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Review of Michelson's and Fizeau's experiments

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ABSTRACT

The construction of the theory of special relativityis based inter alia on the interpretation of Michelson's and Fizeau's experiments. Even today there are dilemmas about Michelson's experiment. A very simple explanation for this experiment will be given in this paper. The research undertaken will prove that Michelson applied the principle of Galileo in his experiment, but he implemented it only partially. Now this research will implement this principle completely. As a consequence is obtained a conclusion that Michelson's expectation(the idea of the experiment) was wrong. Next, we will point out the confusion of the physicists regarding the nature of the relative motion being studied. One such confusion appeared in Fizeau's experiment. The kind of relative motion studied in this experiment is not of such nature to which the principle of Galileo is valid. Therefore, this experimentcannot be counted as deserved for assessing theprinciple of Galileo. For the same reason it cannot be taken as proof for the theory of special relativity.

KEYWORDS: Michelson's experiment, Lorentz factor, velocity of light, the theory of special relativity, Galileo principle

INTRODUCTION

The theory of special relativity claims that answeredsome of theproblemsof nineteenth centuryphysics. Among others, two problematicexperiments of this periodwereexplainedby TSR: Michelson's experiment and Fizeau'sexperiment.At thattimetheidea about the existence of cosmic ether was strong. The ether raised dilemmaaboutits features and created thegreat confusion in physics. Physicists change theirbeliefsaboutetherand itsfeatures and often depending on problem considering. The confusionsabout etherhad contributed to wrong reviewing of problems.

The TSR has removed the ether from agenda, but retained the old explanations and conclusionsfor the problems.Furthermore, the results ofTSR werealmost as those of ether theory. Then, to resolve some problematic issues and"paradoxes" that are created from TSR, one must use thesimilar machinations as in the case when we should review the ether theory depending from problem. However, if we carefully review the issues upon which was built TSR, will be seen that they have the most accurate and naturally explanation, if we avoid TSR completely.

Review of Michelson's experiment

In 1878, Maxwell gave the idea of the possibility of measuring the velocity of ether through the influence of Earth's velocity on the velocity of light spreading on its surface. In 1881 Michelson tried to prove that experimentally. The experiment didn't show the result that the physicist was expecting. The physicistsrather than reviewing the calculation in accordance with experiment, they had cared to explain "the astounding" result of this experiment.

The setting of interferometer with one arm in the direction of Earth's motion

The setting of interferometer with one arm in the direction of Earth's motion is exactly the same as setting that made by Michelson (Michelson and Morley, 1887). Michelson idea was to observe the existence of ether. In other words, by measuring the velocity of light spreading when it spreads in different directions towards Earth's motion, he expected to find the influence of Earth's velocity (v) on the velocity of light (c).

Michelson's interferometer can be seen in figure 1. The mirror m_1 divides the ray that descends to it in two parts which then move in the directions of the mirrorsm_2 and m_3 along the wings of the interferometer with length l.

According to Michelson, after the reflection the rays return to mirror m_1 but not in equal times. His intention was to measure this difference between these times.

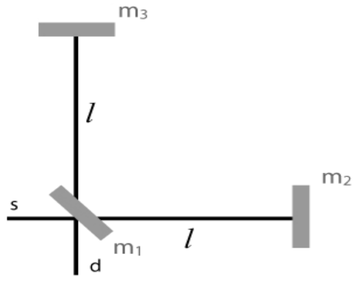

Figure 1. The diagram of Michelson interferometer. The source of light is at s, the 45 degree line is the half-silvered mirror m_1;m_2 and $m_3$are mirrors and d is the observer (Klinaku, 2010).

The Michelson's calculations: with t_1 he noted the time in which the ray of light travels from mirror m_1 to mirror m_2 and backwards and with t_2 he designated the time in which the ray of light travels from mirrorm_1 to mirror m_3 and backwards. The calculations of these times are as presented in equations 1 and 2. For the time t_1:

$$\boldsymbol{t_1} = \frac{l}{c-v} + \frac{l}{c+v} = \frac{2l}{c}\frac{1}{1-\frac{v^2}{c^2}}. \quad (1)$$

For the time t_2:

$$\boldsymbol{t_2} = 2\frac{\sqrt{x^2+l^2}}{c}. \ (2)$$

While, for the difference of these times he obtained:

$$\mathbf{t_1} - \mathbf{t_2} = \frac{2l}{c}\left(\frac{1}{1-\frac{v^2}{c^2}} - \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\right)(3)$$

And after some approximations Michelson got this equation:

$$\boldsymbol{t_1} - \boldsymbol{t_2} = \frac{l}{c}\frac{v^2}{c^2}. \ (4)$$

And he concluded that this difference can even be measured.

The result of the experiment was negative. Thus, the difference between the times of the rays spreading didn't turn out to be exact $\boldsymbol{t_1} - \boldsymbol{t_2} = \frac{l}{c}\frac{v^2}{c^2}$ as Michelson expected but it equals to 0. This created different interpretations amongst the physicists. Subsequently, a very strange idea began to dominate: the wing of the interferometer which is in the same direction with the motion of the Earth gets shorter as a result of motion, as a result of cooperation ether-matter.

All the efforts of these physicists were concentrated to mathematically get this shortening factor $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$, which caused the difference between the times (1), which was later called the Lorentz factor.

Michelson has judged based on the Galileo principle of relativity, but he has applied this principle only partially. Michelson judges that the oblique road of the ray is caused by Earth's displacement for the length x. However, this displacement has to be taken in account even for the arm of the interferometer that is in the same direction with Earth's motion, therefore forright calculation of $t_1$one must write:

$$\boldsymbol{t_1} = \boldsymbol{t_1(i)} + \boldsymbol{t_1(k)} = \frac{\boldsymbol{l+x}}{\boldsymbol{c+v}} + \frac{\boldsymbol{l-x}}{\boldsymbol{c-v}}. \quad (5)$$

Due to the same reason, for the ray that propagates through the other arm of the interferometer the right calculation is:

$$t_2 = t_2(i) + t_2(k) = \frac{l_1}{u} + \frac{l_1}{u} = 2\frac{\sqrt{x^2 + l^2}}{\sqrt{v^2 + c^2}}. \qquad (6)$$

Earth's velocity$v$ contributes on the oblique direction of the light (the hypotenuse of the triangle, see figure 2), then the light's velocity in this direction cannot be c, but another velocity that is noted with u.

By doing so, we entirely apply Galileo principle. Even for (5) and (6) is:

$$x = l\frac{v}{c}. \qquad (7)$$

And for the difference between the times we obtain:

$$t_1 - t_2 = \frac{l + l\frac{v}{c}}{c + v} + \frac{l - l\frac{v}{c}}{c - v} - 2\frac{\sqrt{l^2\frac{v^2}{c^2} + l^2}}{\sqrt{v^2 + c^2}} = \frac{2l}{c} - \frac{2l}{c} = 0 \qquad (8)$$

$$t_1 = t_2 \qquad (9)$$

So, not only the result of Michelson's experiment is zero; moreover, even the expectation from this experiment is zero(Klinaku, 2010).

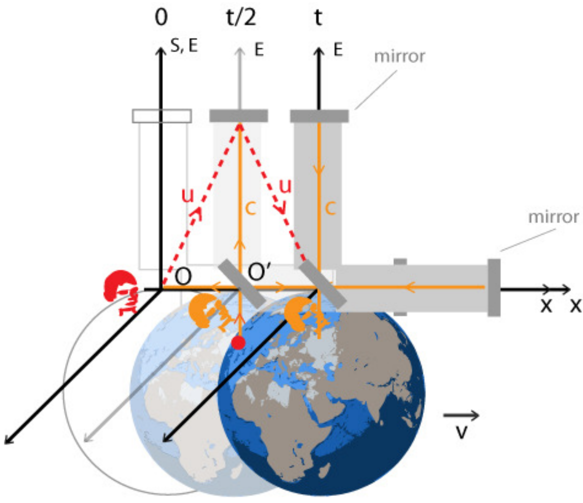

Figure 2. Full view of Michelson's experiment (Klinaku, 2010).

For a more detailed explanation figure 2 helps which shows the complete aspect of Michelson's experiment.For the observer in Earth (system E), from figure 2 it can be seen that the ray of light in the transversal arm of the interferometer doesn't even change the direction.

The triangle formed by moving of the ray of light isn't formed for this observer. In other words, the Earth velocity doesn't have any effect on the spreading of light in this environment. This is true for every observer from figure 2. Consequently, the Lorentz factor doesn't appear on the calculation.

The setting of the interferometer under an acute angle with direction of Earth's motion

Letus now put the interferometer in order that,one of interferometer'sarmcloses an acute angle ϑ with the direction of Earth's motion, as is shown in figure 3.

One such review of Michelson's experiment was done by Claus Lämmerzahl (Lämmerzahl, 2005).

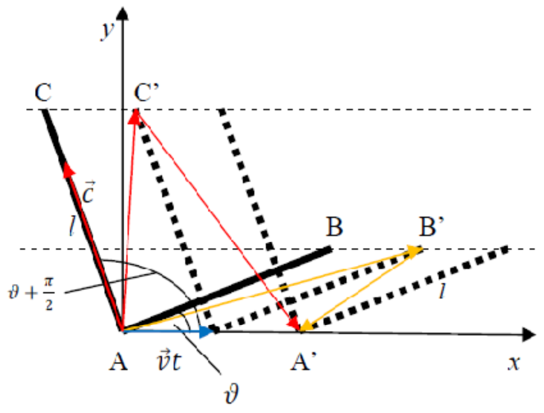

Figure 3. The interferometer (CAB) is placed so that the arm AB closes the angle ϑ with the direction of Earth's motion (x axis).

The coordinates of point B for the time t = 0 are: $B\big(x(B), y(B)\big) = (l\cos\vartheta, l\sin\vartheta)$, while after the time t the light will reach the point B' with coordinates: $B'\big(x(B'), y(B')\big) = (l\cos\vartheta + vt, l\sin\vartheta)$.

We require the time t within which the light passes the path AB'. Let us suppose that in this path the velocity of light is c, as TSR claims and as Lämmerzahl has used, than we obtain:

$$ct(AB') = \sqrt{(l\cos\vartheta + vt)^2 + l^2\sin^2\vartheta} \qquad (10)$$

$$ct(AB') = \sqrt{\left(\vec{l} + \vec{v}t\right)^2} \qquad (11)$$

$$\vec{c}t(AB') = \vec{l} + \vec{v}t(AB') \qquad (12)$$

$$t(AB') = \frac{\vec{l}}{\vec{c} - \vec{v}} \qquad (13)$$

The last equation is the same as Michelson's calculation. But, from this equation we obtain:

$$\vec{c} = \frac{\vec{l}}{t(AB')} + \vec{v}. \qquad (14)$$

The equation (14) arises the question what kind of velocity presents this term:

$\frac{\vec{l}}{t(AB')}$?

It certainly represents the velocity of light$\vec{c}$, i. e. the velocity of light with which the light passes the path l. It follows that the velocity on the left side of equation (14) is not $\vec{c}$, but greater than $\vec{c}$ and represents the Galileo principle for light propagation on the path AB'. So the right form of equation (14) is:

$$\vec{c'} = \vec{c} + \vec{v}. \qquad (15)$$

Further, the fact that the times ($t_1 and t_2$) for which the light spreads through the interferometer's arms are equal, as indicated in (9), can be easily verified from figure 3. Thefigure 3shows that the vector sum of light paths throughthearmACis identical to the vector sum of light paths through the arm AB. To calculate this let's note: the path AC'let's mark with $\vec{l_1}$, the path C'A'let'smarkwith$\vec{l_2}$, the path AB'let's mark with $\vec{l_3}$ and the path B'A'let's mark with $\vec{l_4}$. Then we can write:

$$\vec{l_1} + \vec{l_2} = 2\vec{v}t \qquad (16)$$

$$\vec{l_3} + \vec{l_4} = 2\vec{v}t \qquad (17)$$

On the right side of these equations stays the time t within which the interferometer passes the half of path AA'. But even if it is considered that these two "half" of the path AA' passed for different times (t and t'), does not change anything at the end, because even in this case the vector that represents the sum of vectors in (16) and (17) is the same for both equations.

The same result is obtained even with other calculations from figure 3.

Review of Fizeau's experiment

Ifwe make a classification of relativemotions,it will build a multi-staged diagram, because the relative motions are varied. There are no principles that can be applied equally to all relative motions.

Even a simple classification of these motions would indicate that the Galileo principle of relativity is not applicable to all types of relative motions. The same should apply to the theory of special relativity.

The motions of Fizeau's experiment represent relative motion, which take place within a reference system and in moving medium. One such motion differs essentially from the relative motion conducted in two reference systems and in resting medium, for which Galileo discovered the principle of relativity, respectively, known as velocity-addition formula. What Galileo had studied was presented in figure 4a, for which applies specifically the velocity-addition formula:

$$c_{lab} = \frac{c}{n} + v \qquad (18)$$

Where$c_{lab}$is the velocity of light measured by the observer staying in origin of resting system, n is the refractive index of water and v the velocity of wagon filled with water. So, in figure 4a there is a system at rest (the lab) and another system where the event happens (wagon) which moves with velocity v, relative to the former. The water rests on the wagon and velocity of wagon does not affect the velocity of light across the water. But the figure 4a not represents the Fizeau's experiment.

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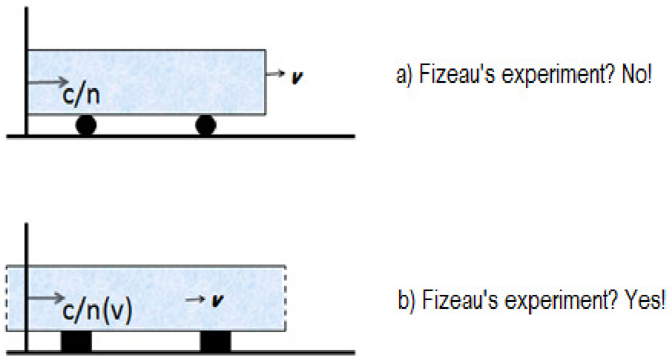

a) Fizeau's experiment? No!

b) Fizeau's experiment? Yes!

Figure 4. Wagon filled with water (a) and the moving water in tube (b).

In figure 4b there is only one reference frame, filled with water that moves with velocity v. In water it is released a beam of light. There's only one system, because the velocities of the two motions are measured only toward this system. The problem is to find the velocity of light in this environment. This represents the Fizeau's experiment. But in this case nor be required to apply the Galileo principle of relativity. In other words, the outcome of this experiment can't be judge for the accuracy of the Galileo principle, as well as that can't be taken as an argument for verification of TSR.Indeed, in Fizeau's experiment there are two bodies that move in areference system,whichareinconstantfrictionwitheachotherandaffecteachother's velocity.

Fizeau, influenced by the supposed ether and by the Fresnel's drag factor (Fizeau, 1859), and Max von Laue, influenced by the TRS (von Laue, 1907), have brought this formula as a solution of Fizeau's experiment:

$$\boldsymbol{c_{lab}} = \frac{\boldsymbol{c}}{\boldsymbol{n}} + \boldsymbol{v}\left(\boldsymbol{1} - \frac{\boldsymbol{1}}{\boldsymbol{n^2}}\right) \qquad (19)$$

where$c_{lab}$is the speed of light measured by the observer who ceases, n is the refractive index of water, and v is the water velocity. Fizeau's assumption to apply equation (18) in this experiment is unsustainable, not because of these or those features of ether, but because that the relative motion of this experiment is essentially different from that for which the equation (18) is valid.

Equation (19) is certainly not the last word for an explanation of Fizeau's experiment, because Fizeau and Max von Laue have brought it as an approximation.

So, the relative motion of Fizeau's experiment is not a simple relative motion, and therefore in this experiment can't be tested Galileo principle and TRS. This motion is more complex, where the velocity of one body (the light) is affected by friction with another body in motion (the water). Finally, the problem that Fizeau's experiment raises is: "dynamic index of refraction, $n(v)$". The Physics knows how to find the refraction index for different materials at rest ("static index of refraction, n"), but yet doesn't know the variation of this index when these materials move with a certain velocity($n(v)$ =?).

CONCLUSIONS

It was proved in two ways that Michelson's experiment shows no surprise. This experiment confirms that the light obeys to the Galileo principle. With this we avoided the need for medieval explanation offered by FitzGerald, Lorentz and Einstein with TSR, which is the contraction of the body in the direction of motion. We avoided too, the need for inventing postulates in physics (Poincare, 1905and Einstein, 1905)whichclaimtoexplainthe general motion of matter. Next, it was proved that Fizeau's experiment cannot throw down the Galileo principle, nor proved the theory of special relativity. This experiment raises the existing of "dynamic index of refraction, $n(v)$".

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