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ON THE CONSTANCY OF THE SPEED OF LIGHT IN VACUUM FOR ALL OBSERVERS

Sanjay M. Wagh
Central India Research Institute, 34, Farmland, Ramdaspeth, Nagpur 440 010, India

ABSTRACT

Here, we analyze the way the measurement of the speed of light is made and show that the relative time is not implied by the constancy of the speed of light in vacuum for all observers. It is rather the "universal" time that is consistent with the way the speed of light can be measured.

Indexing terms/Keywords

measuring the speed of light; constancy of the speed of light for all observers; nature of time

Academic Discipline And Sub-Disciplines

Physics; Optics; Relativity

SUBJECT CLASSIFICATION

E.g., Mathematics Subject Classification; Library of Congress Classification

TYPE (METHOD/APPROACH)

Theoretical analysis.

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INTRODUCTION

Constancy of the speed of light in vacuum for all observers is an assumption pivotal to Einstein's theory of relativity [1, 2, 3, 4, 5 ,6, 7]. In particular, the relative nature of time; that time runs at different rates for different observers in relative motion, was postulated by Einstein for the consistency of the aforementioned assumption (restricted to inertial observers) and the special principle of relativity.

On appealing to the invariance properties of Maxwell's equations in free space, Einstein showed [2, 3, 4, 5, 6, 7] that the Lorentz transformations are needed for the consistency of the constancy of the speed of light (in vacuum) and the special principle of relativity. The time-transformation of Lorentz then implied relative time, which was the basis of further analysis of physical phenomena in special relativity. Minkowski's 4-dimensional formulation [3, 4] of “flat" space-time was then a logically imminent step.

Then, the relative nature of time was naturally incorporated within Einstein's formulation [3, 6, 7] of the general theory of relativity, which demands that the results of special relativity hold “locally" within a curved space-time that represented gravity within the ideas of this theory.

The question that we raise here is that of the “necessity" of the relative time for the constancy of the speed of light to hold for all observers. To this end, we analyze “essentials” of the nature of the measurement of the speed of light in any conceivable experiment.

To begin with, we emphasize that if the body of light, light quantum, has [8] zero (rest) mass, then the concept of force is vacuous for it. Thus, the path of a light quantum cannot be changed [9] without annihilating the one traveling along the original path and then creating a new one to travel along the new direction. Thence, the path of motion of light quantum cannot be observed. It can nevertheless be inferred from the locations of the emission and absorption of a light quantum. Therefore, the speed of light can be inferred only in the manner of noting the instants of the emission and absorption of a light quantum, and measuring the distance between the locations of these events.

MEASURING THE SPEED OF LIGHT

An experimental arrangement of Figure 1 is then conceivable for the measurement of the speed of light. A source S of light is at rest in the laboratory and “four" detectors of light are situated at locations marked as A, B, C, D in Figure 1. In the rest frame of the source S, the distances are arranged to be (SA) = (SC) = d = (PB) = (PD), where a reflector cum beam-splitter is located at point P. We also arrange that (SP) = (AB) =(CD) = L, in the rest frame of the source.

In the experimental arrangement of Figure 1, events of light detection at A and C are arranged to be “simultaneous" in the rest from of the source S. Similarly, the events of light detection at B and D are also arranged to be “simultaneous" in the rest frame of the source S, we emphasize.

Then, if the source emits light at instance t=0, light will be received at detectors A and C at time d/c, where c is the speed of light (in vacuum). The light from S will be received at P at time L/c. After the beam-splitting at P, the light will then be received at B and D at time L/c+d/c.

Thus, the time difference between instances of light detection at detectors of A and B is L/c. Similarly, the time difference between events of light detection at detectors of C and D is also L/c. The observer of the rest frame of the source then measures the speed of light to be c, as the involved distances are pre-arranged to be (AB)=L=(CD).

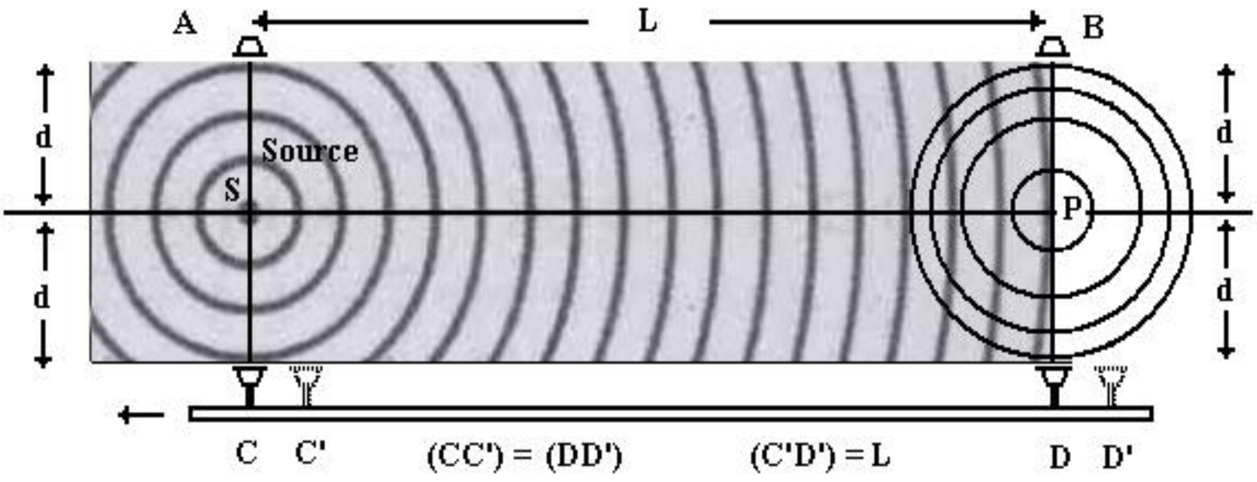

Fig 1: Measuring the speed of light with simultaneity of events in the rest frame of the source.

Within the aforementioned experimental arrangement, it is our purpose now to introduce the following changes while still maintaining the “simultaneity" of light detection events of the above type within the rest frame of the source S. To this purpose, we attach the light detectors at C and D to a platform that can be moved in a desired manner.

If the platform (and the detectors on it) were moving with uniform velocity u as shown in Figure 1, then the detector, originally located at C' relative to the source S, will move to position C in time d/c if the distance (CC')=ud/c in the rest frame of the source. It will then receive the light from the source S, with its detection of light being “simultaneous" with that of detector at A.

Now, in order for the detector, originally located at D', to receive light from P simultaneously with the detector at B, it must also move to position D in time d/c. Thus, the distance (DD')=ud/c in the frame of the source. In this manner, the time difference of instances of light detection by stationary detectors A and B will be equal to the time difference of instances of light detection by moving detectors originally at C' and D'. It follows that the distance (C'D') will be equal to L in the frame of the platform if the speed of light measured by the corresponding observer is to be c, the same as that measured by the observer of the rest frame of the source S.

Evidently, there is no “necessity" of assuming “relative time" for the constancy of the speed of light in these two frames of reference, while maintaining the simultaneity of the involved events in the rest frame of the source S.

Furthermore, for the uniformly accelerated motion of the platform with acceleration a, with its motion commencing from the state of rest relative to the source S, distances needed to maintain the aforementioned simultaneity of light detections are (CC') = $ad^2/2c^2$ = (DD'). Then, the time difference of instances of light detection by stationary detectors A and B will be equal to the time difference of instances of light detection by moving detectors. The distance (C'D')=L, then for the speed of light measured by the observer of the platform to be c.

In general, for the (arbitrary) motion of the platform, the distances (CC') and (DD') will have to be equal and suitable for the simultaneity of light detections at A and C, and at B and D. Then, the time difference of instances of light detection at A and B will be equal to that at C and D, with (C'D')=L for the speed of light measured by the observer of the platform to be equal to c.

There does not therefore arise any “necessity" whatsoever of assuming the “relative time” for the constancy of the speed of light even for a general situation, while maintaining the simultaneity of events of the aforementioned nature in the rest frame of the source.

CONCLUDING REMARKS

In conclusion, we have then shown that the assumption of relative time is not necessary for the constancy of the speed of light to hold for all observers. In fact, the simultaneity of events of light detection at A and C, and those at B and D, forces the time difference of light detections at A and B to be equal to that of light detections at C and D. Thus, time runs [10, 11] at the same rate [12] for the involved observers.

The issues raised here appear to have been missed in the past primarily because the quantum nature of light was not properly grasped in the era during which the idea of the relative time of the special relativity got formulated.

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I dedicate this article to my (late) parents.

REFERENCES

[1] Whittaker, E. T. 1958. A History of the Theories of Aether and Electricity - The Classical Theories, London: Thomas Nelson and Sons.

[2] Wagh, S. M. and Deshpande, D. A. 2012, Essentials of Physics, Volume(s) I \& II, New Delhi: Prentice-Hall.

[3] Einstein, A. 1968. Relativity: The Special and the General Theory, London: Methuen & Co. Ltd.

[4] Einstein, A. 1952. The principle of relativity: A collection of original papers on the special and general theory of relativity. Notes by A Sommerfeld, New York: Dover.

[5] Einstein, A. 1923. Fundamental ideas and problems of the theory of relativity, Lecture at the Nordic Assembly of Naturalists at Gothenburg, July 11, 1923.

[6] Einstein, A. 1970. Albert Einstein: Philosopher Scientist, Ed. P A Schlipp, La Salle: Open Court Publishing Company - The Library of Living Philosophers, Vol VII.

[7] Pais, A. 1982. Subtle is the Lord ... The science and the life of Albert Einstein, Oxford: Clarendon Press.

[8] Dirac, P. A. M. 1927. The Quantum Theory of the Emission and Absorption of Radiation, Proc. Roy. Soc. A, 114, 243-265.

[9] In 1927, Dirac stated [8] that the light quantum has the peculiarity that it apparently ceases to exist when it is in … the zero state in which its momentum, and therefore its energy, is zero. When a light quantum is absorbed it can be considered to jump into the zero state, and when one is emitted it can be considered to jump from the zero state to one in which it is in physical evidence, so that it appears to have been created.

[10] Wagh, S. M. 2013. On acceleration dependence of Doppler effect in light, Pramana, 81(3), 439-448. (doi:10.1007/s12043-013-0584-6).

[11] Wagh, S. M. 2014. Measuring velocity and acceleration using Doppler shift of a source with an example of Jet in SS433', J Astrophys Astr, 35(4), 595-605. (doi:10.1007/s12036-014-9304-y).

[12] One may, conceivably, use length contraction and time dilation to still get the speed of light to be the same in the involved reference frames, but such an approach “must” maintain the equality of the time difference of events at A and B and that of those at C and D. This is a consequence of the “simultaneity'' of the events as pre-arranged within the considered experimental setup, we note.

Author’ biography with Photo

SANJAY M. WAGH, PhD, is currently director at the Central India Research Institute, Nagpur, India. His earlier research was conducted while at the Tata Institute of Fundamental Research, Mumbai, India; at the Harvard-Smithsonian Center for Astrophysics, Cambridge, USA; and at the Inter University Center for Astronomy & Astrophysics, Pune, India.

In 2007, he discovered a mathematical way of defining Measures over any Category. These works led him to propose the Universal Theory of Relativity, which has “universal” or “absolute” time. In 2009, he proposed that light consists of momentum-less quanta of only energy, and also explained the wave properties of radiation as the wavy fluctuations of the number of quanta resulting from the characteristics of the process of their emission. This emission-mechanism for the wave of quanta then explains the results of Michelson-Morley type experiments without needing “relative” time.

His research interests include Theoretical Astrophysics, Image Processing, Fundamental Physical Interactions, Nano-scale phenomena, the Joshi effect, Physics of Sports, Category Theory, and Universal Relativity.