The explanation of the Michelson-Morley experiment results by means of the theory of ether

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It is commonly thought that the Michelson-Morley experiment from 1887 and Kennedy-Thorndike experiment from 1932 demonstrated that the universal frame of reference (ether) does not exist and that the velocity of light in vacuum is absolutely constant. The analysis of this experiment led to the creation of the Special Theory of Relativity (STR).

The article explains why Michelson-Morley and Kennedy-Thorndike experiments could not detect the universal frame of reference.

In this article, a different transformation of time and position than the Lorentz transformation is derived on the basis of the geometric analysis of the Michelson-Morley and Kennedy-Thorndike experiments. The transformation is derived based on the assumption that the universal frame of reference (ether) exists. Ether is a frame of reference in which the velocity of light is constant in every direction. In inertial frames of reference moving in the ether, the velocity of light may be different.

Keywords: universal frame of reference, ether, coordinate and time transformation, the speed of light in one direction

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1. Introduction

The article an explanation the results of the Michelson-Morley [1] and Kennedy-Thorndike [2] experiments, assuming the existence of the universal frame of reference (ether), in which the velocity of light is constant, is presented. In inertial frames of reference moving in the ether, the velocity of light may be different. The transformations from the inertial system to the ether and from the ether to the inertial system was derived by the geometric method.

The velocity of light in one direction has never been accurately measured. In all accurate laboratory experiments, as in the Michelson-Morley experiment, only the average velocity of light, travelling on a closed trajectory, was measured. In these experiments, light always comes back to the source point. Therefore, the assumption about the constant velocity of light (instantaneous velocity) adopted in the Special Theory of Relativity is not experimentally justified. The derivation presented in this article is based on the assumption resulting from these experiments, that is for every observer, the average velocity of light travelling the way to and back is constant.

The transformation «ether - inertial system» (26)-(27) derived in this article by the geometric method was already derived in articles [3] and [4] by other method. In that case, the author obtained this transformation thanks to the synchronization of clocks in inertial frames by the external method. Work [5] demonstrated that although the transformation from work [4] has the same form as the transformation derived in this article, it has different meaning. The transformation obtained in work [4] is equivalent to the Lorentz transformation. It is only the Lorentz transformation differently written down after a change in the manner of time measurement in the inertial frame of reference. The transformation derived in this article has a different meaning than the Lorentz transformation, because it was obtained from different assumptions on the properties of light.

2. The Assumptions

In the presented analysis of the Michelson-Morley and Kennedy-Thorndike experiments, the following assumptions are adopted:

I. There is a universal frame of reference (ether) with respect to which the velocity of light in vacuum is the same in every direction.
II. The average velocity of light on its way to and back is for every observer independent of the direction of light propagation. This results from the Michelson-Morley experiment.
III. The average velocity of light on its way to and back does not depend on the velocity of the observer in relation to the ether. This results from the Kennedy-Thorndike experiment.
IV. In the direction perpendicular to the direction of the velocity of the body, moving in relation to the ether, there is no contraction or elongation of its length.
V. The transformation «ether - inertial system» is linear.

The transformation derivation presented in this article differs from the derivation by the geometric method of the Lorentz transformation which is the basis for the STR. In STR in the derivation of the Lorentz transformation, it is assumed that the reverse transformation has the same form as the original transformation. Such an assumption stems from the belief that all inertial frames are equivalent. In the derivation presented in this article, we do not assume what form the reverse transformation has.

Assumptions concerning the velocity of light adopted in this article are also weaker than those adopted in the STR. In the STR, it is assumed that the velocity of light is absolutely constant, despite the fact that it has not been proven by any experiment. In this article, the assumption resulting from experiments is adopted, i.e. the average velocity of light on the way to the mirror and back is constant (assumption II and III). In the presented considerations, the velocity of light by assumption is constant only in one highlighted frame of reference - in the ether (assumption I).

Assumptions IV and V are identical to those on which the STR is based.

In work [6] and [7], identical transformations were derived as in this article, but with the adopted additional assumption. For this, it was necessary to conduct the full analysis of the Michelson-Morley experiment in which also the second stream of light, parallel to velocity v, is taken into account. In that case, only one stream of light was analyzed.

3. Time and way of the light flow in the ether

Let us consider inertial system U', which moves in relation to system U related with the ether at velocity v (Figure 1). In system U', there is a mirror at distance D' from the beginning of the system. Light in the system U moves at constant velocity c. From system U', from point $x'=0$ in time $t=0$, a stream of light was sent in the direction of the mirror. Having reached the mirror, the reflected light moves in the system U in the opposite direction at velocity with the negative value $-c$.

We assume the following symbols for the observer from the system U: t_1 is the time of the light flow to the mirror, t_2 is the time of the light return to the starting point. L_1 and L_2 are ways which were travelled by light in the system U in one direction and in another.

When light moves in the direction of the mirror, then the mirror runs away from it at velocity v. When light comes back to point $x'=0$ after the reflection from the mirror, then this point runs towards it at velocity v. For an observer from system U, distance D' parallel to velocity vector v is seen as D. We obtain

$$L_1 = D + v \cdot t_1, \qquad L_2 = D - v \cdot t_2 \tag{1}$$

$$t_1 = \frac{L_1}{c} = \frac{D + v \cdot t_1}{c}, \qquad t_2 = \frac{L_2}{c} = \frac{D - v \cdot t_2}{c} \tag{2}$$

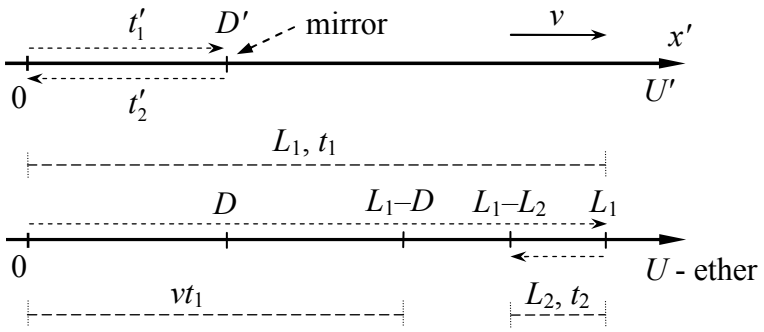

Fig. 1. The time and the flow path of light to the mirror and back

Dependencies (2) should be solved due to t_1 and t_2. We then obtain time and way of flow in the ether

$$t_1 = \frac{D}{c - v}, \qquad t_2 = \frac{D}{c + v}$$
$$L_1 = c \cdot t_1, \qquad L_2 = c \cdot t_2 \tag{3}$$

4. The Geometrical Derivation of the Transformation

We analyze the results of the Michelson-Morley experiment, as shown in Figure 2. The inertial system U' move sat a relative velocity v to the inertial system U, associated with the ether, parallel to the axis x. Axes x and x' lie on one straight line.

At the moment when origins of systems overlap, clocks in both systems are synchronized. Clocks in system U related to the ether are synchronized by the internal method [4]. Clocks in system U' are synchronized by the external method in such a manner that if the clock of system U indicates time $t=0$, then the clock of system U' next to it is also reset, that is $t'=0$.

In the system U', an experiment measuring the velocity of light in vacuum perpendicular and parallel to the direction of movement of the system U' in relation to the ether was conducted. In each of these directions, light travels to the mirror and back. Figure 2 presents in part *a*) the flow path of light seen by the observer from the system U', while in part *b*) the path seen by the observer from the system U.

In system U light has always constant velocity c (assumption I). Considerations concern the flow of light in vacuum.

In accordance with conclusions resulting from the Michelson-Morley experiment it has been assumed that the average velocity of light c_p on the way to the mirror and back in system U' is the same in every direction, in particular in the parallel direction to the axis y' (assumption II). It has

also been assumed that the average velocity of light c_p on the way to the mirror and back does not depend on the velocity of an observer in relation to the ether (assumption III).

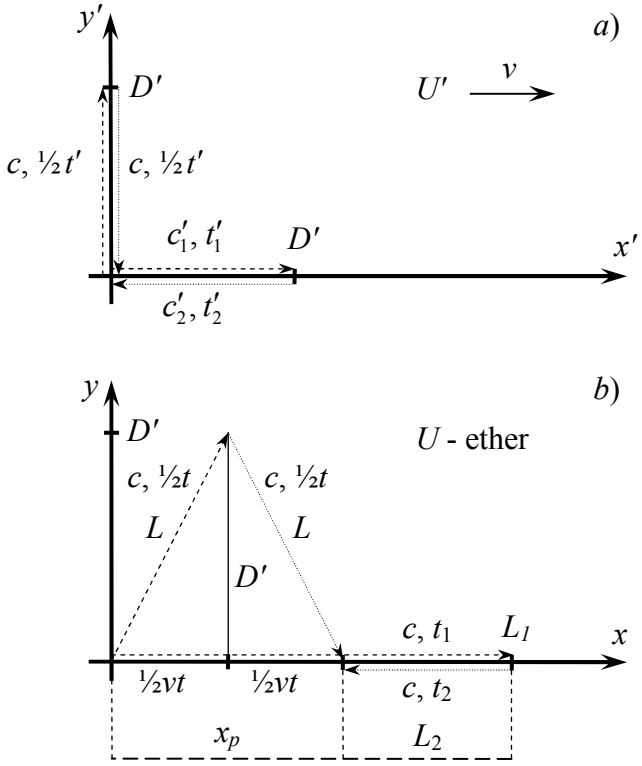

Fig.2. Paths of two streams of light
a) seen by an observer from the system *U′*,
b) seen by an observer from the system *U* (ether)

From assumption II and III it follows that the average velocity of light c_p in the inertial frame of reference is the same as the velocity of light c in the system U. If we allow that the average velocity of light c_p in the system U' is a function of the velocity of light c in the system U dependent on the velocity v, we can write

$$c_p = f(v)c \tag{4}$$

From assumption III the average velocity of light is the same for different velocities of the Earth relative to the ether, so $f(v_1)=f(v_2)$. Since $f(0)=1$, therefore $f(v)=1$ for every velocity v. It follows that $c=c_p$.

The mirrors are associated with the system U' and placed at distance D' from the origin. One mirror is located on the axis x', the second one on the axis y'. We assume that the distance D', which is perpendicular to the velocity v is the same for observers from both systems (assumption IV). Therefore, in Figure 2, there is the same length D' in part *a*) and part *b*).

The flow time of light in the system U, along the axis x, in the direction to the mirror is marked as t_1. The flow time back is marked as t_2.

The flow time of light in the system U', along the axis x', in the direction to the mirror is marked as t'_1. The flow time back to the source is marked t'_2.

Total time is marked respectively as t and t' ($t=t_1+t_2$ and $t'=t'_1+t'_2$).

The light stream, moving parallel to the axis y', from the point of view of the system U moves along the arms of an isosceles triangle of side length L. Since the velocity of light is constant in the system U, therefore, the time of movement along both arms is the same and is equal to $1/2t$.

In the system U, the light stream parallel to the axis x, in the direction of the mirror overcomes distance L_1 during time t_1. On the way back, it travels distance L_2 during time t_2. These distances are different due to the movement of the mirror and the source point of light in the ether.

In the experiment, both light streams come back to the source point at the same time, both in system U and system U'. It results from assumption II and from the mirrors' setting at the same distance from the point of light emission.

For an observer of U' and U, the velocity of light can be written as

$$\frac{2D'}{t_1'+t_2'}=\frac{2D'}{t'}=c=\frac{2L}{t}=\frac{L_1+L_2}{t_1+t_2} \tag{5}$$

From equation (5) light paths L and D' as a function of the velocity of light c and the light flow times t, t' respectively in the systems U and U' can be determined

$$L=\frac{ct}{2};\quad D'=\frac{ct'}{2} \tag{6}$$

The velocity of the system U' relative to the absolute frame of reference U, i.e. the ether is marked by v. Since x_p is the path that the system U' travelled in time t, of the light flow, we have

$$v=\frac{x_p}{t};\quad x=vt \tag{7}$$

Using the geometry of Figure 2, the length L can be expressed as

$$L=\sqrt{(1/2x_p)^2+D'^2}=\sqrt{(1/2vt)^2+D'^2} \tag{8}$$

Having squared equation (8) and taken (6) into account, we obtain

$$(1/2ct)^2=(1/2vt)^2+(1/2ct')^2 \tag{9}$$

After arranging we obtain

$$t^2(c^2-v^2)=(ct')^2 \tag{10}$$

$$t=t'\frac{1}{\sqrt{1-(v/c)^2}}\quad \text{for}\quad x'=0 \tag{11}$$

The above relation describes only times t and t' that involve the full light flow to the mirror and back. It should be noted that these are times measured in point x'=0. However, if we assume that the length D' can be chosen so that time flow of light is any time, so the relationship (11) is true for any time.

Length D' associated with the system U' that is parallel to the axis x, and is seen from the system U as D. If light flows in the absolute frame of reference U to the mirror, is chasing the mirror, which is away from it at length D. After reflection, light returns to the source point, which runs against him. Using equations (3), we obtain the equations for light flow paths in both directions along the axis x' in the system U

$$L_1=ct_1=c\frac{D}{c-v};\qquad L_2=ct_2=c\frac{D}{c+v} \tag{12}$$

From equations (12) the sum and difference in length the L_1 and L_2, which light travelled in the system U, can be determined

$$\begin{aligned} L_1 + L_2 &= D\frac{c}{c-v} + D\frac{c}{c+v} = 2D\frac{1}{1-(v/c)^2}, \\ L_1 - L_2 &= D\frac{c}{c-v} + D\frac{c}{c+v} = 2D\frac{v}{c}\cdot\frac{1}{1-(v/c)^2} \end{aligned} \tag{13}$$

From the second equation, the distance that the system U' travelled in half of the light flow time $1/2t$ can be determined, so we have

$$1/2x_p = 1/2vt = \frac{L_1 - L_2}{2} = D\frac{v}{c}\frac{1}{1-(v/c)^2} \tag{14}$$

Since it was assumed that in the system U the velocity of light c is constant, therefore both distances, which are travelled by light $2L$ and L_1+L_2 are the same

$$2L = L_1 + L_2 \tag{15}$$

After substituting (8) and the first equation (13) we obtain

$$2\sqrt{(1/2vt)^2 + D'^2} = 2D\frac{1}{1-(v/c)^2} \tag{16}$$

After reducing by two, raising to the square and taking (14) into account we can write

$$\left(D\frac{v}{c}\frac{1}{1-(v/c)^2}\right)^2 + D'^2 = D^2\left(\frac{1}{1-(v/c)^2}\right)^2 \tag{17}$$

From equation (17) a dependence for the length contraction can be determined

$$\begin{aligned} D'^2 &= D^2\left(\frac{1}{1-(v/c)^2}\right)^2(1-(v/c)^2) \\ D' &= D\left(\frac{1}{1-(v/c)^2}\right)\sqrt{1-(v/c)^2} = D\frac{1}{\sqrt{1-(v/c)^2}} \end{aligned} \tag{18}$$

$$D = D'\sqrt{1-(v/c)^2} \tag{19}$$

Lengths D and D' which are distances between mirrors and the point of light emission occur in the above dependence. Since length D' can be selected on a voluntary basis; therefore, dependence (19) is true for any value of D'.

Having introduced (11) to (7), we have

$$x = vt'\frac{1}{\sqrt{1-(v/c)^2}} \quad \text{for} \quad x' = 0 \tag{20}$$

We assume that the transformation from the inertial system U' to the system U is linear (assumption V). If linear factors dependent on x' are added to the transformation of time and position (11), (20), transformations with unknown coefficients a, b can be obtained

$$\begin{aligned} t &= t'\frac{1}{\sqrt{1-(v/c)^2}} + ax' \\ x &= vt'\frac{1}{\sqrt{1-(v/c)^2}} + bx' \end{aligned} \tag{21}$$

Transformation (21) should be valid for any time and position. In a particular case, it is valid at the moment of clocks' synchronization, that is when $t=t'=0$ for the point with coordinates D' in system U'. In this connection, we introduce $t=t'=0$, $x'=D'$ and $x=D$ into (21). Having taken (19) into account, we obtain

$$\begin{aligned} 0 &= aD' \\ \sqrt{1-(v/c)^2}\,D' &= bD' \end{aligned} \tag{22}$$

We obtain coefficients a and b

$$\begin{aligned} a &= 0 \\ b &= \sqrt{1-(v/c)^2} \end{aligned} \tag{23}$$

Finally, the transformation from any inertial system U' to the system U, associated with the ether takes the form

$$t = \frac{1}{\sqrt{1-(v/c)^2}}t' \tag{24}$$

$$x = \frac{1}{\sqrt{1-(v/c)^2}}vt' + \sqrt{1-(v/c)^2}\cdot x' \tag{25}$$

After transformations of the above equations, we obtain the inverse transformation, that is the transformation from the system U, associated with the ether to the inertial system U'

$$t' = \sqrt{1-(v/c)^2}\cdot t \tag{26}$$

$$x' = \frac{1}{\sqrt{1-(v/c)^2}}(-vt + x) \tag{27}$$

5. Relative Velocities Between Systems

We will now denote inertial system U' as U_1. From this inertial system, another inertial system U_2 is observed. In relation to the system U (ether), inertial system U_1 has velocity v_1, while inertial system U_2 has velocity v_2. We determine the relative velocity $v_{2/1}$ of system U_2 seen from system U_1.

Let dx be a change in the position of system U_2 in time dt seen from system U. Now it can be written that

$$v_2 = \frac{dx}{dt} \tag{28}$$

Let dx_1 be a change in the position of system U_2 in time dt_1 seen from system U_1. Now it can be written that

$$v_{2/1} = \frac{dx_1}{dt_1} \tag{29}$$

In order to determine the relative velocity of system U_2 in relation to system U_1, we will calculate differentials from transformations (26)-(27) ($t_1=t'$, $x_1=x'$, $v_1=v$)

$$\begin{cases} dt_1 = \sqrt{1-(v_1/c)^2}\cdot dt \\ dx_1 = \dfrac{1}{\sqrt{1-(v_1/c)^2}}(-v_1 dt + dx) \end{cases} \tag{30}$$

We introduce the above differentials into formula (29)

$$v_{2/1} = \frac{\dfrac{1}{\sqrt{1-(v_1/c)^2}}(-v_1 dt + dx)}{\sqrt{1-(v_1/c)^2}\,dt} \tag{31}$$

$$v_{2/1} = \frac{-v_1 + \dfrac{dx}{dt}}{1-(v_1/c)^2} \tag{32}$$

Having taken dependence (28) into account, we obtain the searched formula for the relative velocity of inertial system U_2 in relation to inertial system U_1

$$v_{2/1} = \frac{v_2 - v_1}{1-(v_1/c)^2} \tag{33}$$

6. The Velocity of Light in the Inertial Frame of Reference

Now we calculate the velocity of light in any inertial system U_1.

Consider three inertial reference systems U_1, U_2 and U_3 moving in the ether in parallel to the x axis, Figure 3.

Systems U_2 and U_3 are associated with light, but move in opposite directions. Therefore, their velocities in the ether are $v_2=c$ and $v_3=-c$. The system U_1 moves in the ether at the velocity $v_1 \geq 0$. From equation (33), the velocity of light. measured in the system U_1, can be calculated

$$c_{p1} = v_{2/1} = \frac{c - v_1}{1-(v_1/c)^2} = \frac{c^2(c-v_1)}{c^2 - v_1^2} = \frac{c^2(c-v_1)}{(c+v_1)(c-v_1)} = \frac{c^2}{c+v_1} \leq c \tag{34}$$

and

$$c_{p2} = v_{3/1} = \frac{-c - v_1}{1-(v_1/c)^2} = -\frac{c^2(c+v_1)}{c^2 - v_1^2} = -\frac{c^2(c+v_1)}{(c+v_1)(c-v_1)} = -\frac{c^2}{c-v_1} \leq -c \tag{35}$$

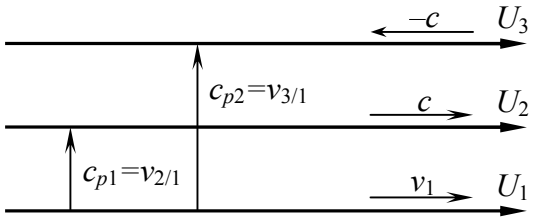

Fig. 3. The velocity of light in one direction

When light travels in the ether in the same direction as the inertial system U_1, then the velocity of light in the system is expressed by equation (34). When light travels in the ether in the direction opposite to the inertial system U_1, then the velocity of light in the system is expressed by equation (35). The velocity of light in system U_1 assumes values as in Figure 4.

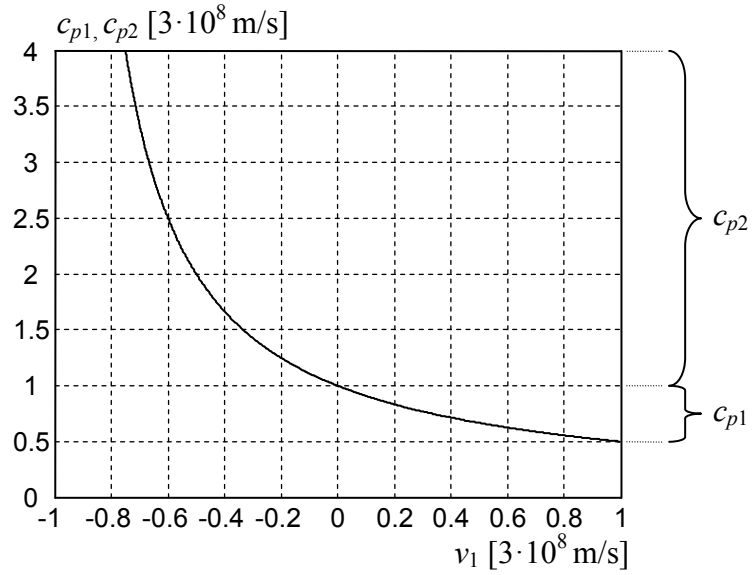

Fig. 4. The velocity of light in the inertial system moving with the speed v_1 relative to the ether

It follows that if the system U_1 moves at velocity close to c, then light running in the same direction in relation to the system U_1 has velocity close to $1/2c$. Light running in the opposite direction has infinite velocity to the system U_1. Thus, the velocity of light in relation to the inertial system can be very high, because the system clocks go more slowly than in the ether. The velocity of light in the ether is exactly c.

In the system U_1, let light run in parallel to velocity v_1 of the system U_1 relative to the ether. Just as in the Michelson-Morley experiment, light runs along the way L over time t'. At the end of the way, light is reflected in the mirror and goes back along the same way L over time t''. Then, the average velocity of light can be described on the basis of (34) and (35) and is equal to

$$c_{sr} = \frac{2L}{t'+t''} = \frac{2L}{\frac{L}{c_{p1}}+\frac{L}{c_{p2}}} = \frac{2L}{\frac{L}{\frac{c^2}{c+v_1}}+\frac{L}{\frac{c^2}{c-v_1}}} = \frac{2}{\frac{c+v_1}{c^2}+\frac{c-v_1}{c^2}} = \frac{2}{\frac{2c}{c^2}} = c \tag{36}$$

This velocity agrees with the results of the Michelson-Morley and Kennedy-Thorndike experiments, which shows that the average velocity of light is constant and is equal to c (the average velocity, not instantaneous). We have shown that the Michelson-Morley experiment does not imply that the current velocity of light is constant in every direction.

Velocities expressed in dependencies (34) and (35) are different. The first one refers to the direction compatible with velocity v_1, and the other concerns the direction opposite to velocity v_1. However, the average velocity of light is constant and is equal to c.

In works [5], [8] and [9] a general formula for the velocity of light running in any direction in vacuum is derived

$$c'_{\alpha'} = \frac{c^2}{c+v\cos\alpha'} \tag{37}$$

For light moving in a material medium motionless in relation to the observer, it has the form of ([5])

$$c'_{s\alpha'} = \frac{c^2 c_s}{c^2 + c_s v\cos\alpha'} \tag{38}$$

In these two dependencies, angle α' is the angle, measured by the observer, between the vector of its velocity in relation to the ether and the vector of the velocity of light. Velocity c_s is the velocity of light in the material medium motionless in relation to the ether seen by the observer motionless in relation to the ether.

Formulas (37) and (38) come down to formulas (34) and (35), if we substitute $c_s=c$ and $\alpha'=0$ rad or $\alpha'=\pi$ rad. Formulas (37) and (38) also have the property presented in (36). It is sufficient to verify that for the velocity of light expressed by formula (38), the average velocity on the way to the mirror and back is equal to

$$c'_{sr}=\frac{2L}{t'_{s\alpha'}+t'_{s(\pi-\alpha')}}=\frac{2L}{\frac{L}{\frac{c^2c_s}{c^2+c_sv\cos\alpha'}}+\frac{L}{\frac{c^2c_s}{c^2+c_sv\cos(\pi-\alpha')}}} \tag{39}$$

$$c'_{sr}=\frac{2}{\frac{c^2+c_sv\cos\alpha'}{c^2c_s}+\frac{c^2-c_sv\cos\alpha'}{c^2c_s}}=\frac{2}{\frac{2c^2}{c^2c_s}}=c_s \tag{40}$$

From dependence (40) it follows that c_s is also the average velocity of light on the way to the mirror and back in the material medium motionless in relation to the observer. Despite the fact that the velocity of light expressed by formula (38) depends on angle α' and velocity v, the average velocity of light on the way to the mirror and back is always constant and is equal to c_s.

7. Conclusion

Derived transformations (24)-(25) and (26)-(27) are consistent with the Michelson-Morley and Kennedy-Thorndike experiments. From the above transformations it follows that the measurement of the velocity of light in vacuum by means of the previously applied methods will always give the average value equal to c. This happens despite the fact that for the moving observer the velocity of light has a different value in different directions. The average velocity of light is always constant and independent of the velocity of the inertial frame of reference. Due to this property of the velocity of light, the Michelson-Morley and Kennedy-Thorndike experiments could not detect the universal frame of reference.

It follows from the conducted analysis that the explanation of the results of the Michelson-Morley experiment on the basis of the universal frame of reference is possible. Stating that the Michelson-Morley experiment proved that the velocity of light is absolutely constant is untrue. Stating that the Michelson-Morley experiment proved that there is no universal frame of reference in which light propagates and moves at a constant velocity is also untrue.

Admitting that the velocity of light may depend on the direction of its emission does not differentiate any direction in space. The velocity of light which is measured by the moving observer is significant here. It is the velocity at which the observer moves in relation to the universal frame of reference that differentiates the characteristic direction in space, but only for this observer. For the observer motionless in relation to the universal frame of reference, the velocity of light is always constant and does not depend on the direction of its emission. If the observer moves in relation to the universal frame of reference, then from his perspective space is not symmetrical. The case of this observer will be similar to the case of the observer moving on water and measuring the velocity of the wave on water. Despite that the wave propagates on water at the constant velocity in every direction, from the perspective of the observer moving on water, the velocity of the wave will be different in different directions.

At present, it is believed that the STR is the only theory explaining the Michelson-Morley and Kennedy-Thorndike experiments. This article proved that different theories in accordance with

these experiments are possible. In works [5], [8] and [9], a new physical theory of kinematics and dynamics of bodies based on the transformation determined here, called by the authors the Special Theory of Ether, was derived.

The Michelson-Morley experiment and Kennedy-Thorndike experiment were conducted many times by different teams. Also modified and improved versions of this experiment, like the experiment with sapphire crystals from 2015 [10], were conducted. Each of the experiments only confirmed that the average velocity of light is constant. Therefore, assumptions, on which the presented derivation is based, are experimentally justified.

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