Michelson-Morley Experiment and The Second Postulate of STR

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Abstract

This note discusses the fact that the Second Postulate in the Special Theory of Relativity (STR) is an absolute statement which implicitly acknowledges, despite the claim in [3] to the contrary, the existence of what was known as "ether". The stated absolute property of light to have a "definite velocity c independent of the emitting body" implicitly requires, especially from the point of view of the stationary observer, propagation of light to occur in an ubiquitous absolute medium external to any system (ether). If the outcome of the Michelson-Morley experiment is null, as is widely accepted, then it is an experiment rejecting the Second Postulate, respectively, disproving STR.

Recent publications [5-7] indicate problems in the Special Theory of Relativity (STR) [3]. In order to overcome these problems more efficiently it is necessary to understand better what led to them. It is discussed below that the results from the experiment of Michelson and Michelson-Morley [1,2], considered as one of the most solid experimental proofs of STR, actually disproves it.

In the founding paper on STR [3] one reads the following declared intention:

> "The introduction of a "luminiferous" ether will prove to be superfluous inasmuch as the view here to be developed will not require an "absolutely stationary space" provided with special properties, nor assign a velocity-vector to a point of the empty space in which electromagnetic processes take place."

However, right from the beginning the following is postulated ("Second Postulate – Postulate of the constancy of the velocity of light") and is offered as the basis of the theory to be developed:

> " … light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body."

Careful consideration of this postulate reveals that it states exactly the conditions under which the theoretical derivations in Michelson-Morley paper [2] are carried out (**cf.** ***Addendum***) the truthfulness of whose outcome had been the object of the experimental exploration undertaken by these

authors. Experiments in [1,2] reveal that the basis for these derivations is non-physical. Indeed, it is considered nowadays a well-established fact that the experimental results reported in [2], using a specially constructed interferometer, are null – no quantity $D\frac{v^2}{V^2}$ (in fact $2D\frac{v^2}{V^2}$ because turning of the apparatus to 90^o is applied), derived if ether concept is considered real (**cf.** ***Addendum***), is observed.

To remedy the situation and to sustain the ether concept Lorentz [4] proposed that the arm of the interferometer traveling along the direction of the Earth's motion has somehow contracted by $\frac{1}{2}D\frac{v^2}{V^2}$.

However, there is no physical basis for such contraction to occur.

As said above, Michelson and Morley [2] experimentally detect no effect, expected on the grounds of the existence of universal velocity of light, independent of the motion of any system. The only way, as was also mentioned, to explain away the negative outcome from Michelson-Morley's result is to assume, in agreement with Lorentz, that in the system of the interferometer its arm parallel to the direction of Earth's motion shortens by an appropriate value.

On the other hand, contrary to such proposal, STR claims such contraction from the point of view of an outside observer who sees the interferometer in motion. STR derives this, from the stationary observer's point of view, using a postulate which, applied by the stationary observer's point of view, is nothing else but admission (although, as the above quotation from [3] shows, denying it in words) of the existence of ether and of propagation of light solely dependent on ether's properties – velocity of light independent of the velocity of the moving system (velocity of light independent of the velocity of the source of that light). However, using such understanding of the nature of light propagation as a means for proving the contraction is unacceptable because this is exactly the same understanding which leads to the paradox regarding the simultaneity of two events [7]. Let us expand on this a bit.

The strange part in the STR Second Postulate (assuming ether does not exist, as claimed in STR) is not the claim that the velocity of light is c for an observer at rest with the system (at rest also with respect to the source of that light). This is common sense. The strange part in the STR Second Postulate is the claim that the velocity of light emitted in the moving system should still be seen as c by an observer in the stationary system. In other words, despite the fact that the source of light moves with respect to the

stationary observer at velocity v along the x-axis, the stationary observer should see, according to the Second Postulate, the velocity of light emitted from that source as c instead of as c + v. This, contrary to the statement in [3] that ""luminiferous ether" will prove to be superfluous", can only have physical meaning if one assumes the existence of an ubiquitous entity (ether) whose properties the propagation of light is entirely due to.

However, the negative outcome from the Michelson-Morley experiment does not support the view that such ubiquitous entity is real, provided no contraction proposal in the system of the interferometer is accepted. The consequences from that are dramatic for STR – Second Postulate is non-physical with all the consequences that follow from that. In effect this proves that STR is invalid.

On the other hand, if the Lorentz contraction proposal in the system of interferometer is accepted as the explanation for the negative outcome from Michelson-Morley's experiment, then this most significantly means that we accept the ether theory and its ubiquitous nature as the carrier of light.

If that is the case, i.e. if the reality of the ether is considered proven, then we have no reason to believe that the ether hypothesis is not applicable from the point of view of an observer in the moving frame. However, in such a case, another paradox, inexplicable even if the Lorentz contraction hypothesis is accepted, promptly arises – the light from the simultaneous flashing of two light sources positioned at the two ends of the train moving along the x-axis will not arrive at the same local time with an observer situated at mid-distance between those two sources. The light from the front source will arrive sooner while the light from the rear source will arrive with a delay. This can be easily understood by observing the derivation in ***Addendum*** when applied to two sources of light. If the mentioned observer uses the comparison of those two arrival times, as proposed in STR [3], as the criterion for whether the two sources have flashed simultaneously, he will be in error. The two arrival times are unequal, which, according to the criterion for simultaneity in STR [3], means there has not been simultaneity. Simultaneity, however, has actually occurred. The error which the observer in the moving system makes regarding simultaneity is exactly the same as the error which an observer in the stationary system makes regarding the same events of flashing, provided the latter observer uses the same criterion for simultaneity. Thus, no relativity of simultaneity will be observed – both stationary and moving observers will see two actually simultaneous events as non-simultaneous.

Curiously, while the hypothesis for Lorentz contraction can be used to explain away the null result of Michelson-Morley's experiment and

therefore can assert the reality of the ether, the same contraction, on the contrary, cannot explain away the paradox and contradiction with STR which appears regarding two actually simultaneous events in the moving frame (when ether is assumed and definition of simultaneity given in [1] is used).

If one objects that it might be the case but we do not have sensitive enough instruments to measure it one should notice that even so, as said, this will be in contradiction with STR – in STR the stationary and the moving observer are not in agreement regarding simultaneity. Not to speak about the fact that equality of times for light propagation should not be used as a criterion for simultaneity of two event if one wants to obtain reliable results unaffected by existence or not of the elusive ether.

Thus, one notices the following – if one accepts the ether and this could help explain the independence of the velocity of light from the velocity of its source, as seen by the stationary observer, then from the point of view of the observer residing in the moving system, the constancy of the light velocity is inexplicable.

Notice that if ether is not considered real and therefore c + v is not seen as c by the stationary observer, two simultaneous events occurring in the moving system will be seen as simultaneous both from the point of view of the stationary and from the point of view of the moving system. This will be the correct, physically consistent approach.

Thus, there is no basis to believe that there are reasons for Michelson-Morley's null result to be explained away by the Lorentz contraction proposal [4] and that therefore there are no grounds to believe that the ether is real. Rejection of the reality of ether through the experiments of Michelson-Morley is definitive.

Once reality of ether is rejected one should conclude the following regarding the definition of simultaneity presented in [1]. While in the absence of ether this definition may be considered suitable from the point of view of the stationary system (stationary also with respect to the source of light) it fails from the point of view of a system which sees the source of light moving but does not add the velocity of that motion to c. If ether is considered real then the said definition of simultaneity fails both from the point of view of the moving and from the point of view of the stationary system.

The said definition of simultaneity, proposed in [1], is crucial for STR because the derivation of the Lorentz transformations is based on it. Failure of this definition upon the acceptance of the Second Postulate leads to the non-physical nature of the Lorentz transformations and because the Lorentz

transformations are the basis of all developments in STR their lack of physical meaning propagates further into various other problems [5-7].

Conclusion

The null result from Michelson-Morley experiment [2] indicates that it is incorrect to consider that propagation of light has nothing to do with the motion of the source which creates that light and that said propagation is external to any system. For instance, it cannot be accepted that once the initial moment of inducing of a light pulse occurs, some ubiquitous medium (ether) takes over, the propagation of light begins to occur only due to the properties of that ether and that the light source only had the initial role of triggering the "vibration" of the ether. Continuing this line of reasoning leads to the conclusion that a picture whereby "light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body" is non-physical and that conclusion directly follows from the results of the Michelson-Morley experiment [2]. But postulating that "light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body" is exactly the statement of the "Second Postulate" as it appears in [3]. Thus, a consistent scientific approach, honoring the results of Michelson-Morley [2], requires rejection of the "Second Postulate" [3], and respectively, requires rejection of STR itself.

References

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Addendum

Theoretical derivation [2] of the quantity whose value is to be compared with the value of the same quantity obtained experimentally

In Michelson's famous founding paper [1] and in the joint Michelson-Morley paper [2] one finds the following simple considerations which are the theoretical basis of the study having the ultimate goal of comparison with the results of an experiment. Assume the existence of ether. Denote (in author's notation) by V the velocity of light, by v the speed of the Earth with respect to the ether, by D the distance between two points and by *d* the distance through which the Earth moves, while the light travels from one point to the other. Suppose that the light is propagating in the same direction as the Earth's motion.

The derivations are carried out by implying that the propagation of light is some property of the assumed existence of the ubiquitous entity ether. In other words, once the emission of light is triggered, its propagation is already only a property of the ether and has nothing to do any more with the state of motion of the emitting body.

Obviously, the reason the studies in papers [1,2] were undertaken is to answer whether this picture is correct. In pursuit of this answer, Michelson [1] and Michelson-Morley [2] provide the mentioned simple derivation deliberately based on the picture involving ether. Then they set up an

experiment intended to check whether its outcome will coincide with the theoretical derivation.

If the ether picture is accepted then one may write the following simple relations, as is done in [1]:

$$\mathrm{T} = \frac{\mathrm{D} + d}{\mathrm{V}} = \frac{d}{\mathrm{v}}$$

where T is the time required for the light to pass from one point to the other. The time T_1, necessary for the light to pass in the opposite direction, which obviously is shorter than time T (light meets the final destination faster on the reverse path) will then be

$$\mathrm{T}_1 = \frac{\mathrm{D} - d_1}{\mathrm{V}} = \frac{d_1}{\mathrm{v}}$$

where d_1 is the distance through which the Earth moves, while the light travels in the opposite direction (obviously, because the light traverses the path in the opposite direction the value of d_1 will be less than the value of d).

From the above one can immediately see that

$$\mathrm{T} = \frac{\mathrm{D}}{\mathrm{V} - \mathrm{v}} \quad \text{and} \quad \mathrm{T}_1 = \frac{\mathrm{D}}{\mathrm{V} + \mathrm{v}}$$

Thus, the sum of T and T_1 is:

$$\mathrm{T} + \mathrm{T}_1 = 2\mathrm{D}\frac{\mathrm{V}}{\mathrm{V}^2 - \mathrm{v}^2}$$

So, what have we done so far ? In order to obtain the above result we have accepted the existence of something which is an absolute medium (the ether) and that the propagation of light is only a property of that medium. In other words, we have accepted that propagation of light has nothing to do with the motion of the source which creates that light – once the initial moment of creation of a light pulse occurs the ether takes over and, as mentioned, the propagation of light is only due to properties of the ether. Thus, the light source only serves to trigger the “vibration” of the ether. Notice, if we did not accept the above the formulae derived so far will not be valid.

From the above result we obtain the overall distance the light covers when moving to and fro along the direction of Earth's motion

$$\left(\mathrm{T}+\mathrm{T}_1\right)\mathrm{V}=2\mathrm{D}\frac{\mathrm{V}^2}{\mathrm{V}^2-\mathrm{v}^2}=2\mathrm{D}\frac{1}{1-\frac{\mathrm{v}^2}{\mathrm{V}^2}}\approx 2\mathrm{D}\left(1+\frac{\mathrm{v}^2}{\mathrm{V}^2}\right)$$

(neglecting the fourth power terms).

As far as the times for propagation of the light in the direction perpendicular to the direction of Earth's motion it has initially been proposed [1] that it should be

$$\mathrm{T}^{\perp}+\mathrm{T}_1^{\perp}=2\mathrm{T}_{\mathrm{o}}=2\frac{\mathrm{D}}{\mathrm{V}}$$

because despite the supposed existence of ether, the propagation of light perpendicular to the motion of the Earth will be unaffected by that motion – light will pass between the initial and final destination just as in the case when the perpendicular arm is at rest ($\mathrm{T}^{\perp}$ and $\mathrm{T}_1^{\perp}$ are the times of the forward and reverse traveling of light in a direction perpendicular to the direction of the Earth's motion.) Obviously, the overall path which the light traverses in a direction perpendicular to the direction of Earth's motion in such case should be 2D.

In fact, later the proposal that light covers distance 2D perpendicular to the motion of Earth had been corrected [2] because obviously, as seen in Fig.1 on p.335 of [2], actually the light goes along the path *ab'* which is $\sqrt{\frac{\mathrm{V}^2+\mathrm{v}^2}{\mathrm{V}^2}}=\sqrt{1+\frac{\mathrm{v}^2}{\mathrm{V}^2}}\approx\left(1+\frac{1}{2}\frac{\mathrm{v}^2}{\mathrm{V}^2}\right)$ (neglecting the fourth power terms) times longer than the path *ab* = D. And because this path is covered twice (when light moves to and fro) the overall distance the light covers in the direction perpendicular to the motion of Earth is in fact $2\mathrm{D}\left(1+\frac{1}{2}\frac{\mathrm{v}^2}{\mathrm{V}^2}\right)$.

Obviously, if the theory of the ether were true there should be a difference between the quantities $2\mathrm{D}\left(1+\frac{\mathrm{v}^2}{\mathrm{V}^2}\right)$ and $2\mathrm{D}\left(1+\frac{1}{2}\frac{\mathrm{v}^2}{\mathrm{V}^2}\right)$ equal to $\mathrm{D}\frac{\mathrm{v}^2}{\mathrm{V}^2}$ (the earlier derivation $2\mathrm{D}\frac{\mathrm{v}^2}{\mathrm{V}^2}$ in [1] was incorrect).

We will not go into the details of the experiment but will note that further the numerical value of this theoretically found quantity $D\frac{v^2}{V^2}$ (in fact $2D\frac{v^2}{V^2}$ because turning of the apparatus to 90^o is applied), obtained provided there indeed is an absolute entity called ether, is then compared with the numerical value which is obtained experimentally. Obviously, if the experimental value coincides with the theoretical value $2D\frac{v^2}{V^2}$ then it will be a confirmation of the existence of the ether, otherwise the reality of the ether will be disproved. The results in [1,2] confirm the latter outcome.