section V of reference [6] that the relativistic Doppler Effect is the geometric mean of the two types of classical Doppler Effects for all angles of emission and receipt. Further, Classical Doppler Effect (as estimated by the source) : Relativistic Doppler Effect : Classical Doppler Effect (as estimated by the receptor) remains as $(1/\gamma) : 1 : \gamma$ where

γ is the reciprocal of $\sqrt{1-\frac{v^2}{c^2}}$. This is so for all angles of emission and receipt [6].

The Doppler Effect as estimated by the inertial frame co-moving with the source of light for the longitudinal case is [6]

$$f_S = f'\left(1-\frac{v}{c}\right) \qquad \text{------------------------ (1)}$$

This estimate is derived from the assumption that light travels at speed c as observed by K'. f_S is the frequency that is expected to be observed by the receptor when the emitted frequency is f'; this estimate is derived assuming that light travels at speed c with respect to the source of light (with respect to the inertial frame K', co-moving with the source).The subscript s in the LHS of equation (1) signifies that this is the estimate as derived by observers in frame K' co-moving with the source. However the actual observed frequency for the longitudinal case as given by special relativity is [7]

$$f_{SR} = f'\sqrt{\frac{c-v}{c+v}}$$ -------------------- (2)

$$= f'\sqrt{\frac{1-v/c}{1+v/c}}$$ -------------------- (2)

Where is f_{SR} is the Doppler Effect as given by special relativity for the longitudinal case.

The ratio of f_S to f_{SR} is

$$\frac{f_S}{f_{SR}} = \sqrt{1-\frac{v^2}{c^2}}$$ ---------------------- (3)

The inertial frame K' associated with the source explains this ratio due to the slow running of the clock associated with the receptor. (Please note that f_s is the frequency that would have been observed by the receptor, if there was no slow running of clocks associated with receptor and light travels at c with respect to K')

Similarly the inertial frame co-coving with the receptor estimates the Doppler Effect to be [6]

$$f_R = \frac{f'}{1+v/c}$$ ------------------------ (4)

This estimate is arrived at by the assumption that the light ray travel at c with respect to the receptor co-moving with inertial frame K. The ratio of f_R to f_{SR} is

$$\frac{f_R}{f_{SR}} = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$ ------------------------ (5)

The above discrepancy is explained by the observers associated with the receptor due to the effect of the clocks associated with the source running slow. These observers associated with the receptor state that the actual emission frequency is

$f'\sqrt{1-\frac{v^2}{c^2}}$ and the same is observed to be f' by the source because the clocks associated with the source are running slow. We also note that ratios f_S / f_{SR} as given in equation (3) and f_R / f_{SR} as given in equation (5) remain the same for the transverse Doppler effect case as derived in . In fact, these two ratios remain constant for all angles of receipt [6].

Thus we find that without having to resort to synchronizing spatially separated clocks, 1) the inertial frame co-moving with source, observes that the clock associated with the moving receptor is running slow and 2) the inertial frame co-moving with the receptor observes (utilizing only the particular clock associated with the receptor) that the clock located at the source (and co-moving with the source) is running slow.

The above two observations are contradictory to each other. They do not involve spatially separated and synchronized clocks - synchronized by a convention or definition [2]. Thus the contradiction cannot be ignored or associated with problems in synchronizing spatially separated clocks.

In order to resolve the above contradiction, we need to examine the assumption that observers in K and K' made in order to arrive at their estimates of Doppler Effect. They both assumed that light travels at c with respect to their respective inertial frames. Both these assumptions may not be correct and we suggest that light travels at c with respect to the source only in the vicinity of the source and it travels at c with respect to the receptor in the vicinity of the receptor. Thus the speed of light; we suggest, will be c with respect to material objects in the vicinity of those material objects.

Conclusion:

Without resorting to spatially separated and synchronized (by a convention or definition) clocks, we have shown that moving clocks run slow. This was under the assumption that light travels at c with respect to all inertial frames. Since inertial frames are equivalent, the statement that "moving clock runs slow" creates a contradiction. We resolve this contradiction by suggesting that light travels at speed c with respect to material objects in the vicinity of those material objects (like the source of light and receptor). This resolution will maintain the equivalence of all inertial frames that are in relative motion with respect to each other. The other possible resolution can be a preferred inertial frame as envisaged originally by Dr. Lorentz wherein the moving objects actually contract along the direction of motion by a factor $(1-v^2/c^2)^{1/2}$ and moving clocks actually run slow by a factor $(1-v^2/c^2)^{1/2}$. This resolution will not hold all inertial frames to be equivalent.

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