Research Article Open Access

Journal of Modern Classical Physics & Quantum Neuroscience

ISSN: 3068-4196

DOI: doi.org/10.63721/26JPQN0152

A Kinetic Reflection-Based Explanation of the Negative Result in Michelson's Experiment and its Implications for Determining Earth's Velocity

Dimitrie Olenici[1*] and Stefan Bogdan Olenici-Craciunescu[2]

[1]*Astronomical Observatory, Stefan cel Mare University, Suceava, Romania*

[2]*Aumovio Technologies Romania*

Citation: *Dimitrie Olenici (2026) A Kinetic Reflection-Based Explanation of the Negative Result in Michelson's Experiment and Its Implications for Determining Earth's Velocity. J. of Mod Phy & Quant Neuroscience 2(1), 1-62. WMJ/JPQN-152*

Abstract

For more than a century, the Michelson–Morley experiment has stood as a cornerstone of modern physics — the "crucial experiment" that seemed to disprove the existence of the ether and paved the way for Einstein's theory of relativity. Yet, what if Michelson's famous null result did not mean the absence of the ether, but rather the limits of classical optics?

In this groundbreaking study, Michelson's experiment is revisited through the lens of kinetic optics - a new approach in which light reflected by moving mirrors behaves differently than in static conditions. Through detailed calculations, experimental data, and a critical re-examination of Michelson's assumptions, it is shown that the absence of fringe shifts can be fully explained by a phenomenon called kinetic reflection.

Combining historical analysis, theoretical rigor, and original experimental results, this article invites readers to reconsider one of the most iconic experiments in the history of science — not as a failure, but as a door toward a deeper understanding of light, motion, and the nature of space itself.

***Corresponding authour:** Dimitrie Olenici, Astronomical Observatory, Stefan cel Mare University, Suceava, Romania, Romania.

Submitted: 19.01.2026 **Accepted:** 21.01.2026 **Published:** 28.02.2026

Introduction

In 1881, A.A. Michelson conducted the so-called "experimentum crucis" to demonstrate Earth's movement through the light-propagating ether using an interferometer with perpendicular arms. One of the interferometer's arms was oriented parallel to Earth's velocity, and the other perpendicular to it. Michelson hoped that by rotating the interferometer by 90˚, he would observe a shift in the interference fringes of 0.04 of a fringe width. As is well known, the result was negative.

As is known, Michelson used a cross-shaped interferometer in which a light beam from a source S is split into two components by a half-silvered mirror placed diagonally between the interferometer arms. In Figure.1, we can see the original drawing proposed by Michelson [1].

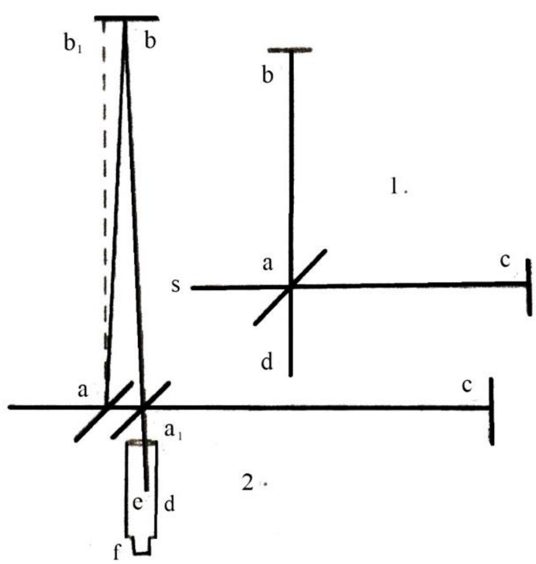


Figure1.1: Drawing from the original article by A. A. Michelson.

Notation:

s – light source

a – central mirror

b – mirror in the arm perpendicular to Earth's velocity

c – mirror in the arm parallel to Earth's velocity

Path of Light Rays in the Two Arms

Michelson describes the setup as follows: "Let it now be required to find the difference in the two paths, aba_1 and aca_1."

Let's consider:

V - velocity of light

v - velocity of the Earth in its orbit

D - distance from a to b or a to c (see Fig. 1.1 - 1)

T - time taken by light to travel from a to c

T_i - time taken by light to return from c to a′ (see Fig.1.1 - 2)

Then $T = \frac{D}{V-v}$, $T_i = \frac{D}{V+v}$. The whole time of going and coming is$\cdot T + T_i = 2D\frac{V}{V^2-v^2}$ and the distance traveled in this time is $2D\frac{V^2}{V^2-v^2} = 2D(1+\frac{v^2}{V^2})$, neglecting the fourth order terms. The length of the other path is evidently $2D\sqrt{1+\frac{v^2}{V^2}}$ or to the same degree of accuracy, $2D(1+\frac{v^2}{2V^2})$. The difference is therefore $D\frac{v^2}{V^2}$. If now the whole apparatus be turned through 90˚the difference will be in the opposite direction, hence the displacement of the interference fringes should be $2D\frac{v^2}{V^2}$. Considering only the velocity of the Earth in its orbit, this would be $2D \times 10^{-8}$. If, as was the case in the first experiment, $D = 2 \times 10^6$ waves of yellow light, the displacement to be expected would be 0.04 of the distance between the interfernce fringe.

In the first experiment one of the principal difficulties encountered was that of revolving the apparatus without producing distortion; and another was its extreme sensitiveness to vibration. This was so great that it was impossible to see the interference fringes except at brief intervals when working in the city, even at two o'clock in the morning. Finally, as before remarked, the quantity to be observed, namely, a displacement of something less than a twentieth of the distance between the interference fringes may have been too small to be detected when masked by experimental errors."

The experiment was repeated several times in different ways, but a fringe shift was never observed, nor was an explanation found.

Therefore, the experiment was repeated in 1887 with Edward Morley using an interferometer with arm lengths of 11m. This time, a shift in the ether wind of 8 km/s was obtained; however, the result was not considered satisfactory, and the research continued.

Following, we present a table with some of these experiments [2].

Name	**Location**	**Year**	**Arm length (meters)**	**Fringe shift expected**	**Fringe shift measured**	**Ratio**	**Upper Limit on Vaether**	**Expe-rimen-tal Reso-lution**	**Null result**
Michelson	Potsdam	1881	1.2	0.04	≤ 0.02	2	~ 20 km/s	0.02	≈
									yes
Michelson and Morley	Cleveland	1887	11	0.4	< 0.02	40	~ 4–8 km/s	0.01	≈
					or ≤ 0.01				yes
Morley and Miller	Cleveland	1902–1904	32.2	1.13	≤ 0.015	80	~ 3.5 km/s	0.015	Yes
Miller	Mt. Wilson	1921	32	1.12	≤ 0.08	15	~8–10 km/s	Unclear	Unclear
Miller	Cleveland	1923–1924	32	1.12	≤ 0.03	40	~ 5 km/s	0.03	Yes
Miller	Cleveland	1924	32	1.12	≤ 0.014	80	~ 3 km/s	0.014	Yes
(sunlight)									
Tomaschek	Heidelberg	1924	8.6	0.3	≤ 0.02	15	~ 7 km/s	0.02	Yes
(star light)									

Miller	Mt. Wilson	1925–1926	32	1.12	≤ 0.088	13	~ 8–10 km/s	Unclear	Unclear
Kennedy	Pasadena/Mt. Wilson	1926	2	0.07	≤ 0.002	35	~ 5 km/s	0.002	Yes
Illingworth	Pasadena	1927	2	0.07	≤ 0.0004	175	~ 2 km/s	0.0004	Yes
Piccard & Stahel	with a Balloon	1926	2.8	0.13	≤ 0.006	20	~ 7 km/s	0.006	Yes
Piccard & Stahel	Brussels	1927	2.8	0.13	≤ 0.0002	185	~ 2.5 km/s	0.0007	Yes
Piccard & Stahel	Rigi	1927	2.8	0.13	≤ 0.0003	185	~ 2.5 km/s	0.0007	Yes
Michelson et al	Pasadena (Mt. Wilson optical shop)	1929	25.9	0.9	≤ 0.01	90	~ 3 km/s	0.01	Yes
Joos	Jena	1930	21	0.75	≤ 0.002	375	~ 1.5 km/s	0.002	Yes

Recently, repetitions of the Michelson-Morley experiment have been conducted using other modern technologies, however, these are also not considered satisfactory because the values obtained are extremely small, around 30m/s, leading to the idea that the ether is partially or totally dragged along. See the table below.

Author	**Year**	**Description**	**Upper bounds**
Louis Essen	1955	The frequency of a rotating microwave cavity resonator is compared with that of a quartz clock	~3 km/s
Cedarholm et al.	1958	Two ammonia masers were mounted on a rotating table, and their beams were directed in opposite directions.	~30 m/s
Mössbauer rotor experiments	1960–68	In a series of experiments by different researchers, the frequencies of gamma rays were observed using the Mössbauer effect.	~2.0 cm/s
Jaseja et al.	1964	The frequencies of two He–Ne masers, mounted on a rotating table, were compared. Unlike Cedarholm et al., the masers were placed perpendicular to each other.	~30 m/s

Shamir and Fox	1969	Both arms of the interferometer were contained in a transparent solid (plexiglass). The light source was a Helium–neon laser.	~7 km/s
Trimmer et al.	1973	They searched for anisotropies of the speed of light behaving as the first and third of the Legendre polynomials. They used a triangle interferometer, with one portion of the path in glass. (In comparison, the Michelson–Morley type experiments test the second Legendre polynomial)[A 27]	~2.5 cm/s
Author	Year	Description	Δc/c
Wolf et al.	2003	The frequency of a stationary cryogenic microwave oscillator, consisting of sapphire crystal operating in a whispering gallery mode, is compared to a hydrogen maser whose frequency was compared to caesium and rubidium atomic fountain clocks. Changes during Earth's rotation have been searched for. Data between 2001 and 2002 was analyzed.	$\lesssim 10^{-15}$
Müller et al.	2003	Two optical resonators constructed from crystalline sapphire, controlling the frequencies of two Nd:YAG lasers, are set at right angles within a helium cryostat. A frequency comparator measures the beat frequency of the combined outputs of the two resonators.	
Wolf et al.	2004	See Wolf et al. (2003). An active temperature control was implemented. Data between 2002 and 2003 was analyzed.	
Wolf et al.	2004	See Wolf et al. (2003). Data between 2002 and 2004 was analyzed.	
Antonini et al.	2005	Similar to Müller et al. (2003), though the apparatus itself was set into rotation. Data between 2002 and 2004 was analyzed.	$\lesssim 10^{-16}$
Stanwix et al.	2005	Similar to Wolf et al. (2003). The frequency of two cryogenic oscillators was compared. In addition, the apparatus was set into rotation. Data between 2004 and 2005 was analyzed.	
Herrmann et al.	2005	Similar to Müller et al. (2003). The frequencies of two optical Fabry–Pérot resonators cavities are compared – one cavity was continuously rotating while the other one was	

		stationary oriented north–south. Data between 2004 and 2005 was analyzed.	
Stanwix et al.	2006	See Stanwix et al. (2005). Data between 2004 and 2006 was analyzed.	
Müller et al.	2007	See Herrmann et al. (2005) and Stanwix et al. (2006). Data of both groups collected between 2004 and 2006 are combined and further analyzed. Since the experiments are located at difference continents, at Berlin and Perth respectively, the effects of both the rotation of the devices themselves and the rotation of Earth could be studied.	
Eisele et al.	2009	The frequencies of a pair of orthogonal oriented optical standing wave cavities are compared. The cavities were interrogated by a Nd:YAG laser. Data between 2007 and 2008 was analyzed.	≲10−17
Herrmann et al.	2009	The frequencies of a pair of rotating, orthogonal optical Fabry–Pérot resonators are compared. The frequencies of two Nd:YAG lasers are stabilized to resonances of these resonators.	
Nagel et al.	2015	The frequencies of a pair of rotating, orthogonal microwave resonators are com	

This enigmatic subject has preoccupied us for over 40 years. During this time, we have analyzed various possible classical interpretations of the negative result of Michelson's experiment, including the replacement of the laws of classical static optics with those of kinetic optics, as well as their experimental verification [4, 5, 6, 7, 8].

Was Michelson Rrong?

After careful analysis, we concluded that Michelson started on the wrong track from the beginning, as follows:

- He assumed that when the interferometer is rotated by 90˚, the round-trip times in the two arms are reversed, but he did not verify this.
- He did not consider the second law of light reflection on the central mirror M.
- Another shortcoming of Michelson's reasoning is that he considers the reflection of light on the interferometer mirrors to be instantaneous, which is not true. This would mean a return to the ancient principle of action at a distance.

- The dilemma of the interferometer arm lengths: In his calculations, Michelson assumed that the arms of the interferometer were equal in length, which is optically very difficult to achieve.
- He did not take into account the fact that, along with the Sun, the Earth moves through the galaxy at a speed of 220 km/s and toward the Solar Apex at a speed of 16.5 km/s.
- Using the Huygens–Fresnel principle for moving mirrors (kinetic reflection), it is found that the direction of the reflected light beam matches Michelson's prediction, even when the central mirror is positioned on the bisector between the interferometer arms. This also holds true for the round-trip travel times of the light beams.
- Next, we will analyze one by one the inadvertences presented above.

Note: In his calculations, Michelson used series expansions of some terms. Nowadays we have very accurate computers and it is not necessary to use series expansions, which become complicated for large formulas.

Detailed Presentation of Michelson's Calculations

Let us once again represent the path of the light pulses in the arms of the interferometer, as found in the current works, Figure. 3.1.

We will use the following notations: L - the common length of the interferometer arms, c - the speed of light through the light-propagating ether, considered fixed, and v - the speed of the Earth through the ether. The two components that leave the central mirror M are reflected on mirrors A and B placed at the ends of the two interferometer arms and then return to the central mirror, forming interference fringes.

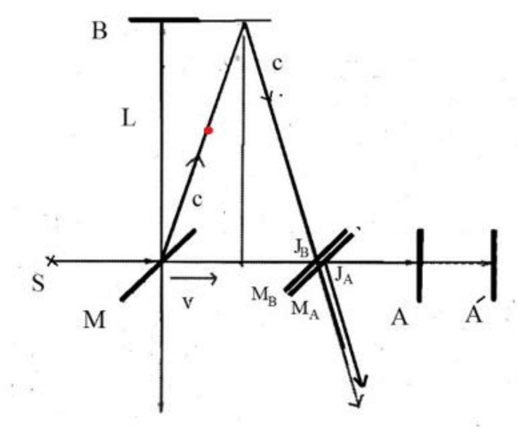


Figure 3.1: The true representation of the path of light pulses in Michelson's experiment.

Note: All our calculations are carried out in a reference frame attached to the presumed ether, considered fixed, through which light travels at a speed of $c = 300000\ km/s$, while the interferometer, along with the Earth, moves at a speed of $v = 30\ km/s$. In the following, by the notations T_A^0, T_A^{90}, T_A^{180}, T_A^{270} and T_B^{90}, T_B^{180}, T_B^{270}, T_B^{360} we understand the round-trip time intervals in arms A and B at positions 0˚, 90˚, 180˚, 270˚, and 360˚ counterclockwise relative to Earth's velocity.

In Michelson's opinion, by placing arm A parallel to Earth's velocity around the Sun and arm B perpendicular to it, the round-trip time in the two arms should be different. In arm MA, the round-trip time should be $T_A^0 = \frac{2Lc}{c^2-v^2}$, while the round-trip time in arm B is $T_B^{90} = \frac{2L}{\sqrt{(c^2-v^2)}}$ and the time difference between the two arms would be:

$$\delta T_{AB}^{0-90} = \frac{2Lc}{c^2 - v^2} - \frac{2L}{\sqrt{(c^2 - v^2)}} = \frac{2L}{c}\left(\frac{1}{1 - \frac{v^2}{c^2}} - \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}\right)$$

Taking into account that $v^2 \ll c^2$, and using serial development

$(1 - x)^n \approx 1 - nx$, Michelsin obtained:

$$\frac{2Lc}{c^2-v^2} = \frac{2L}{c}\left(\frac{1}{1-\frac{v^2}{c^2}}\right) \approx 2\frac{L}{c}\left(1 + \frac{v^2}{c^2}\right) \text{ and } \frac{2L}{\sqrt{(c^2-v^2)}} \approx \frac{2L}{c}\left(1 + \frac{v^2}{2c^2}\right)$$

The difference DT_{AB}^{0-90} has the value:

$$\delta T_1 = T_{AB}^{0-90} = 2\frac{L}{c}\left(1 + \frac{v^2}{c^2} - 1 - \frac{v^2}{2c^2}\right) = 2\frac{L}{c}\frac{v^2}{2c^2} = \frac{L}{c} \cdot 10^{-8}\ s/m$$

Numerically $\delta T_1 = T_{AB}^{0-90} = Lx3.333333333x10^{-9}\ s/m$

Take in account that $L = 1.2m$ this has the value:

$$\delta T_1 = T_{AB}^{0-90} = 4x10^{-9}s$$

In this case, considering that $c\Delta t = \Delta\lambda$, the optical path difference between the two arms becomes $\varDelta\lambda_1 = c \cdot$

$\delta T_1 = L \times 10^{-8}$.

According to Michelson:

If now the whole apparatus be turned through 90º, the difference will be in the opposite direction, hence the displacement of the interference fringes should be $2D\frac{v}{c}$. Considering only the velocity of the Earth in its orbit, this would be $2D \times 10^{-8}$. If, as was the case in the first experiment, $D = 2 \times 10^{-8}$ waves of yellow light, the displacement to beexpected would be 0.04 of the distance between the interference fringes."

Upon a 90° rotation, the round-trip times in the two arms are reversed, meaning:

$T_A^{90} = \frac{2L}{\sqrt{(c^2-v^2)}}$ and $T_B^{180} = \frac{2L}{\sqrt{(c^2-v^2)}}$

Now, according to Michelson, the difference in round-trip time intervals in the two arms becomes:

$$\delta T_2 = T_A^{90} - T_B^{180} = \frac{2L}{\sqrt{(c^v - v^2)}} - \frac{2Lc}{c^2 - v^2}$$

In this case, $\Delta\lambda_2 = -\Delta\lambda_1$ and upon rotating the interferometer by 90°, a fringe shift appears, given by the formula:

$$N = \frac{\Delta\lambda_1 - \Delta\lambda_2}{\lambda}$$

For $L = 1.2m$ and the wavelength $\lambda = 5.9 \times 10^{-7}m$ we obtain $N = 0.04$ fringe.

Observation: Over time, researchers have proposed various interpretations of the negative result of the Michelson experiment. The most famous and unanimously accepted to date is offered in the framework of Albert Einstein's theory of relativity.

A short material is to be prepared ……………….

The Arrow of time and The Arrow of Differences

Considering that the arrow of time points from past to future, we cannot take negative time intervals into account.

Therefore, when rotating the interferometer, we measure how the optical path difference between the light sources in the two arms changes, as well as the position of the interference fringe. To understand this, let us analyze what happens when we switch the positions of the light sources see Figure. 4.1.

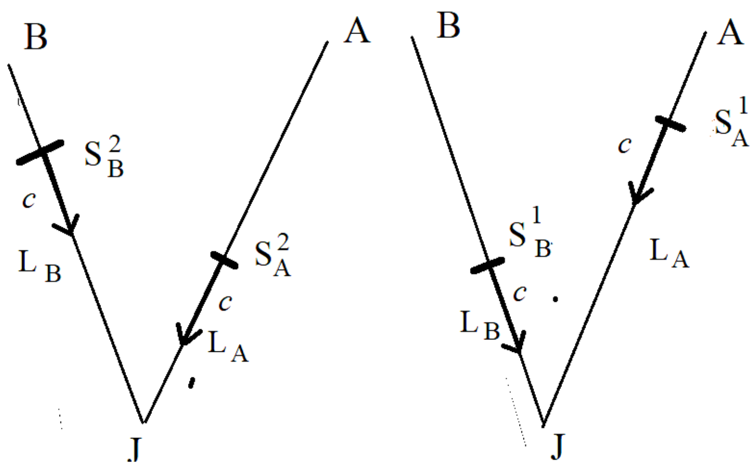


Figure 4.1: Interferometer with portable light sources.

Let us imagine an interferometer with two light sources placed on two fixed rods, A and B, whose positions can be adjusted along these rods.

1. The light sources are initially located at positions S_A^1 and S_B^1. The light pulses from these sources interfere at point J. They travel distances L_A^1 and L_B^1, respectively, and the optical path difference is:

$$\Delta\lambda_1 = L_A^1 - L_B^1$$

2. Now, the light sources are at positions S_A^2 and S_B^2. The light pulses now travel distances L_A^1 and L_B^1, and the optical path difference is:

$$\Delta\lambda_2 = L_B^2 - L_A^2$$

If $L_A^1 = L_B^2$ and $L_B^1 = L_A^2$ then$\Delta\lambda_1 = \Delta\lambda_2$, and even if we switch the positions of the sources, no fringe shift will appear at point J!

From our point of view, a similar situation occurs when rotating Michelson's interferometer. In other words, both in the initial position and after a 90° rotation, the optical path differences have positive and equal values:

$$\delta T_{AB}^{0-90} = \delta T_{BA}^{180-90}$$

and the difference of the differences is zero:

$T_A^0 = \frac{2Lc}{c^2-v^2}$ and $T_B^{90} = \frac{2L}{\sqrt{(c^2-v^2)}}$

$$\delta T_{AB}^{0-90} = \frac{2Lc}{c^2-v^2} - \frac{2L}{\sqrt{(c^2-v^2)}}$$

$T_A^{90} = \frac{2L}{\sqrt{(c^2-v^2)}}$ and $T_B^{180} = \frac{2Lc}{c^2-v^2}$

$$\delta T_{BA}^{180-90} = \frac{2Lc}{c^2-v^2} - \frac{2L}{\sqrt{(c^2-v^2)}}$$

$$\Delta T = \delta T_{AB}^{0-90} - \delta T_{BA}^{180-90} =$$

$$= \left(\frac{2Lc}{c^2-v^2} - \frac{2L}{\sqrt{(c^2-v^2)}}\right) - \left(\frac{2Lc}{c^2-v^2} - \frac{2L}{\sqrt{(c^2-v^2)}}\right) \equiv 0$$

In conclusion, since the optical path differences are equal when the interferometer is rotated by 90°, no fringe shift can occur. This could be one of the explanations for the null result of Michelson's experiment

Reconsidering The Calculations by Taking into Account an Interferometer with Arms of Different Lengths

In his experiments, Michelson assumed that the arms of the interferometer had the same length. In reality, from a technical standpoint, this is impossible to achieve at the level of a wavelength. Even if the difference is only a few wavelengths, this discrepancy no longer aligns with the calculations previously presented.

In the following, we present how the theoretical calculations appear in the case of an interferometer with arms of different lengths, both in the initial position and after a 90° rotation Fig 5.

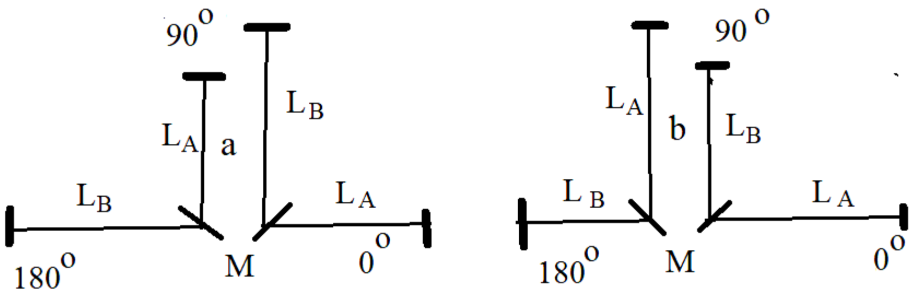


Figure 5: Positions of an interferometer with unequal arms:
a) Arm $L_B > L_A$; b) Arm $L_A > L_B$

In the initial position, the round-trip time difference is:

$$\delta T_{AB}^{0-90} = 2 \cdot L_A \frac{c}{(c^2 - v^2)} - 2 \cdot L_B \frac{1}{\sqrt{c^2 - v^2}}$$

After a 90° rotation, this becomes:

$$\delta T_{AB}^{90-180} = 2 \cdot L_A \frac{1}{\sqrt{c^2 - v^2}} - 2 \cdot L_B \frac{c}{(c^2 - v^2)}$$

The difference of the differences thus becomes:

$$\Delta T = \left(2L_A \frac{c}{(c^2 - v^2)} - 2L_B \frac{1}{\sqrt{c^2 - v^2}}\right) - \left(2L_A \frac{1}{\sqrt{c^2 - v^2}} - L_B \frac{c}{(c^2 - v^2)}\right)$$

$$\Delta T = 2(L_A + L_B) \cdot \frac{c}{(c^2 - v^2)} - 2(L_A + L_B) \cdot \frac{1}{\sqrt{c^2 - v^2}}$$

$$= 2(L_A + L_B) \cdot \left(\frac{c}{(c^2 - v^2)} - \frac{1}{\sqrt{c^2 - v^2}}\right)$$

a) Case when arm $L_A > L_B$(Figure. 5.b)

Let us consider, for example, that $L_B = 0.95L_A$. In this case, the difference Δ_a becomes:

$$\Delta a = 2(L_A + 0.95L_A)\left(\frac{c}{(c^2 - v^2)} - \frac{1}{\sqrt{c^2 - v^2}}\right) = 2 \cdot 1.95 \cdot L_A\left(\frac{c}{(c^2 - v^2)} - \frac{1}{\sqrt{c^2 - v^2}}\right)$$

At the limit, for increasingly smaller differences:

$$\Delta_a \approx 4L_A\left(\frac{c}{(c^2 - v^2)} - \frac{1}{\sqrt{c^2 - v^2}}\right)$$

b) Case when arm $L_B > L_A$ (Figure. 4.a)

Let us consider, for example, that $L_A = 0.95L_B$. In this case, the difference Δ_b becomes:

$$\Delta_b = 2(0.95L_B + L_B)\left(\frac{c}{(c^2 - v^2)} - \frac{1}{\sqrt{c^2 - v^2}}\right) = 2 \cdot 1.95 \cdot L_B\left(\frac{c}{(c^2 - v^2)} - \frac{1}{\sqrt{c^2 - v^2}}\right)$$

And in this case, in the limit: $\Delta_b \approx 4L_B\left(\frac{c}{(c^2 - v^2)} - \frac{1}{\sqrt{c^2 - v^2}}\right)$

Therefore, since the two arms are never perfectly equal, a more realistic approach for the time interval difference is to use the formula $\Delta T \approx 4L \cdot \left(\frac{c}{(c^2 - v^2)} - \frac{1}{\sqrt{c^2 - v^2}}\right)$ where L represents the common length assumed by the experimenter.

The Actual Path of Light Rays in the Interferometer Arms When the Central Mirror Makes Angles Of 45° With the Interferometer Arms

As is known, Michelson considers that the path of the light impulse from arm A, after the 90° rotation of the interferometer, appears as shown in Fig. 6.1. He does not explain how the light impulse, which passes through mirror M and should travel in a straight line toward mirror A, is deflected toward point JA, and then, after reflection from it, meets the central mirror again at position M′.

Also, Michelson believes that the return of the light pulses to different points does not influence the results.

” It may be remarked that the rays ba and ca do not now meet exactly in the same point a_i though the difference is of the second order; this does not affect the validity of reasoning.”

But he does not specify what the maximum distance between these points is and his calculations are as if the light pulses meet again at the same point.

In the ether reference system, the light pulses return to the central mirror at points J_A and J_B located at a distance $p = J_A J_B$ gived by formula:

$$p = v\sqrt{(J_A^2 + J_B^2)}$$

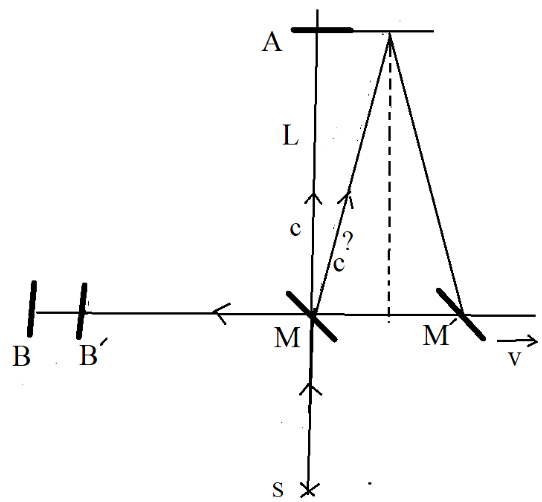


Figure 6.1: The dilemma of the direction of the light impulse in arm A during the 90° rotation of the interferometer.

Next, let us analyze the round-trip time and the return positions pp of the light impulses on the central mirror. In our calculations, we will forgo series expansions and approximations, and instead use an electronic computer, which provides us with highly precise results.

Let's assume that the central mirror M is on the bisector between the interferometer arms, making angles of 45˚ with them, and that the light reflection occurs instantaneously on its mirrors.

Calculation of the Round-Trip Time When Arm A Is Parallel to Earth's Velocity, And Arm B Is Perpendicular to Earth's Velocity

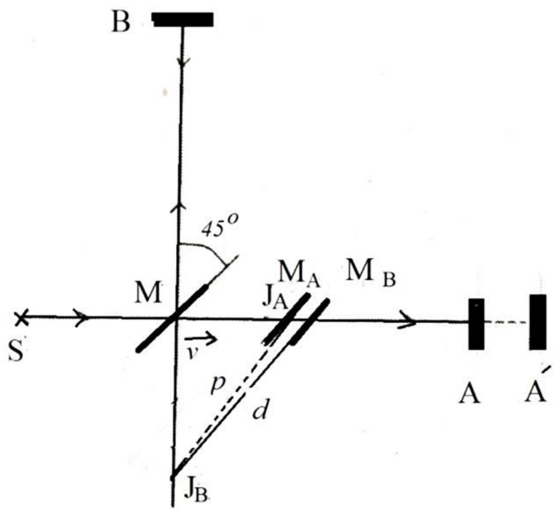


Figure. 6.2: The Path of Light Pulses in the Initial Position of the Interferometer with the Central Mirror Placed at 45˚ Relative to the Interferometer Arms.

a) Calculation of the round-trip time T_A^0 in arm A

From Fig. 6.2, we observe that the light pulse leaves point M, reaches the mirror of arm A at point A′, and returns to the central mirror at the point marked J_A.

In this case, we can write the relations:

-On the way out: $cT_i = L + vT_i$ and thus $T_i = \frac{L}{c-v}$

-On the way back: $cT_r = L - vT_r$ and thus $T_r = \frac{L}{c+v}$

The total time $T_A^0 = T_i + T_r = \frac{2Lc}{c^2-v^2}$ evidently has the same value as proposed by Michelson:

$$T_A^0 = \frac{2Lc}{c^2 - v^2}$$

b) Calculation of the round-trip time in arm B placed at 90˚ relative to Earth's velocity.

Similarly, from Fig. 6.2, we observe that the light pulse leaves point M, is reflected by the mirror of arm B at point B, and returns to the central mirror at point J_B. Here, we can write the relations:

- On the way out: $cT_i = L$ and $T_i = \frac{L}{c}$
- On the way back: $c \cdot T_r = L + MJ_B$, but $MJ_B = v \cdot T_B$ and the return time becomes: $cT_r = L + vT_B^{90}$, $T_r = \frac{L}{c} + \frac{v}{c}T_B^{90}$

The total time becomes:

$$T_B^{90} = \frac{2L}{c - v}$$

In this case, the time differences become:

$$\delta T_{AB}^{0-90} = \frac{2Lc}{c^2 - v^2} - \frac{2L}{c - v}$$

Numerically, for L=1.2m the difference δT_{AB}^{0-90} has the value:

$$\delta T_{AB}^{0-90} = -\,8.000000079988467 \times 10^{-13} s$$

On the other hand, we also find that the light pulses that leave the central mirror M from the same point, return to it at different points J_A and J_B. The distance $p = J_A J_B$ is calculated with the formula:

$$p = J_{AB} = v\sqrt{(T_A^2 + T_B^2)}$$

In this case $p = v\sqrt{\left(\frac{2Lc}{c^2 - v^2}\right)^2 + \left(\frac{2L}{c - v}\right)^2} = 2 \cdot L \times 0.00014142842\ s/m$

For $L = 1.2m$ we get that, $p \approx 0.339mm$

Calculation Of the Round-Trip Time in The Interferometer Arms When They Are Rotated By 90˚ From The Initial Position

If Michelson had been curious enough to analyze the path of the light rays and the round-trip time intervals in the two arms rotated by 90˚, he would have found that they do not reverse and are not equal either Fig.6.3.

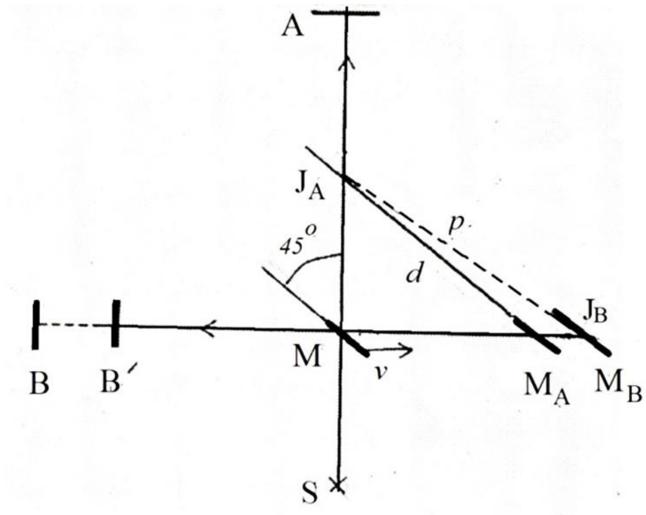


Figure 6.3: The path of light pulses in the interferometer rotated by 90˚ and with the central mirror positioned at 45˚ relative to the interferometer arms.

a) Calculation of the round-trip time in arm A positioned at 90˚ relative to Earth's velocity.

In this case, the path of the light rays looks like in Fig.6.3 and we can write the relationships.

- On the way, the incident ray travels the distance MA, and we can write:

$cT_i = MA = L$ and $T_i = \frac{L}{c}$

- On the return, the reflected ray travels the distance AJ_A and we can write:

$cT_r = L - AJ_A$, but $AJ_A = vT_A$ (since the central mirror M is positioned at 45˚)

$cT_r = L - vT_A$, $T_r = \frac{L}{c} - \frac{v}{c}T_A$

The total round-trip time becomes:

$T_A = T_i + T_r = \frac{L}{c} + \frac{L}{c} - \frac{v}{c}T_A$, $T_A\left(1 + \frac{v}{c}\right) = \frac{2L}{c}$

$$T_A^{90} = \frac{2L}{c + v}$$

b) Calculation of the round-trip time in arm B positioned at 180˚ (antiparallel) relative to Earth's velocity.

In this case, from Figure.6.3, we observe that the light pulse leaves point M, reflects on the mirror of arm B at point B', and meets the central mirror again at point J_B. Here we can write the relationships:

- on the way out: $cT_i = L - vT_i$ and $T_i = \frac{L}{c+v}$

- on the way back: $cT_r = L + vT_r$ and $T_r = \frac{L}{c-v}$

The total round-trip time becomes:

$$T_B = T_i + T_r = \frac{2Lc}{c^2 - v^2}$$

$$T_B^{180} = \frac{2Lc}{c^2 - v^2}$$

Now the time difference becomes:

$$\delta T_{AB} = T_A^{90} - T_B^{180} = \frac{2L}{c+v} - \frac{2Lc}{c^2 - v^2}$$

$$\delta T_{AB}^{90-180} = \frac{2L}{c+v} - \frac{2Lc}{c^2 - v^2} = -\frac{2Lv}{c^2 - v^2} = -\frac{2L}{v(10^8 - 1)}$$

Numerical: $\delta T_{AB}^{90-180} = -L \times 6.666666733333335 \times 10^{-13}\, s/m$

For $L = 1.2m$ we get:

$\delta T_{AB}^{90-180} = -8.000000080000001 \times 10^{-13}$s

In this case the distance $p = J_A J_B$ has the value:

$$p = v\sqrt{\left(\frac{\mathbf{2}Lc}{\boldsymbol{c^2 - v^2}}\right)^2 + \left(\frac{2L}{c+v}\right)^2} = L \times 2.8 \times 10^4 = 0.336\, mm$$

$$p \approx 0.336mm$$

Calculation of the Round-Trip Time When Arm a Is At 180° Relative to Earth's Velocity and Arm B is At 270° Relative to Earth's Velocity

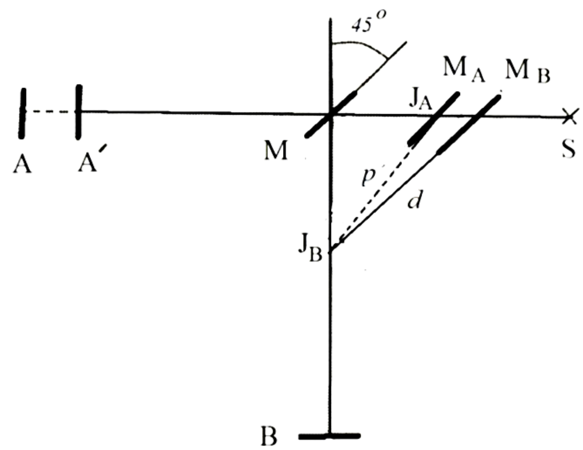


Figure 6.4: The path of the light pulse in arm A positioned at 180° relative to Earth's velocity and arm B is at 270° relative to Earth's velocity.

a) Calculation of the round-trip time in arm A

- On the way: $cT_i = L - vT_i$ and $cT = \frac{L}{c+v}$

- On return: $cT_r = L + vT_r$ and $cT_r = \frac{L}{c-v}$

The total time becomes: $T_A^{180} = \frac{2Lc}{c^2-v^2}$

b) Calculation of the round-trip time in arm B

- On the way: $cT_i = L$ and $T_i = \frac{L}{c}$

- On return: $cT_r = L - vT_B$ and $T_r = \frac{L}{c} - \frac{v}{c}T_B$,

$T_B = Tr + Ti = \frac{2L}{c} - \frac{v}{c}T_B$ and $T_B\left(1 + \frac{v}{c}\right) = \frac{2L}{c}$,

$$T_B = \frac{2L}{c+v}$$

In this case, the time difference becomes:

$$\delta T_{AB}^{180-270} = \frac{2Lc}{c^2 - v^2} - \frac{2L}{c+v} = \frac{2Lv}{c^2 - v^2}$$

$$\delta T_{AB}^{180-270} = \frac{2Lv}{c^2 - v^2} = \frac{2L}{v(10^8 - 1)}$$

Numerical: $\delta T_{AB}^{180-270} = L \times 6.666666733333335 \times 10^{-13}\, s/m$

For $L = 1.2m$ we get:

$$\delta T_{AB}^{180-270} = 8.000000080000001 \times 10^{-13} s$$

and

$$p \approx 0.339mm$$

Calculation of the Round-Trip Time When Arm A Is At 270° Relative to Earth's Velocity And Arm B Is At 360° Relative to Earth's Velocity

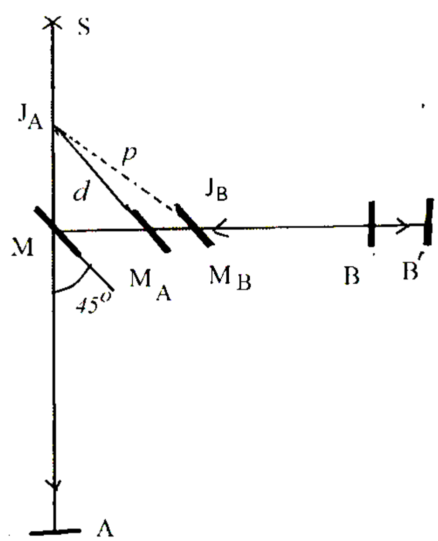


Figure 6.5: The path of the light pulse in arm B positioned at 360° relative to Earth's velocity and arm A at 270°relative to Earth velocity.

a) Calculation of the round-trip time in arm A

Time on the way: $cT_i = L$ and, $T_i = \frac{L}{c}$

Time on return: $cT_r = L + vT_A$ and $T_r = \frac{L}{c} + \frac{v}{c} T_A$

The total time becomes: $T_A^{270} = \frac{2L}{c-v}$

b) Calculation of the round-trip time in arm B

-Time on the way: $cT_i = L + vT_i$ and $T_i = \frac{L}{c-v}$

-Time on return: $cT_r = L - vT_r$ and $T_r = \frac{L}{c+v}$

The total time becomes: $T_B^{360} = \frac{2Lc}{c^2-v^2}$

Time difference: $\delta T_{AB}^{270-360} = \frac{2L}{c-v} - \frac{2Lc}{c^2-v^2} = \frac{2Lv}{c^2-v^2} = 2L \times \frac{1}{v(10^8-1)}$

Numerically, it has the value:

$$\delta T_{AB}^{270-360} = L \times 6.666666733333335 \times 10^{-13}\, s/m$$

For $L = 1.2m$ we get:

$$\delta T_{AB}^{270-360} = \quad 8.000000080000001 \times 10^{-13} s$$

In this case the deviation p has also the value: $p \approx 0.339mm$

Let's now calculate the difference of the differences and the shift of the interference fringes. We denote the difference of the differences in the four positions of the interferometer by $\Delta T_1, \Delta T_2, \Delta_{T3}, \Delta T_4$.

$$\Delta T_1 = \delta T_0^{90} - \delta T_{90}^{180} = \left(\frac{2Lc}{c^2 - v^2} - \frac{2L}{c - v)}\right) - \left(\frac{2L}{c + v} - \frac{2Lc}{c^2 - v^2}\right) \equiv 0$$

Considering that $D\lambda = c \cdot \Delta T$ and $N = \frac{D\lambda}{\lambda}$ we obtain: $D\lambda = c \cdot 0 = 0$ and $N_1 = 0$

$$\Delta T_2 = \delta T_{90}^{180} - \delta T_{180}^{270} = \left(\frac{2l}{c + v} - \frac{2Lc}{c^2 - v^2}\right) - (\frac{2Lc}{c^2 - v^2} - \frac{2L}{c + v}) = \frac{-4Lv}{c^2 - v^2}$$

$$\Delta\, T_2 = -4L \cdot \frac{1}{v(10^8 - 1)}$$

In this case $\Delta\, T_2 = -L \times 1.333333346666667 \times 10^{-12} s/m$

For$L = 1.2m$ we get:

$$D\lambda_2 = -0.00048m$$

According to Michelson's logic, for $L = 1.2m$ și $\lambda = 5.9 \times 10^{-7}m$ the fringe shift should be:

$$N_2 = \frac{D\lambda_2}{\lambda} = -813{,}589$$

In this case, the fringe shift is approximately 20340 times greater than Michelson's estimated shift and is in the opposite direction.

$$\Delta_3 = DT_{180}^{270} - DT_{270}^{360} = \left(\frac{2Lc}{c^2 - v^2} - \frac{2L}{c+v}\right) - \left(\frac{2L}{c-v} - \frac{2Lc}{c^2 - v^2}\right) =$$

$$= \frac{4Lc}{c^2 - v^2} - \frac{4Lc}{c^2 - v^2} = 0$$

In this case, the fringe shift is $N_3 = 0$N3

$$\Delta_4 = DT_{270}^{360} - DT_{0}^{90} = \left(\frac{2L}{c-v} - \frac{2Lc}{c^2 - v^2}\right) - \left(\frac{2Lc}{c^2 - v^2} - \frac{2L}{c-v}\right) = \frac{4L}{v(10^8 - 1)}$$

$$\Delta_4 = \frac{4Lv}{c^2 - v^2} = L \times 1{,}333333346666667 \times 10^{-12} s/m$$

For $L = 1.2m$ we get $D\lambda 4 = 0.00048m$

In this case the fringe shift:

$$N_4 = \frac{D\lambda_4}{\lambda} = -813{,}589$$

In this case, the fringe shift has the value: $N_4 = 813.559$ and is positive.

It is worth noting that at 90° and 180° rotations, no fringe shift occurs, while at 180° and 270° rotations, very large fringe shifts of $\pm 813{,}559$ appear.

On the other hand, we observe that upon return, the light pulses meet the central mirror at different points, J_A and J_B between which there is a distance $p \approx 0.339mm$.

Since ∂J_{AB} is proportional to L, it means that increasing the length of the interferometer arms would not lead to a better result but would instead reduce the chances of detecting the shift of the interference fringes.

In conclusion from this study, we find that for different positions of the interferometer used by Michelson in 1881, the fringe displacement can vary between ± 815.559 and that the light pulses return to different points on the central mirror located at about $0.339mm$. These inconsistent results regarding fringe displacement compel us to explore other explanations for the negative outcome of Michelson's experiment.

Calculation of Time Intervals Considering the Second Law of Light Reflection

In Figure. 7.1, we can see the path of the light pulses in the two arms and the corresponding times as encountered in most studies regarding Michelson's experiment [3].

Arm A is positioned parallel to Earth's velocity and makes an angle of 0° with it, while arm B makes an angle of 90° relative to Earth's velocity.

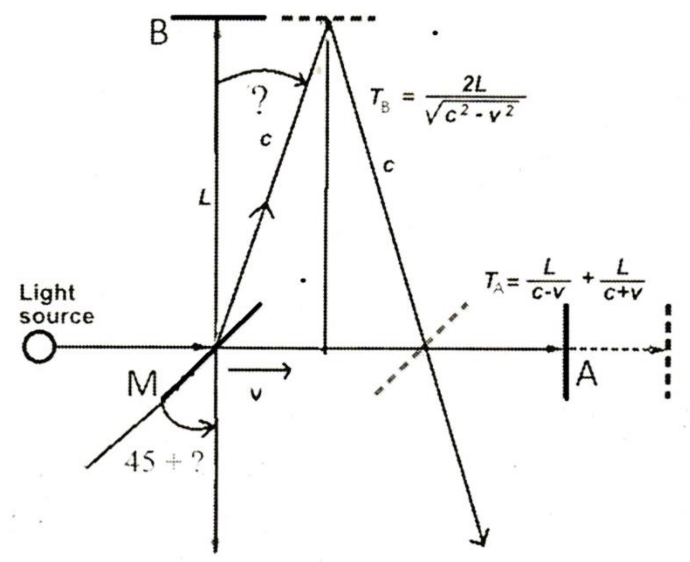


Figure 7.1: The position of the central mirror and the path of the light pulses in the interferometer-arms in the usual presentation of Michelson's experiment.

Michelson assumed that the path of the light beam in arm B looks like in Fig. 7.1 but does not specify the position of the central mirror that determines the direction of the reflected beam. In accordance with the second law of reflection one solution for the light pulses to return to the same point as Michelson requested is for the central mirror to be rotated by a small angle relative to the bisector between the arms of the interferometer.

Let's denote by γ the angle made by the light beam reflected by the central mirror M and the arm B of the interferometer. Considering the second law of reflection, we deduce that the central mirror M must make an angle of $45^{\circ} + \frac{\gamma}{2}$ with arm B, and $45^{\circ} - \frac{\gamma}{2}$ with arm A, as shown in Figure. 7.2.

From the analysis of Fig. 7.2, we observe that we can write: $sin\,\gamma = \frac{v}{c} = 10^{-4}$ and $\gamma = 20.63''$.

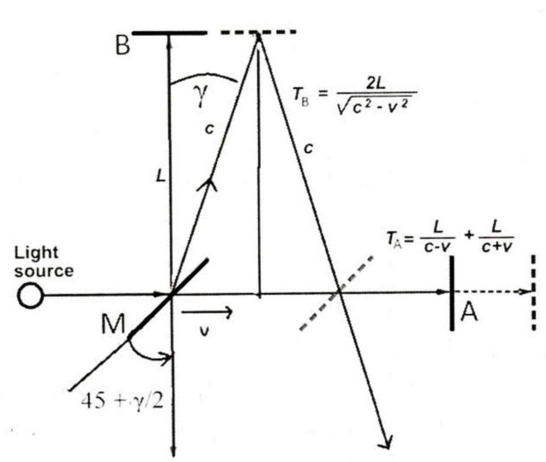


Figure 7.2: The correct position of the central mirror M relative to the arms of the interferometer according to which Michelson's calculations are valid.

Let's now recalculate the round-trip times in the arms of the interferometer in the initial position and at rotations of 90˚, 180˚, and 270˚.

Calculation of the Round-Trip Times In Arm A Positioned Parallel To Earth's Velocity And Arm B Positioned Perpendicular To Earth's Velocity

In this case, it is evident that the round-trip times are literally the same as those found by Michelson, namely: $T_A^0 = \frac{2Lc}{c^2-v^2}$ and $T_B^{90} = \frac{2L}{\sqrt{c^2-v^2}}$,

However, numerically, if we do not expand in series, and take in account that $c = v \times 10^4$ the time difference becomes:

$$\delta(T_A^0 - T_B^{90}) = \frac{2Lc}{c^2 - v^2} - \frac{2L}{\sqrt{c^2 - v^2}} = \frac{2L}{v \times 10^4}\left(\frac{1}{1 - 10^{-8}} - \frac{1}{\sqrt{1 - 10^{-8}}}\right)$$

Numerically this is:

$$\delta T = \frac{2L}{3 \times 10^4} \cdot 4.999999969612645 \times 10^{-9}\, s/m$$

For $L = 1.2m$ we get:

$$\delta T^1 = \delta T^{0-90} = 3.9999999756901156 \times 10^{-17} s$$

Calculation Of the Round-Trip Time When The Interferometer Is Rotated By 90°

a) Calculation of the round-trip time T_A^{90}in arm A

In arm A looks like in Fig. 7.3, and the beam reflected by mirror A meets the central mirror M at point J_A. We can write the following relationships:

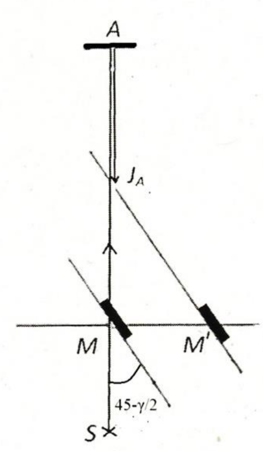


Figure.7.3: The path of the light pulse in arm A positioned at 90° relative to Earth's velocity.

-Calculation of the outgoing time T_i: $cT_i = L$; $T_i = \frac{L}{c}$

-Calculation of the return time T_r: $cT_r = AJ_A = L - MJ_A$,

However, $MJ_A = MM' \, tan\left(45^\circ + \frac{\gamma}{2}\right)$where $MM' = vT_A$

$cT_r = L - vT_A \, tan\left(45^\circ + \frac{\gamma}{2}\right)$, where:

$$tan\left(45^\circ + \frac{\gamma}{2}\right) = \frac{\left(cos\frac{\gamma}{2} + sin\frac{\gamma}{2}\right)}{\left(cos\frac{\gamma}{2} - sin\frac{\gamma}{2}\right)} = \frac{\sqrt{(1 + sin\,\gamma)}}{\sqrt{(1 - sin\,\gamma)}}$$

Replacing $sin\,\gamma = \frac{v}{c}$, after performing the calculations, we find:

$$T_r = \frac{L}{c} - \frac{v}{c} \cdot T_A \cdot \frac{\sqrt{c+v}}{\sqrt{c-v}}$$

$$T_A^{90} = T_i + T_r = \frac{2L}{c} - \frac{v}{c} \cdot T_A \cdot \frac{\sqrt{c+v}}{\sqrt{c-v}}$$

$T_A^{90}\left(1 + \frac{v}{c} \cdot \frac{\sqrt{c+v}}{\sqrt{c-v}}\right) = \frac{2L}{c}$ $\qquad$ $T_A^{90} = \frac{2L}{v(10^4 + \frac{\sqrt{10^4+1}}{\sqrt{10^4-1}})}$

Numerically this is:

$$T_A^{90} = L \times 6{,}666000133310005 \times 10^{-9}\, s/m$$

For $L = 1.2m$ we get:

$$T_A^{90} = 7.999200159972006 \times 10^{-9} s$$

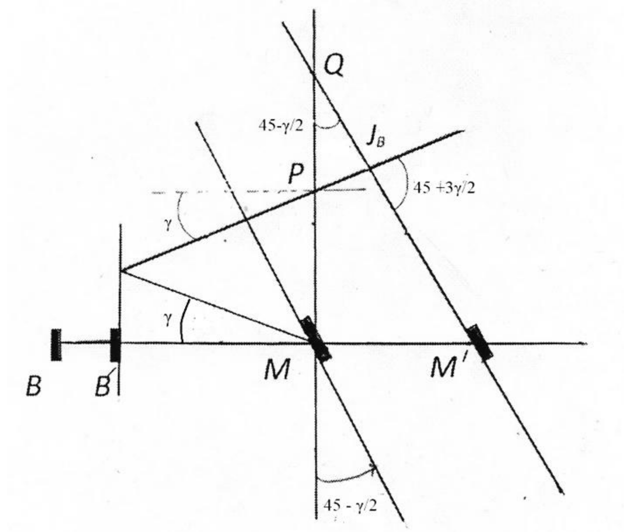


Figure 7.4: The path of the light pulse in arm B positioned at 180˚ relative to Earth's velocity.

b) Calculation of the round-trip times when arm B is rotated by 180˚ relative to Earth's velocity-T_B^{180}

In this case, the path of the light pulse in arm B looks like in Fig. 7.4.

-Calculation of the outgoing time: T_i^{180}

From Fig. 5.4, we observe that we can write: $BM = L, \frac{L-vT_i}{cT_i^{180}} = cos\,\gamma$

$L = vT_i^{180} + cT_i^{180}\,cos\,\gamma$ from which: $T_i^{180} = \frac{L}{v+c\,cos\,\gamma}$

- Calculation of the return time T_r^{180}

Since the central mirror M makes an angle of $45^{\circ} - \frac{\gamma}{2}$ with arm B, after reflection on mirror B at point B', the light pulse meets the central mirror at point J_B. In this case, we can write the relationships: $cT_r^{180} = B'P + PJ_B = cT_i^{180} + PJ_B$.

In the triangle PQJB, we can write the relationships:

$$\frac{PJ_B}{sin\left(45^{\circ} - \frac{\gamma}{2}\right)} = \frac{PQ}{sin\,\beta}$$

Where: $\beta = 180^{\circ} - \left(45^{\circ} - \frac{\gamma}{2}\right) - (90^{\circ} - \gamma) = 45^{\circ} + 3\frac{\gamma}{2}$

$$PQ = MQ - MP$$

where MP is obtained from the relationship $\frac{\frac{MP}{2}}{cT_i} = sin\,\gamma$ and has the value:

$MP = 2cT_i = \frac{L}{v+c\,cos\,\gamma}$, MQ is obtained from the relationship: $\frac{MQ}{MM'} = tan\left(45^\circ + \frac{\gamma}{2}\right)$ where $MM' = vT_B^{180}$.

By substituting, we obtain: $PQ = v\,tan\left(45^\circ + \frac{\gamma}{2}\right) \cdot T_B^{180} - 2cT_i^{180}\,sin\,\gamma$ and

$$PJ_B = PQ \cdot \frac{sin\left(45^\circ - \frac{\gamma}{2}\right)}{sin\left(45^\circ + 3\frac{\gamma}{2}\right)}$$

By expanding, we obtain: $cT_r^{180} = cT_i^{180} + \frac{PQ \cdot sin\left(45^\circ - \frac{\gamma}{2}\right)}{sin\left(45^\circ + 3\frac{\gamma}{2}\right)} =$

$$= cT_i^{180} + \left[vT_B^{180}\left(\frac{sin\left(45^\circ + \frac{\gamma}{2}\right)}{sin\left(45^\circ - \frac{\gamma}{2}\right)}\right) - 2cT_i^{180}\,sin\,\gamma\right] \cdot \frac{sin\left(45^\circ - \frac{\gamma}{2}\right)}{sin\left(45^\circ + 3\frac{\gamma}{2}\right)}$$

$$cT_r^{180} = cT_i^{180}(1 - 2\,sin\,\gamma)\frac{sin\left(45^\circ - \frac{\gamma}{2}\right)}{sin\left(45^\circ + 3\frac{\gamma}{2}\right)} + vT_B^{180}\,tan\left(45^\circ + \frac{\gamma}{2}\right)\frac{sin\left(45^\circ + \frac{\gamma}{2}\right)}{sin\left(45^\circ + 3\frac{\gamma}{2}\right)}$$

$$T_r^{180} = T_i^{180}(1 - 2\,sin\,\gamma)\frac{sin\left(45^\circ - \frac{\gamma}{2}\right)}{sin\left(45^\circ + 3\frac{\gamma}{2}\right)} + \frac{v}{c}T_B^{180}\,tan\left(45^\circ + \frac{\gamma}{2}\right)\frac{sin\left(45^\circ - \frac{\gamma}{2}\right)}{sin\left(45^\circ + 3\frac{\gamma}{2}\right)}$$

Considering that $T_B^{180} = T_i^{180} + T_r^{180}$, we find:

$$T_B^{180} = 2T_i^{180}(1 - sin\,\gamma)\frac{sin\left(45^\circ + \frac{\gamma}{2}\right)}{sin\left(45^\circ + 3\frac{\gamma}{2}\right)} + \frac{v}{c}T_B^{180}\,tan\left(45^\circ + \frac{\gamma}{2}\right)\frac{sin\left(45^\circ - \frac{\gamma}{2}\right)}{sin\left(45^\circ + 3\frac{\gamma}{2}\right)}$$

$$T_B^{180}\left[1 - \frac{v}{c}tan\left(45^\circ + \frac{\gamma}{2}\right)\frac{sin\left(45^\circ - \frac{\gamma}{2}\right)}{sin\left(45^\circ + 3\frac{\gamma}{2}\right)}\right] = 2T_i^{180}\left(1 - \frac{v}{c}\right)\frac{sin\left(45^\circ - \frac{\gamma}{2}\right)}{sin\left(45^\circ + 3\frac{\gamma}{2}\right)}$$

Considering that: $sin\,\gamma = \frac{v}{c}$, $T_i^{180} = \frac{L}{(v + c\,cos\,\gamma)}$, $tan\left(45^\circ + \frac{\gamma}{2}\right) = \frac{\sqrt{1+sin\,\gamma}}{\sqrt{1-sin\,\gamma}}$,

$\frac{\sin\left(45^\circ + \frac{\gamma}{2}\right)}{\sin\left(45^\circ + 3\frac{\gamma}{2}\right)} = \frac{\sqrt{(1-sin\gamma)}}{(\,cos\gamma(\,cos\frac{\gamma}{2} + sin\frac{\gamma}{2}) + sin\gamma(cos\frac{\gamma}{2} - sin\frac{\gamma}{2})}$, $cos\frac{\gamma}{2} + sin\frac{\gamma}{2} = \sqrt{1 - sin\,\gamma}$, $cos\frac{\gamma}{2} - sin\frac{\gamma}{2} = \sqrt{1 - sin\,\gamma}$, the above expression becomes:

$$T_B^{180}\left(1-\frac{v}{c}\frac{\sqrt{1+\sin\gamma}}{\sqrt{1-\sin\gamma}}\cdot\frac{\sqrt{1-\sin\gamma}}{\cos\gamma\sqrt{1+\sin\gamma}+\sin\gamma\sqrt{1-\sin\gamma}}\right)$$
$$=2T_i^{180}\left(1-\frac{v}{c}\right)\frac{\sqrt{1-\sin\gamma}}{\cos\gamma\sqrt{1+\sin\gamma}+\sin\gamma\sqrt{1-\sin\gamma}}$$

$$T_B^{180}\left(1-\frac{v}{c}\frac{\sqrt{1+\frac{v}{c}}}{\sqrt{1-\frac{v_2}{c_2}}\sqrt{1+\frac{v}{c}}+\frac{v}{c}\sqrt{1-\frac{v}{c}}}\right)=2T_i^{180}\left(1-\frac{v}{c}\right)\frac{\sqrt{1-\frac{v}{c}}}{\sqrt{1-\frac{v_2}{c_2}}\sqrt{1+\frac{v}{c}}+\frac{v}{c}\sqrt{1-\frac{v}{c}}}$$

Replacing $T_i^{180}=\frac{L}{v+c\cos\gamma}$ and $c=v\times 10^4$ we obtain:

$$T_B^{180}=L\times 6{,}6646670999166824\times 10^{-9}\ s/m$$

For $L=1.2m$ we get

$$T_B^{180}=7.997600519900018\times 10^{-9}s$$

It is interesting that, if we take into account the second law of reflection, after a 90° rotation, the round-trip time interval in arm A is also much longer than in arm B. In this case, the difference δ_T^{90-180}has the value:

$$\delta T^2=\delta_T^{90-180}=1.5990400719879844\times 10^{-12}s$$

We recall that the value proposed by Michelson was:

$$\delta T_A^{90}-T_B^{180}=\frac{2L}{\sqrt{(c^v-v^2)}}-\frac{2Lc}{c^2-v^2}=-3.9999999756901157\times 10^{-17}s$$

Calculation Of Round-Trip Times for Rotating Arm A By 180˚ And Arm B By 270˚

a) Calculation of the round-trip time for arm A positioned at 180˚ relative to Earth's speed.

In this case, according to Fig. 7.5, we can write:

- for the outgoing time: $cT_i^{180} = L - vT_i^{180}$ from which $T_i^{180} = \frac{L}{c+v}$
- for the return time: $cT_r^{180} = A'M' = L + vT_r^{180}$ from which $T_r^{180} = \frac{L}{c-v}$

The total time becomes: $T_A^{180} = \frac{2Lc}{c^2-v^2}$ which has the value:

$$T_A^{180} = L \times 6{,}666666733333335 \times 10^{-9}\, s/m$$

For $L = 1.2m$ this becomes:

$$T_A^{180} = 8.000000080000003 \times 10^{-9} s$$

As we can see, T_A^{180} is equal to the time T_A^0 found by Michelson.

Observation: The light pulse returns to the central mirror at the same point from which it departed.

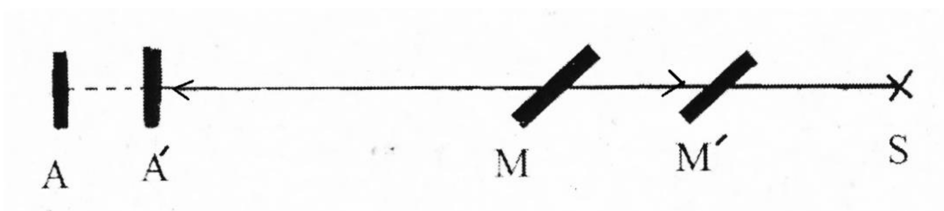


Figure 7.5: The path of the light pulse in arm A positioned at 180˚ relative to Earth's speed

b) Calculation of the round-trip time in arm B positioned at 270˚relative to Earth's velocity

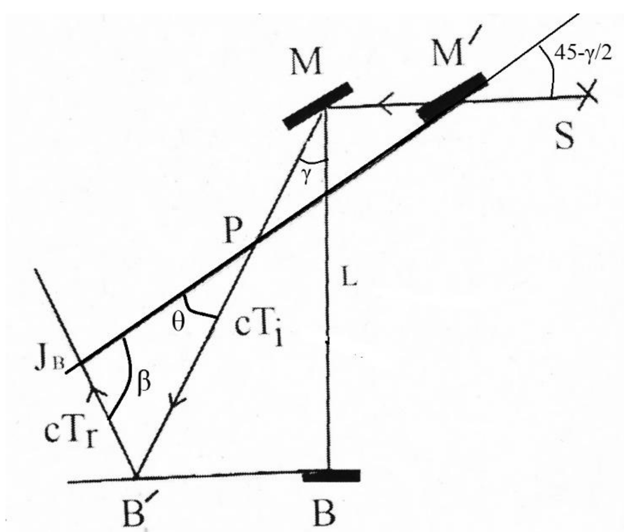


Figure 7.6: The path of the light pulses in arm B positioned at 270˚.

In this case, according to Figure 7.6, we can write:

-for the outgoing time: $\frac{L}{cT_i} = cos\gamma$ from which: $T_i = \frac{L}{c\, cos\,\gamma}$

-for the return time: $cT_r = BJ_B$ from which: $T_r = \frac{BJ_B}{c}$

Applying the sine theorem in triangles $B'J_BP$ and PMM', we can write:

$\frac{cT_r}{sin\,\theta} = \frac{B\prime P}{sin\,\beta}$ and $\frac{PM}{sin\,\theta} = \frac{MM'}{sin(45^\circ - \gamma/2)}$ where: $\theta = 45^\circ - \frac{\gamma}{2}$, $\beta = (\pi - 45^\circ) - \frac{3\gamma}{2}$, where $B'P = cT_i - PM$ and $MM' = v \times T_B$.

After performing the calculations and considering that $c = 10\, \times$, we obtain the following relationship:

$$T_B^{270} = \frac{L(10^4 + 2)}{v(\sqrt{10^8} - 1)(10^4 + 3)}$$

$$T_B^{270} = L \times 6.666000233270019 \times 10^{-9}\, s/m$$

For $L = 1.2m$ we get the value:

$$T_B = 7.999200279924022 \times 10^{-9} s$$

In this case the difference $\delta T^{180-270}$ has the value:

$$\delta T^3 = \delta T^{180-270} = 7{,}998800759 \times 10^{-13} s$$

Calculation of the Round-Trip Times With Arm A Positioned At 270˚ And Arm B Positioned At 360˚ Relative To Earth's Velocity

a) Calculation of the round-trip time in arm A

In this case, according to Figure 5.7, we can write:

- for the outgoing time: $cT_i^{270} = L$ and $T_i^{270} = \frac{L}{c}$

- for the return time: $cT_r^{270} = L + MJ_a$ where: $\frac{MJ_A}{MM'} = tan\left(45^\circ + \frac{\gamma}{2}\right)$ and $MM' = vT_A$.

After performing the calculations, we find:

$$T_A^{270} = 8.000008011 \times 10^{-9}s$$

Return location: In this case, the light pulse does not return to the point from which it departed; it returns at a distance of $M'J_A$.

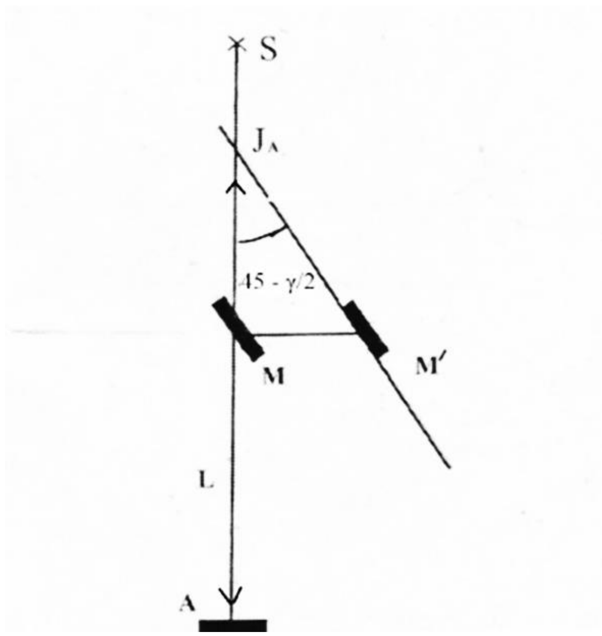


Figure 7.7: The path of the light pulse in arm A positioned at 270˚ relative to Earth's velocity.

b) Calculation of the round-trip time in arm B

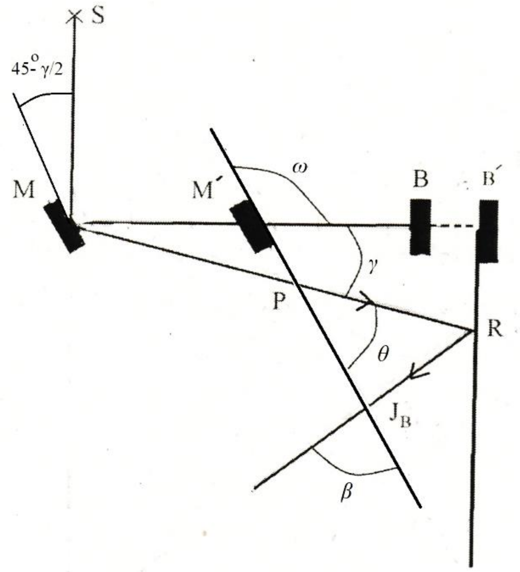


Figure 7.8: The path of the light pulse in arm B positioned at 360˚ relative to Earth's velocity.

In this case, according to Figure 7.8, we can write:

-for the outgoing time: $\frac{L+BB\prime}{cT_i} = cos\,\gamma$, where $BB' = vT_i$ amd,

$$T_i = \frac{L}{c\,cos\,\gamma - v}$$

-for the return time: $cT_r = RJ_B$

Applying the sine theorem in triangles RPJB and PMM′ and considering that:

$\omega = \pi - 45° - \frac{\gamma}{2}$, $\theta = 45^{\circ} - \frac{y}{2}$, and $\beta = \pi - 45^{\circ} - \frac{3\gamma}{2}$, after performing the calculations, we find that:

$$T_B^{360} = L \times 6.60000999810358 \times 10^{-9}\,s/m$$

For $L = 1.2m$ we get:

$$T_B^{360} = 7.920011997\ x\ 10^{-9}s$$

In this case the time difference δT^4 be comes:

$$\delta T^4 = T_A^{270} - T_B^{360} = 7.9996014 \times 10^{-11}s$$

To summarize, the time differences δT for the light pulse paths in the two arms of the interferometer, measured at the four positions, are as follows:

$$\delta T^1 = \delta TA^{0-90} = 3.9999999756901156 \times 10^{-17} s$$
$$\delta T^2 = \delta_T^{90-180} = 1.5990400719879844 \times 10^{-12} s$$
$$\delta T^3 = \delta T^{180-270} = 7{,}998800759 \times 10^{-13} s$$
$$\delta T^{\,4} = T_A^{270} - T_B^{360} = 7.9996014 \times 10^{-11} s$$

Let us now present the differences ΔT^1, ΔT^2, $\Delta T^3$and ΔT^4 in order to evaluate the fringe shift in the four positions. As previously discussed, according to Michelson, the fringe shift N is given by the relation:

$$N = \frac{(\delta T^1 - \delta T^2)c}{\lambda}$$

He considered $\delta T^2 = -\delta T^1 = -3.9999999756901157 \times 10^{-17} s$, and for $\lambda = 5.9 \times 10^{-9} m$, we obtain $N = 0.04$.

If we take into account the second law of light reflection, then for the four positions of the interferometer, the differences between the time intervals ΔT^1, ΔT^2, $\Delta T^3$and ΔT^4 and the corresponding fringe shifts (N_1, N_2, N_3, N_4) would have the following values:

$\Delta T^1 = \delta T_{\,1} \; - \; \delta T^{\,2} = -1.59900007 \times 10^{-12} s$, $N^1 = -\,813.0508831$

$\Delta T^2 = \delta T^2 - \; \delta T^3 = 7.99159990879844 \times 10^{-13} s$, $N^2 = 40.635253714$

$\Delta T^3 = \delta T^3 - \; \delta T^3 = -7.9972132410001 \times 10^{-12} s$, $N^3 = -40.6663796141$

$\Delta T^4 = \delta T^4 - \; \delta T^1 = 7.599597400000024 \times 10^{-11} s$, $N^4 = 38642.020678$

These results lead to a new dilemma: the fringe displacements would have extremely large values, making them difficult to observe or measure accurately.

It is also observed that, in most cases, the light pulses reflected from mirrors A and B do not return to the same point on the central mirror M from which they originated.

Thus, even when taking the second law of light reflection into account, the results remain unsatisfactory.

A correct explanation would require that the light pulses return to the same points on the central mirror, and that the time interval differences are zero for any orientation of the interferometer relative to Earth's velocity.

As we will see next, these conditions are satisfied if we consider that, for mirrors moving through a stationary light propagation medium, the reflection of the light beam does not occur instantaneously. Instead, a phenomenon known as kinetic reflection takes place.

Explanation Using Kinetic Reflection

General Considerations Regarding Kinetic Reflection

In practice, there are situations where the relative speed of optical devices in relation to a light source must be considered. An example of such a situation is the explanation of astronomical light aberration phenomena discovered by J. Bradley in 1728. It is well known in astronomy that, for the image of a star S to appear in the reticle of a telescope, the telescope must be tilted at an angle σ, called the aberration angle, to compensate for Earth's motion speed, as shown in Figure 8.1 [4].

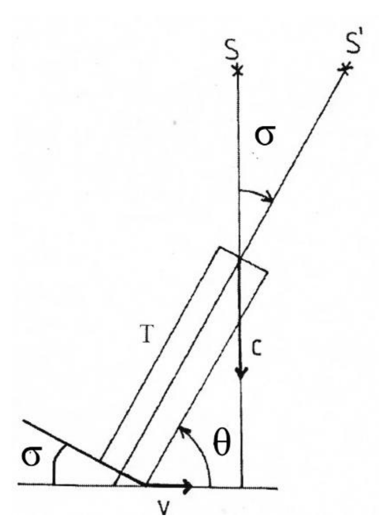


Figure 8.1: The position of a telescope T to compensate Earth's motion speed.

The aberration angle is given by the formula: $sin\,\sigma = \frac{v}{c} sin\,\theta$. Where: $v = 30\ km/s$ is the Earth's motion speed around the Sun on its orbit and $c = 300000\ km/s$ is the speed of light. Due to this inclination, the observer will see the star in the direction SThe above formula was obtained by considering only a single light ray. In reality, the image of the star is given by a light beam. Upon careful analysis, we observe that the plane of the mirror of a reflector telescope (or the objective of a refractor telescope) is also rotated by the same angle σ, as shown in Figure 8.2. Therefore, the light beam coming from the star S will gradually meet the mirror surface MM′, and the reflection will occur on a virtual mirror MM″.

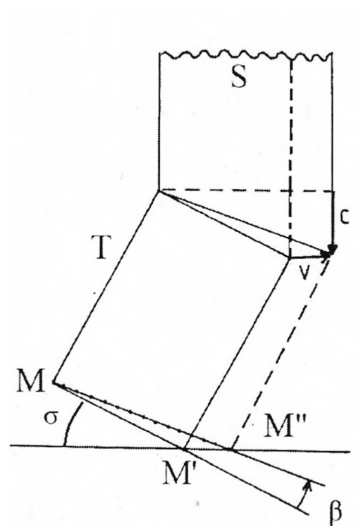


Figure 8.2: The virtual mirror MM" where light reflection occurs due to the aberration phenomenon and Earth motion.

If we accept the phenomenon of astronomical light aberration, then we must accept that similar situations are encountered with the mirrors in the Michelson interferometer. In the following, we will analyze the path of light pulses and time intervals when the mirror is moving in the light propagation medium and the light reflection occurs on a virtual surface rotated relative to the physical mirror surface.

Observation: We call this type of reflection kinetic reflection. By kinetic reflection, we mean the reflection caused by the movement of a mirror—just as kinetic energy refers to the energy generated by the motion of a body.

In practice, there are many cases that need to be analyzed separately depending on the angle of incidence and the angle the mirror makes with Earth's velocity. In the following, we will analyze the situations encountered in Michelson's experiment.

Kinetic Reflection on A Mirror Moving Away from The Light Source

Let's consider a light beam whose wavefront S, with a width AB, approaches the mirror MM' and makes an angle of incidence i with its normal N, and the mirror itself is moving away from the light source at speed v.

The first contact of the wavefront with the mirror will occur at point A'.

According to the Huygens-Fresnel principle, the wavefront surface S coming from the source S will successively meet the moving mirror at points aligned along the direction MM''. Therefore, the light reflection will occur on a virtual surface MM'', rotated relative to the mirror MM' by a small angle β, as shown in Figure 8.3.

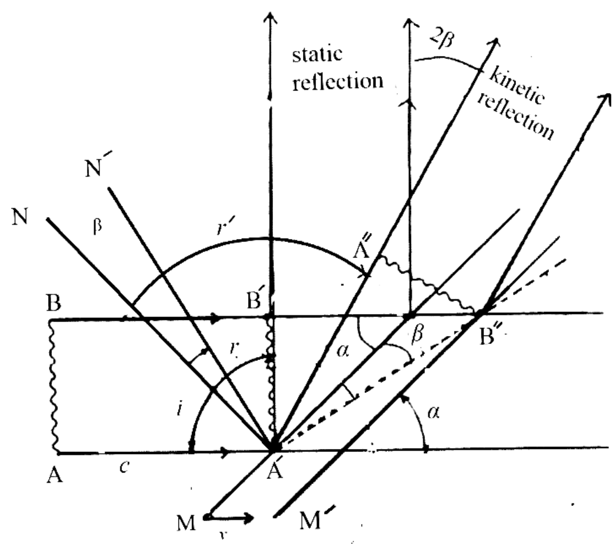


Figure 8.3: Kinetic reflection on a flat mirror moving away at speed v from a wave front AB.

Let's now calculate the value of the angle β as a function of c (speed of light), v (speed of the mirror), α (the angle between the mirror surface and the speed v), and i (the angle of incidence of the light impulse with the normal to the mirror).

Applying the sine theorem in the triangles $A'B'P$and $A'P\ B''$ we can write the relationships:

$\frac{B'B''}{sin\ (i+\beta)} = \frac{A`P}{sin\frac{\pi}{2}}$. where $B'P = ct$, and

$\frac{PB''}{\sin\beta} = \frac{A`B''}{\sin(\pi-\alpha)}$ where $PB' = vt$.

Taking into account that the two triangles have side $A'B''$in common, after performing the calculations we find that:

$$\tan\beta = \frac{v \sin i\ \sin\alpha}{c - v\cos i\ \sin\alpha}$$

In Fig.8.3, we can see the difference between static reflection, when the mirror M is fixed and the reflection is made with respect to the normal N, and cinematic reflection, when the mirror M moves away from the light source and the reflection is made with respect to the normal N' of the virtual mirror.

For an observer situated in the reference system of the light propagation medium, the reflected ray moves away from the normal to the mirror and the reflection angle becomes: $r' = i + 2\beta$.

Kinetic Reflection on a Mirror Approaching the Light Source

Let's now analyze the case when the mirror on which the light reflection occurs is approaching the light source. Similarly, let's consider a beam of light whose wavefront AB propagates through a medium considered fixed with speed c and a mirror M which, in turn, advances through the optical medium with speed v, meeting the wavefront (Figure. 8.4).

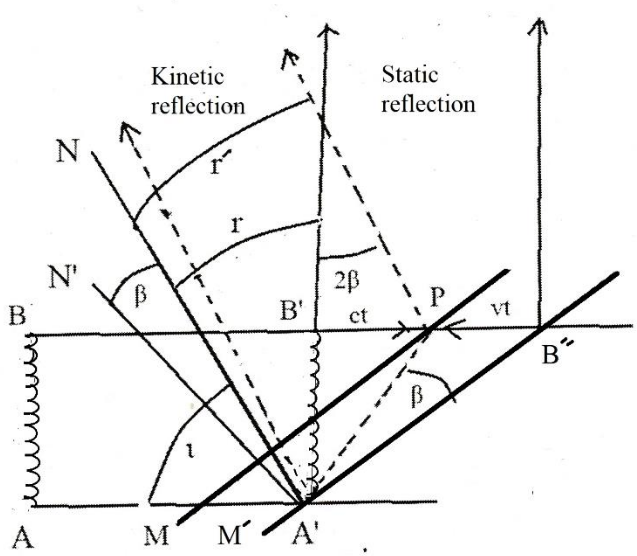


Figure. 8.4: Kinetic reflection when the mirror approaches the light source.

In this case, applying the sine theorem in the triangles $A'B'P$ and $A'P\ B$" we can write:

$\frac{B\prime P}{sin\,(\,i-\beta)} = \frac{A\prime P}{sin\frac{\pi}{2}}$ and $\frac{PB\prime\prime}{sin\beta} = \frac{A\prime P}{sin\alpha}$, where: $B'P = ct$ and $PB'' = vt$. Taking into account that the two triangles share the side A P after performing the calculations we find that:

$$tan\,\beta = \frac{v\,sin\,i \cdot sin\alpha}{c + v\,cosi\,sin\alpha}$$

Observation: In this case, for an observer situated in the reference system of the light propagation medium, the reflected ray from the moving mirror approaches the normal to the mirror and the reflection angle becomes:

$$r' = i - 2\beta$$

The two situations presented above are encountered in Michelson's experiment. Next, considering the kinetic reflection, we will analyze the round-trip times in the interferometer arms in the four positions previously presented.

A) Calculation of round-trip times in arm A positioned at 0˚ relative to Earth's velocity and arm B positioned at 90˚ relative Earth's velocity.

Calculation of round-trip time in arm A

In this case, according to Figure. 8.5, the path of the light impulse is the same as indicated by Michelson, because the light passes through the central mirror M and cinematic reflection does not occur.

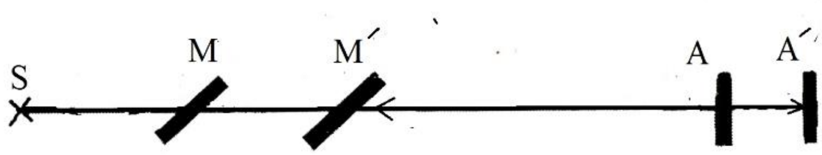


Figure 8.5: Path of the light impulse in arm A positioned parallel to Earth's velocity.

According to Figure.8.5 we can write:

For the outgoing time: $cT_i = MA' = L + vT_i$ and $T_i = \frac{L}{c-v}$

For the return time: $cT_r = L - vT_r$ and $T_r = \frac{L}{c+v}$.

The total time becomes: $T_A^0 = \frac{2Lc}{c^2-v^2}$ and is evidently the same as calculated by Michelson:

$$\boldsymbol{T_A^0} = L \times 1{,}333333346666667 \times 10^{-8}\, s/m$$

Calculation of round-trip time in arm B positioned at 90° relative to Earth's velocity.

In this case, the central mirror M makes an angle $\alpha = 45^{\circ}$ with Earth's velocity, and the angle of incidence of the light coming from source S also has the value $i = 45^{\circ}$ Fig. 8.6.

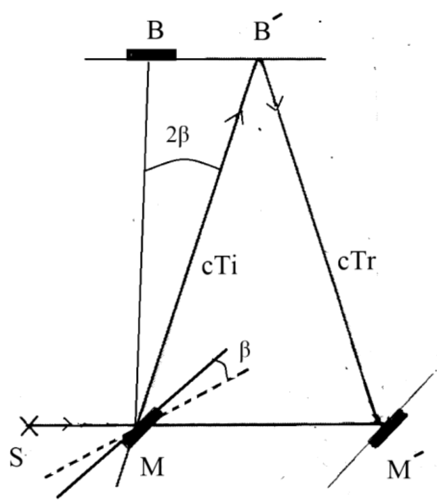


Figure 8.6: Kinetic path of the light impulse in arm B positioned at 90° relative to Earth's velocity

Due to the displacement of the central mirror M from the light source, kinetic reflection occurs on a virtual surface which, as we have seen above, appears rotated relative to the surface of mirror M by an angle β given by the formula.

$$\tan\beta = \frac{v \sin i \ \sin\alpha}{c - v\cos i \ \sin\alpha}$$

In that case we find:

$\tan\beta = \frac{v\sin i \cdot \sin\alpha}{c - v\cos i \cdot \sin\alpha} = \frac{v\ 0.5}{c - v0.5v} = 0.000050002$, and

$\beta = 0.0028649316^{\circ} = 10.31375376''$, $2\beta = 0.0057298632°$,

$$tan\,\beta = 0.000100004979$$

On the other hand, as previously mentioned, if a mirror is rotated by an angle β, the reflection angle r becomes: $r' = i + 2\beta$, where i is the angle of incidence. In this case: $2\beta = 20.62750752''$ and $tan\,2\beta \approx 2\,tan\,\beta$.

Observation: Interestingly, the value of the angle 2β $(20.62750752'')$ obtained through kinetic reflection is very close to the value of the angle γ $(20.62747152'')$ that the light ray must make with arm B to be in agreement with Michelson's calculations where: $sin\,\gamma = \frac{v}{c}$.

Additionally, we observe that in the case of kinetic reflection: $2\beta > \gamma$.

The difference between these two values: $2\beta - \gamma = 0.000036''$ is extremely small, practically nonexistent, and therefore it is not necessary to rotate the central mirror for the ray in arm B to follow the path indicated by Michelson; nature does this through kinetic reflection! **Here is the great mystery of Michelson's experiment!** Now let's calculate the round-trip time according to the path in Figure 8.5.

For the outgoing time: $\frac{MB}{cT_i} = cos\,2\beta$ and $T_i = \frac{L}{c\,cos\,2\beta} = \frac{L}{c \cdot 0.999999995}$.

Since the plane of mirror B is parallel to Earth's velocity $(\alpha = 0°)$, kinetic reflection does not occur at point B′, and the return time is equal to the outbound time. In this case, the total time T_B^{90}:

$$T_B^{90} = \frac{2L}{c\,cos\,2\beta} = L \times 6.6666667 \times 10^{-9}\,s/m$$

The time difference becomes:

$$DT = T_A^0 - T_B^{90} = L \times 6.666666733 \times 10^{-9}\,s/m - L \times 6.6666667 \times 10^{-9}\,s/m$$

$$DT_1 = L \times 3.3 \times 10^{-17}\,s/m$$

The difference $DT_{AB}^{0-90} = L \times 3.310^{-17}\,s/m$ is extremely small compared to Michelson's result.

B) Calculation of the round-trip kinetic time in arm A positioned at 90˚ relative to Earth's velocity and in arm B positioned at 180˚ relative to Earth's velocity

Calculation of the round-trip time in arm A

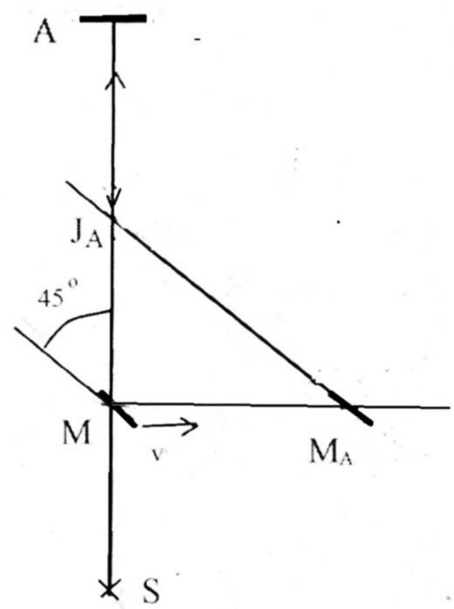


Figure 8.7: Path of the light pulse in arm A positioned at 90˚ relative to Earth's velocity.

According to Fig.8.7, we can write:

For the outgoing time: $MA = L = cT_i$ and $T_i = \frac{L}{c}$

For the return time: $AJ_A = cT_r = L - vT_A$ and $T_r = \frac{L}{c} - \frac{v}{c}T_A$

The total time: $T_A = T_i + T_r = \frac{2L}{c+v} = L \times 6{,}666000066660001 \times 10^{-13}\ s/m$

Numerically: $T_A^{90} = L \times 6{,}666000066660001 \times 10^{-13}\ s/m$

Calculation of the round-trip time in arm B

On the outgoing journey, the light pulse undergoes kinetic reflection on the central mirror M, and the reflection occurs on a virtual surface (dotted line) rotated relative to the plane of mirror M by an angle β, as shown in Fig. 8.8.

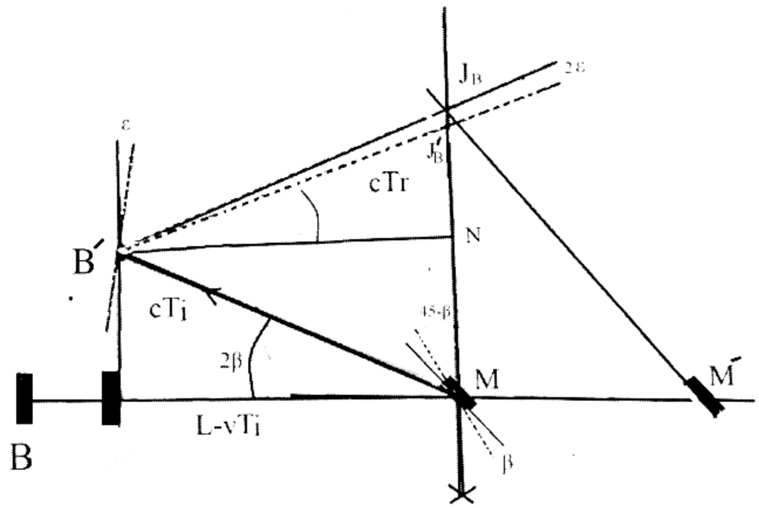


Figure 8.8: Path of the light pulse in arm B positioned at 180˚ relative to Earth's velocity.

In this case, when the central mirror M moves to position M', the light pulse coming from the source S will undergo kinetic reflection on the virtual surface (dotted line) of the central mirror, rotated relative to it by the angle β. On the outbound journey, the reflected ray makes an angle 2β with arm B and will meet the mirror of arm B at point B'.

Considering that the angle of incidence $i = 45°$, the angle α that the surface of mirror M makes with Earth's velocity is also 45˚. Applying the formula for kinetic reflection for the case when it moves away from the wavefront,

$tan\,\beta = \frac{v\,sin\,i \cdot sin\alpha}{c+v\,cosi\,sin\alpha}$, we find:

$tan\,\beta = \frac{v\,sin\,i \cdot sin\alpha}{c+v\,cosi\,sin\alpha} = \frac{v\,sin^2\,45^{\circ}}{c+vcos45sin45} = \frac{0.5}{10000{,}5} = 0.0000499975,$

$\beta = 0.0028646457° = 10.31272452'',$

$$2\beta = 0.0027292914° = 20.6254490''$$

For the outbound time, we can write the relation: $\frac{L-vT_i}{cT_i} = cos\,2\beta$ and

$$T_i = \frac{L}{v + c \cdot cos\,2\beta} = \frac{L}{v(1 + 10^4 \times 0.999999995)}$$

$$T_i = L \times 3{,}333000049993334 \times 10^{-13}\,s/m$$

At point B', a new kinetic reflection will occur due to the movement of mirror B, but this is extremely small and can be neglected.

However, for scientific rigor, let's calculate this small angle ε between mirror B and the virtual reflection surface (dotted line) in Figure. 8.9.

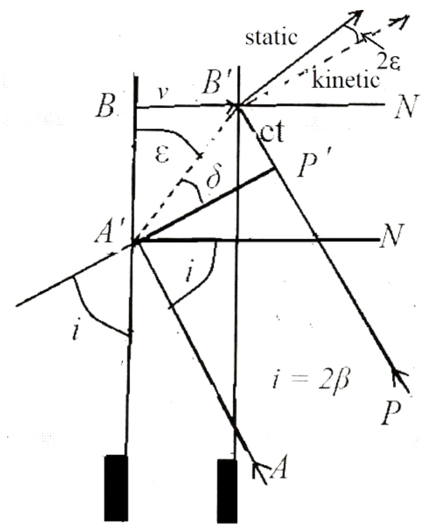


Figure 8.9: Kinetic reflection on mirror B, positioned at 270° relative to Earth's velocity.

In this case, the first contact of the wavefront with mirror B occurs at point A', and the last contact at point B'.

The kinetic reflection will occur on the virtual surface A'B', which makes an angle ε with mirror B. To find the value of angle ε, we apply the sine theorem in triangles A'BB' and A'B'P, which have the common side A'B', and we can write:

$\frac{BB'}{AB'} = \frac{vt}{A'B'} = sin\,\varepsilon$ and $\frac{B'P'}{A'P} = \frac{ct}{A'B'} = sin\,\delta$ where $\delta = i - \varepsilon$ and the angle of incidence has the value $i = 2\beta$.

After equating, we obtain:

$\frac{vt}{sin\,\varepsilon} = \frac{ct}{sin(i-\varepsilon)}$, $v\,cos\,\varepsilon \cdot sin\,i = sin\,\varepsilon \cdot (c + v\,cos\,i)$, $tan\,\varepsilon = \frac{v\,sin\,i}{c+v\cdot cos\,i}$.

Considering that $c = v \times 10^4$ and the angle of incidence in this case is:

$i = 2\beta = 0.00572929144°$ we find that:

$$tan\,\varepsilon = \frac{0.00099995}{10000.9999999995} = 9.9998500149x10^{-9}$$

$\varepsilon = 5.729492016 \times 10^{-7\circ} = 0.0020626171''$.

Therefore, the kinetically reflected ray will approach the normal N of mirror B with an angle $2\varepsilon = 0.0041252342''$, which is extremely small. Consequently, we can consider for the path of the reflected pulse the distance $B'J_B$, which is equal to the distance MB'. In this case, $cT_r = cT_i$ and the total round-trip time is:

$$T_B^{180} = 2L \cdot T_i = 2L \times 3{,}333000049993334 \times 10^{-13}\, s/m$$

$$T_B^{180} = L \times 6{,}666000099986668 \times 10^{-13}\, s/m$$

Now, making the difference $\delta(T_A^{90} - T_B^{180})$, we find:

$$\delta(T_A^{90} - T_B^{180}) = L \cdot 3.3333865 \times 10^{-21}\, s/m$$

The difference of differences is:

$$\Delta_1 = (T_A^{0} - T_B^{90}) - (T_A^{90} - T_B^{180}) = L \times 3.3 \times 10^{-17}\, s/m - 3.33268 \times 10^{-17}\, s/m$$

$$\Delta_1 = L \times 3.268 \times 10^{-19}\, s/m$$

Compared to the value calculated by Michelson, $D_M = L\frac{v^2}{c^2} = L \times 10^{-8}\, s/m$ this is extremely small and therefore no displacement of the fringes can occur.

Calculation of round-trip times kinetically in arm A positioned at 180˚ relative to Earth's velocity and arm B positioned at 270˚ relative to Earth's velocity.

Calculation of round-trip time in arm A

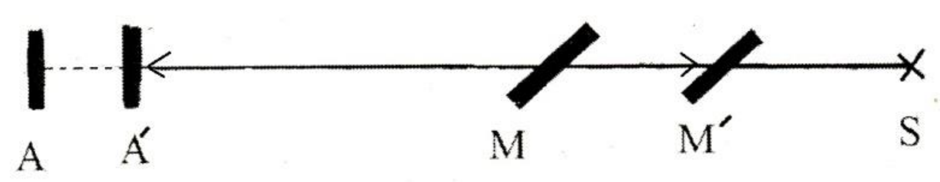


Figure 8.10: The path of the light pulse in arm A positioned at 180˚ relative to Earth's velocity.

Calculation of the outbound time:

In this case, according to Figure.7.10, we can write:

$cT_i = MA' = L - vT_i$ and $T_i = \frac{L}{c+v}$.

Calculation of the return time: $cT_r = A'M' = L + vT_r$ and $T_r = \frac{L}{c-v}$.

The total time becomes $T_A^{180} = \frac{2Lc}{c^2-v^2}$, which is the same as indicated by Michelson for arm A positioned parallel to Earth's velocity. Numerically, this value is:

$$T_A^{180} = L \cdot 6.666666488 \times 10^{-9}\, s/m$$

Calculation of round-trip time in arm B positioned at 270˚ relative to Earth's velocity

In this case, the light pulse coming from source S will undergo cinematic reflection on the surface of the central mirror M and, after reflection, will approach the normal to the mirror at an angle of 2β, as shown in Figure. 8.11.

Considering that the angle of incidence is $i = 45°$ and the angle α formed by the surface of mirror M with Earth's velocity is also 45°, applying the formula for kinetic reflection when it approaches the wavefront, we find:

From Figure. 8.11, we observe that we can write:

- for the outgoing time: $\frac{L}{cT_i} = cos\ 2\beta$ and $T_i = \frac{L}{c\ cos 2\beta}$
- for the return time: $\frac{L}{cT_r} = cos\ 2\beta$, hence $T_r = \frac{L}{c\ cos 2\beta}$, where $cos\ 2\beta = 0.999999995$.

Here, the return time is equal to the outbound time because mirror B moves in the same plane and there is no cinematic reflection.

The total round-trip time is $T_B^{270} = \frac{2L}{c\ cos\ 2\beta}$.

Numerically, this value is:

$$T_B^{270} = \frac{2L}{c\ cos\ 2\beta} = L \cdot 6.666666717 \times 10^{-9}\, s/m$$

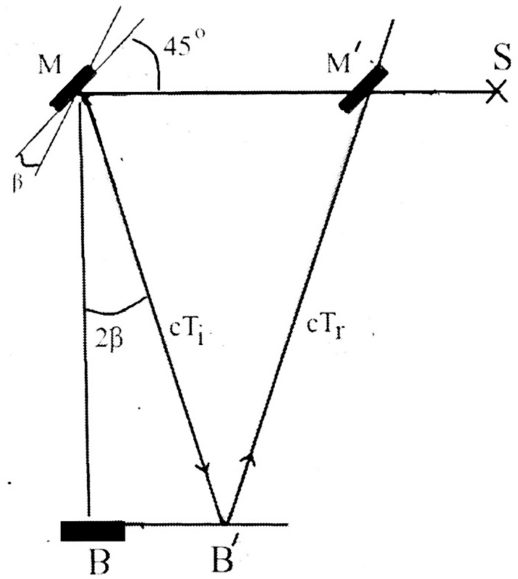


Figure 8.11: The kinetic path of the light pulse in arm B positioned at 270˚ relative to Earth's velocity.

The difference is:

$$\delta T_{AB}^{180-270} = L \cdot 6.666666488 \times 10^{-9}\, s/m - L \cdot 6.6666667177 \times 10^{-9}\, s/m$$

$$\delta T_{AB}^{180-270} = -L \cdot 2.29 \times 10^{-16}\, s/m$$

In this case we observe that the round-trip time in arm B is greater than in arm A.

Now let's calculate the difference of differences Δ_2

$$\Delta_2 = (T_A^{90} - T_B^{180}) - (T_A^{180} - T_B^{270}) = L \cdot 3.33268 \times 10^{-17}\, s/m - (-L \cdot 2.29 \times 10^{-16}\, s/m)$$

$$\Delta_2 = L \cdot 2.62268 \times 10^{-16}\, s/m$$

Therefore, even when the arm A is rotated by 180˚, no fringe displacement can occur.

The path of the light pulse in arm A positioned at 270˚ and arm B positioned at 360˚ relative to Earth's velocity.

Calculation of the round-trip time in arm A, Figure. 8.12

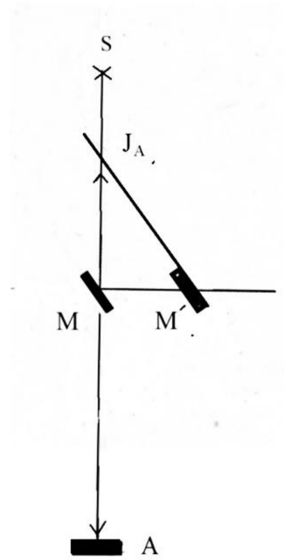


Figure 8.12: The path of the light pulse in arm A positioned at 270˚ relative to Earth's velocity.

In this case, the light pulse leaves from source S, traverses the central mirror M, reflects off mirror A, and upon returning, meets the central mirror at point J_A.

Here, we can write the relationships:

-for the outgoing time, we can write the relationship: $MA = L + cT_i$ and $T_i = \frac{L}{c}$

-for the returning time: $MJ_A = cT_r = L + vT_A$ and $T_r = \frac{L}{c} + \frac{v}{c}T_A$

$T_A = T_i + T_r = \frac{2L}{c} + \frac{v}{c}T_A, T_A = \frac{2L}{c-v}$

Numerically, this value is: $T_A = L \cdot 6.667334 \times 10^{-9}\ s/m$

Calculation of the round-trip time in arm B, Figure. 8.13

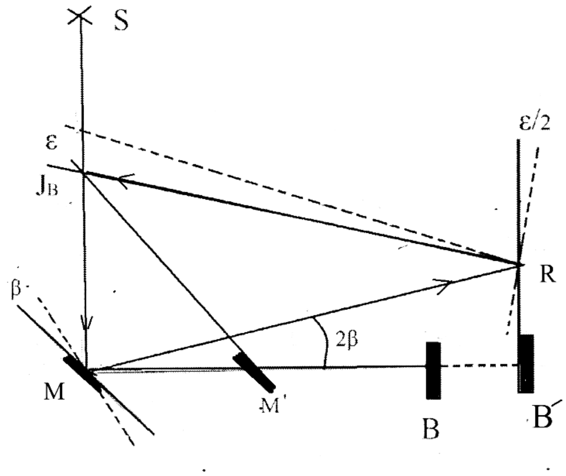


Figure 8.13: The kinetic path of the light pulse in arm B oriented at 360˚ relative to Earth's velocity.

In this case, the light pulse coming from source S meets the central mirror at point M where it undergoes a first kinetic reflection at an angle β. Then, it moves towards mirror B and meets it at point R. Here, it undergoes a new kinetic reflection at an angle ε/2 and returns to the central mirror, meeting it at point J_B'.

The virtual surface where the kinetic reflection occurs on mirror M forms an angle β with its plane, which in this case is calculated using the formula:

$tan\,\beta = \frac{v\,sin\,i\cdot sin\,\alpha}{c - v\,cos\,i\cdot sin\,\alpha} = \frac{v\,sin\,45°\cdot sin\,45°}{c - v\,cos\,45°\cdot sin\,45°} = \frac{0.5}{9999.5} = 0.0000500025,$
$arc\,tan\,\beta = 0.0028649316°.$

The angle 2β formed by the reflected ray with arm B has the value:
$2\beta = 0.00572929862° = 20.6275032''.$

And in this case, we see that the angle $2\beta = 20.6275032''$ is very close to the angle:
$\gamma = 20.6264808''$, but it is slightly smaller, $\gamma - 2\beta = -0.0010224''$.
For the outgoing journey, we can write the relationship: $\frac{MB'}{MR} = \frac{L+vT_i}{cT_i} = cos\,2\beta$ from which we obtain:

$$T_i = \frac{L}{c\,cos\,2\beta - v} = L \cdot 3.333666716 \times 10^{-9}\,s/m$$

For the return journey, after the kinetic reflection at point R, the light pulse travels the distance: $RJ_B'' = cT_r$ where

$\frac{L+vT_i}{cT_r} = cos(2\beta + \varepsilon)$. The value of the angle ε is calculated using the formula:

$tan\frac{\varepsilon}{2} = \frac{v \cdot sin\,2\beta \cdot sin\,90}{c - v \cdot cos\,2\beta \cdot sin\,90} = \frac{v \cdot 4.077624042 \times 10^{-13}}{c - v \cdot 0.9999999924} = 4 \times 10^{-16}$ where:

$arc\,tan\,4 \times 10^{-16} = 2.24183118° \times 10^{-14}$ and $\varepsilon = 4.583662361° \times 10^{-14}$.

Now let's compare $cos\,2\beta$ with $cos(2\beta + \varepsilon)$:

$cos\,2\beta = 0.9999999924$ and $cos(\gamma + \varepsilon) = 0.9999999924$.

Practically, also in this case, the angle ε is so small that it does not affect the space cT_r. Therefore, we can consider that: $cT_r = cT_i$ and in this case, the total round-trip time is:

$T_B^{360} = 2L \cdot 3.333666716 \times 10^{-9}\,s/m = L \cdot 6.667333432 \times 10^{-9}\,s/m.$

Let's now calculate the difference $T_A^{270} - T_B^{360}$.

Take in account that $T_A^{270} = L \cdot 6.667334 \times 10^{-9}\,s/m$ we obtain:

$$T_A^{270} - T_B^{360} = L \cdot 6.667334 \times 10^{-9}\,s/m - L \cdot 6.66733345 \times 10^{-9}\,s/m$$

$$T_A^{270} - T_B^{360}. = L \cdot 5.5 \times 10^{-16}\,s/m$$

Experimental Confirmation of Kinetic Reflection and Earth's Movements

As is known, any theory becomes valid if it also has experimental coverage. To verify whether the kinetic reflection exists, we made an original light deviation experiment with a fixed terrestrial telescope T. In front of the telescope a mirror M was placed at half of the objective O, of a telescope.

So, we were able to see directly the image of a mark A, in front of telescope T who give us information about terrestrial aberration of light and the image of a mark B in a lateral position, after reflection from the mirror.

Observation: To read the position of A, the half of the telescope objective that reproduces the image of landmark B is covered, and to read the position of landmark B, the half of the objective that reproduces the image of landmark A is covered.

Aiming at the landmarks was done with a 63/840 refractor telescope, and reading the positions of the landmarks was done with an ocular micrometer (10-Ormi) both produced by Karl Zeiss Jena and located in the equipment of the Suceava Planetarium (where D. Olenici worked for 25 years).

The readings were made hour by hour when the atmosphere was very transparent. For the readings to be done at night as well, poles from the public lighting or the edges of some windows from some neighbors' houses where the light bulbs were left on all night were chosen as landmarks.
In the figures below we can see the orientation of the telescope towards cardinal point the position of landmarks and the graphs of deviation.

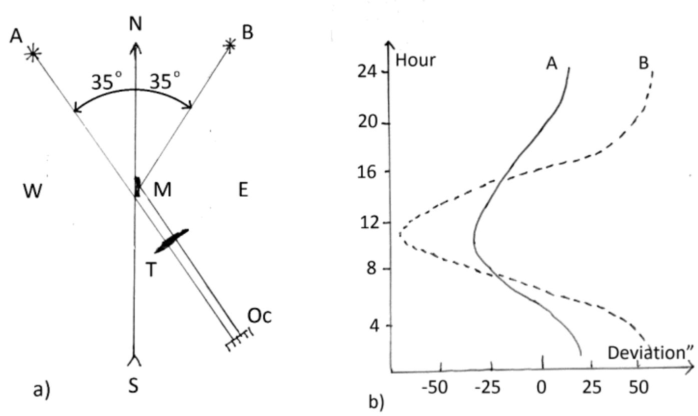


Figure 9.1: a) the position of landmark A at 35˚ N-W, and the position of landmark B at 35˚ N-E. b) the displacement of the image landmarks in the reticle of the telescope for 24 hours.

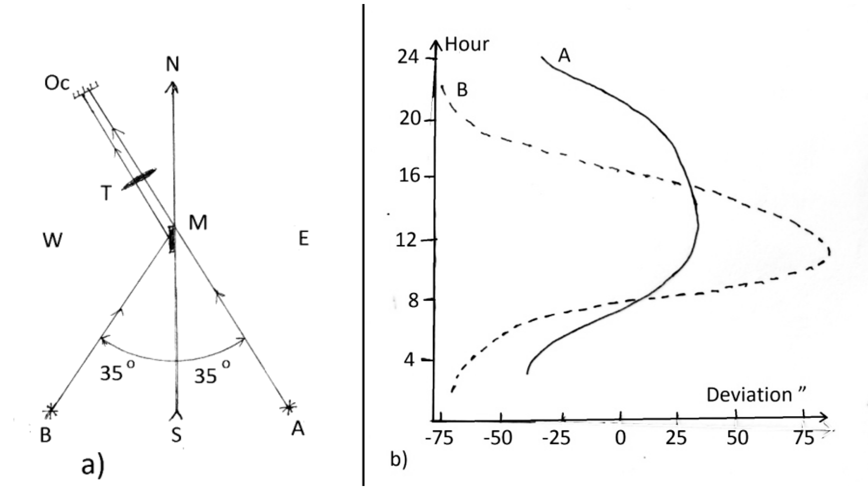


Figure 9.2: a) the position of landmark A at 35˚ S-E, and the position of landmark B at 35˚ S-W,

b) the displacement of the image of landmarks in the reticle of the telescope for 24 hours.

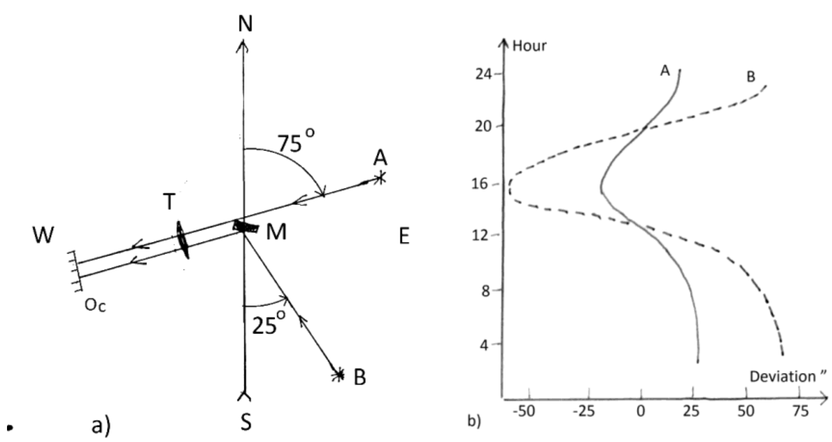


Figure 9.3: a) the position of landmark A at 75˚ N-E, and the position of landmark B at 25˚ S-E,
b) the displacement of the image of landmarks in the reticle of the telescope for 24 hours.

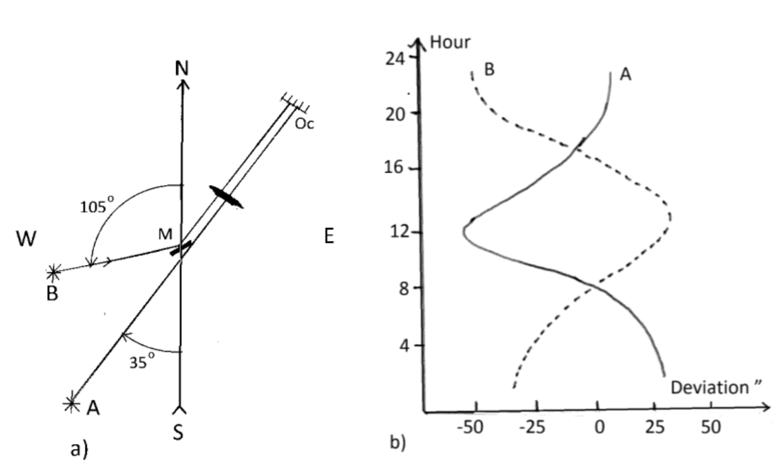


Figure. 9.4: a) the position of landmark A at 35˚ S-W, and the position of landmark B at 105˚ N-W, b) the displacement of the image of landmarks in the reticle of the telescope for 24 hours.

From the analysis of these graphs, we find the following:

- The positions of the landmark images undergo a lateral deviation that depends on the time.
- The deviations of the landmark B images are twice as large as the deviations of the landmark A images. This agrees with the fact that when a mirror is tilted by an angle, the reflected ray rotates by double this angle. In our case the tilt is made by Earth's rotation! This confirms the existence of kinetic reflection.
- From Fig. 9.1. and 9.2 we notice that when the telescope is oriented to the north at 12 o'clock the deviations have negative values and at 24 o'clock they have positive values and if we point the telescope to the south the direction of the deviations is reversed. This is due to -the sense of the position of the telescope in relation to the speed of the Earth.
- As a conclusion of these experimental results, from our point of view that the deviations of the image of the landmarks reflected in the mirror are greater than the directly aimed images and confirm the existence of kinetic reflection and prove the rotation of Earth.
- Kinetic reflection offers us the possibility of carrying out a new "experimentum crucis" to determine the speed of the Earth in the orbit of the Sun.

Proposal for A New "Experimentum Crucis": Demonstrating the Motion Of the Earth Through the Ether Via the Diurnal Deviation of Kinetically Reflected Light

To determine Earth's motion through the ether that propagates light, A. Michelson also proposed - supplementing his article - an experiment based on the reflection of light from a moving mirror. In this experiment, the speed of light could be measured without requiring the light beam to return to its point of origin. (See Fig. 10.1 [3].)

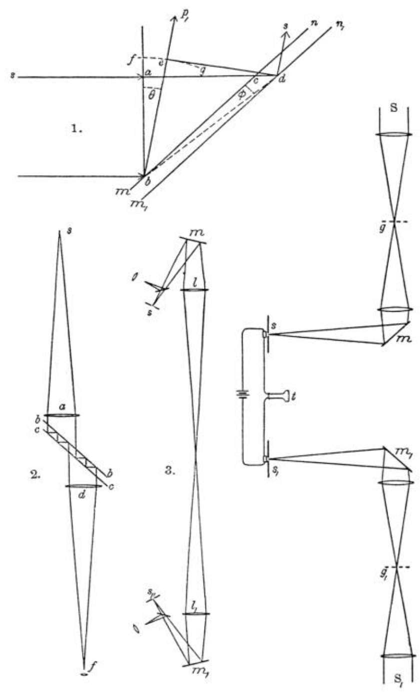


Figure 10.1: Michelson's proposed apparatus to measure Earth's speed through the ether, based on the change in the angle of reflection caused by the motion of a mirror relative to the light source.

Observation: We do not know whether such an experiment has ever been performed. We proposed a similar experiment based on the kinetic reflection of light as early as 1984, but since it was published in Romanian, it did not gain international recognition [4]. At that time, we were not aware of Michelson's original article - a fact we only realized after gaining access to the internet.

In the experiment we proposed, it is observed that a laser beam, kinetically reflected by a mirror due to Earth's rotation around its axis, oscillates over a 24-hour period around a central position.

The magnitude of this deflection depends on the angle of incidence and the orientation of the mirror relative to Earth's velocity.

We now propose two experimental cases:

A. Diurnal Deviation of a Ray of Light Kinetically Reflected by a Mirror Positioned at a 45° Angle to Earth's Velocity

In this case, the mirror M, where the reflection occurs, forms an angle $\alpha = 45°$ with Earth's velocity v, and the angle of incidence is also $i = 45°$.

The virtual surface on which the kinetic reflection occurs is rotated relative to the mirror M by an angle β, whose value is given by the formula:

$$tan\,\beta = \frac{v\,sin\,i\;\;sin\,\alpha}{c\;\mp vcosi\;sin\alpha}$$

where:

- c is the speed of light,
- v is the speed of the Earth.

The minus sign (−) is used when the mirror is moving away from the light source (see Fig. 7.3), and the plus sign (+) is used when the mirror is moving toward the light source (see Fig. 7.4).

At noon (12:00): $tan\,\beta_{12} = 0.0000499975$ and $\beta_{12} = 0.0028646457^{\circ}$

At midnight (24:00): $tan\,\beta_{24} = 0.000050002$ and $\beta_{24} = 0.0028649316^{\circ}$

Since these values are very close, we can approximate the average value as:

$\beta_{12}\;\approx \beta_{24}\;\approx\;0.00286478865° = 10.31323914''$(arcseconds)

Therefore, if we direct a laser beam along the east-west direction and place a mirror inclined at 45° in its path, over the course of 24 hours, due to kinetic reflection, the angle of reflection will be: $r = 45° + 2\beta$ at 12:00 noon, and $r = 45° - 2\beta$ at 12:00 midnight (see Figure. 10.2).

Observation: When projected onto a vertical plane, the laser beam traces an elliptical path (dotted curve). However, we consider only the value d, representing the length of the semi-major axis.

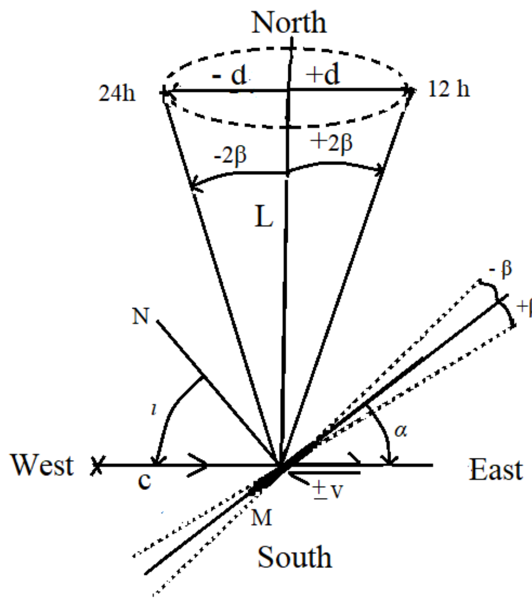


Figure. 10.2: Diurnal deviation of a ray of light oriented in the west-east direction and reflected toward the north cardinal point.

At a distance L, the light ray will experience a deviation d from the north-south direction, given by the relation: $d = L \cdot tan(2\beta)$. Since β is very small, we can approximate: $tan(2\beta) \approx 2\,tan\,\beta$. Thus, the relation becomes:

$$\frac{d}{L} = 2\,tan\,\beta = \frac{2v \cdot 0.5}{c \pm v \cdot 0.5} = \frac{v}{c \pm v \cdot 0.5} \approx \frac{1}{1000 \pm 0.5} \approx 0.0001$$

Therefore, in such an experiment at 1km distance, the reflected ray will deviate by $\pm 0.1m$ over 24 hours, at 5km, the deviation would be $\pm 0.5m$. and at 10 km, the deviation would be $\pm 1m$.

By measuring the deviation d, we can calculate Earth's velocity through the ether using the relation: $\frac{d}{L} = \frac{v}{c \pm v \cdot 05} \approx \frac{v}{c}$ and we find than $v \approx \frac{d \cdot c}{L}$.

For example, if at a distance $L = 1km$ we obtain a deviation $d = 0.1m = 0.0001km$, then:

$$v = \frac{0.00001km \cdot 300000km/s}{1km} = 30\ km/s$$

B. Diurnal Deviation of a Light Ray Kinetically Reflected by a Mirror Positioned at a 90° Angle to Earth's Velocity

Experimentally, we place a flat mirror along the North–South direction and send a laser beam—originating, for example, from the South—which is reflected toward the North. Due to Earth's motion around the Sun, kinetic reflection occurs when the beam strikes the mirror.

During the daytime, between 6 AM and 6 PM, the direction of the kinetically reflected ray appears as shown in Fig.10.3.

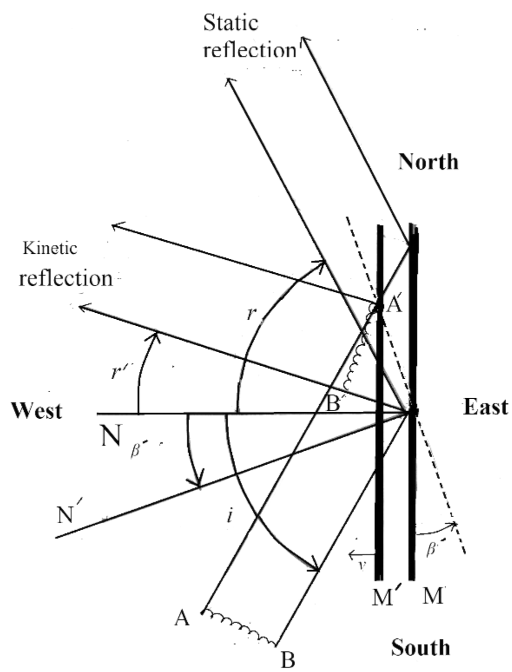


Figure 10.3: Kinetic reflection on a mirror placed perpendicular to Earth's velocity, which is approaching the light source.

In this case, since the mirror is approaching the light source, the value of the angle β′, which the virtual surface of kinetic reflection makes with the surface of mirror M, is calculated using the formula:

$tan\,\beta' = \frac{v\,sin\,i \cdot sin\alpha}{c + vcosi\,sin\,\alpha}$ (see pag 35)

The maximum value is obtained at 12 PM. Since mirror M is oriented along the North–South direction, the angle α it makes with Earth's velocity is 90°, and the formula becomes:

$$tan\,\beta = \frac{v\,sin\,i}{c + vcosi}$$

Considering that $c = v \times 10^4$ the formula becomes:

$tan\,\beta = \frac{sin\,i\cdot}{10^4 + cosi}$.

The cinematic reflection angle becomes:

$r' = i - 2\beta'$.

Let us consider that the angle of incidence is very large, for example: **89°**. In this case:

$tan\,\beta' = 0.0000999848$, $\beta' = 0.005728709°$,

$2\beta' = 0.01145741°$ or $2\beta' = 41.2466904"$

In this case, the angle of reflection will be:

$r' = 89° - 0.011457414°$.

At a distance of $L = 10km$, the reflected ray will experience a transverse deviation of: $d = L \cdot tan\,2\beta' = 1.99969m$ compared to the static reflection angle.

At night, between 6 PM and 6 AM, the direction of the kinetically reflected ray appears as shown in Fig. 10.4.

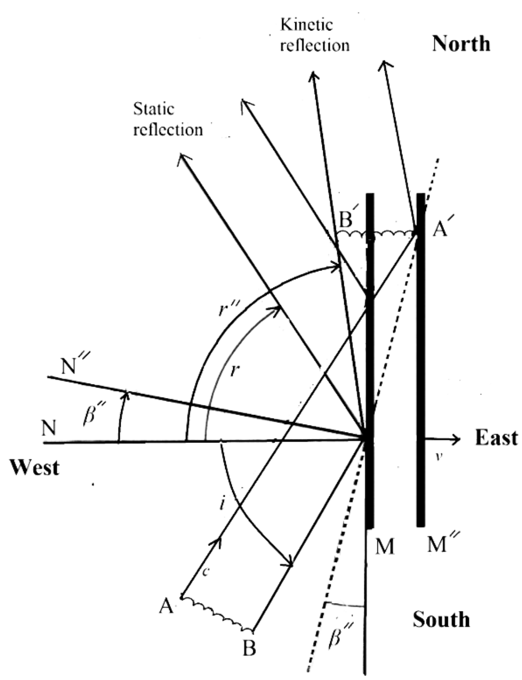


Figure 10.4: Kinetic reflection on a mirror placed perpendicular to Earth's velocity, which is moving away from the light source.

In this case, since the mirror is moving away from the light source, the value of the angle β″, which the virtual surface of kinetic reflection makes with the mirror surface M, is calculated using the formula:

$$tan\, \beta'' = \frac{v\, sin\, i \cdot sin\alpha}{c - \; vcosi\, sin\, \alpha}$$

$$tan\, \beta'' = \frac{v\, sin\, i}{c - vcosi}$$

The maximum value is obtained at midnight (24:00). Considering that the mirror M is oriented along the North-South direction, the angle α it makes with Earth's velocity is 90°, and the formula becomes:

$$tan\, \beta'' = \frac{sin\, i}{10^4 - \; cosi}$$

Considering: $c = v \times 10^4$, the formula becomes:

The kinetic reflection angle becomes:

$r'' = i + 2\beta''$.

Now, for an angle of incidence $i = 89°$, we obtain:

$$r'' = 89° + 0.011457425$$

$tan\, \beta'' = 0.0000999848$,

$\beta'' = 0.0057287128°, or\ 2\beta'' = 0.0114574256°$

$2\beta'' = 41.24673216"\ tan(2\beta'') = 0.0001999618$

In this case, the angle of reflection will be:

At a distance of $L = 10km$, the reflected ray will experience a transverse deviation of: $d'' = L\, tan\, 2\beta'' = 1.999698m$ compared to the static angle of incidence. Therefore, over a 24-hour period, the kinetically reflected ray will oscillate by approximately $\pm\, 2m$ at 10 km away from the mirror, compared to a statically reflected ray (see Fig. 10.5).

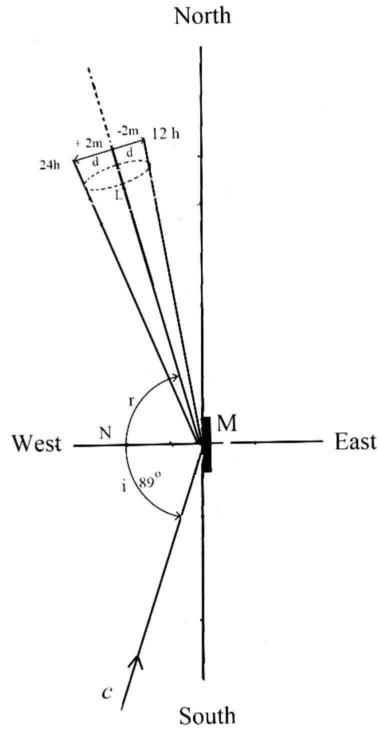


Figure 10.5: Diurnal deviation of a ray of light kinetically reflected by a mirror placed in the north-south direction.

On the other hand, we observe that the values of the angles β′ and β″, expressed in arcseconds, are close to the kinetic reflection angles observed in the experiments we conducted in 1997. This supports our assertion that the hypothesis of kinetic reflection theory is the correct approach for explaining the negative result of A.A. Michelson's-experiment.

Conclusion

- From the above, we see that the negative result of Michelson's experiment can be explained within the framework of classical physics if we use the kinetic reflection of light, as we are dealing with a situation where the optical components are in motion relative to the light propagation medium.
- We cannot use the laws of classical optics, which were established for a static situation, in a kinetic situation.
- In practice, we use the laws of classical optics, which were established for the case when the light source and optical components are considered fixed relative to the light propagation medium, and the results are

satisfactory because the speed of light propagation is very high. In reality, for much higher precision, we should consider the laws of kinetic optics.

In practice, we apply the laws of classical optics, which were developed under the assumption that both the light source and optical components are stationary relative to the medium through which light propagates. These laws yield satisfactory results due to the extremely high speed of light.

In reality, achieving much higher precision requires us to consider the laws of kinetic optics.

A plea for kinetic optics.

Upon closer analysis, we find that along with kinetic reflection at a moving boundary surface between two optical media, kinetic refraction also occurs. In practice, this may have the following consequences:

Modification of the second law of reflection

Modification of the law of refraction,

Alteration of the deviation angle of a prism

Change in the focal length of lenses

Change in the focal length of spherical mirrors.

For example, a spherical mirror with radius R, whose center O moves in the direction OO′ with velocity v, and toward which a wavefront S is approaching with velocity c, will transform into a virtual reflective surface of elliptical shape (dotted curve) with a major semi-axis D_{max} - see Fig.11.1 [8].

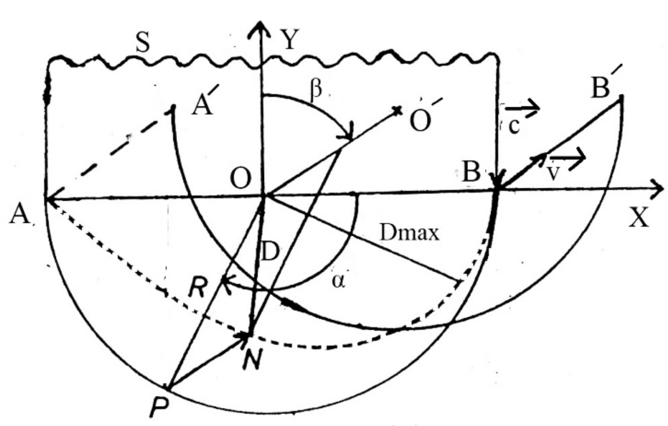
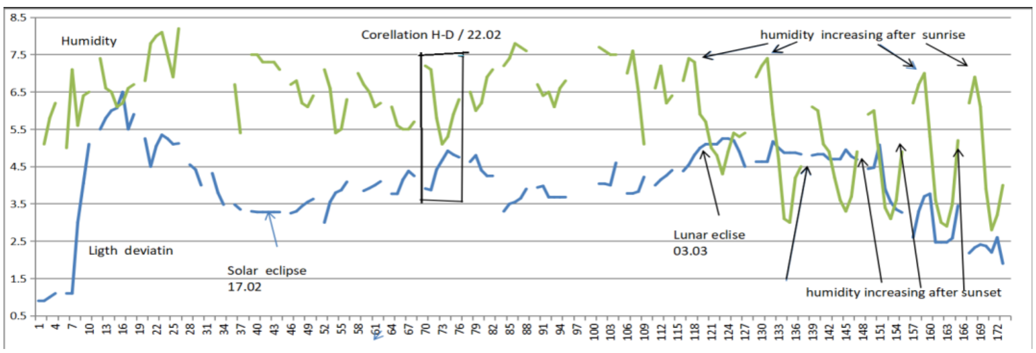


Figure 11.1: The virtual reflective surface of a spherical mirror in motion.

The use of kinetic optics involves corrections to geodetic and astrometric measurements.

The modification of the angles of reflection and refraction that occur in kinetic optics compared to classical (static) optics raises a question regarding the validity of the principle of covariance of physical laws in the theory of relativity.



References

1. Michelson AA, Morley EW (1887) On the relative motion of the Earth and the luminiferous ether. American Journal of Science 3: 333-345.
2. Michelson–Morley experiment Wikipedia https://en.wikipedia.org.
3. Michelson–Morley experiment revisited under the light of https://physics.stackexchange.com.
4. D Olenici (1984) Aspecte inedite ale experientei lui Michelson din 1881 privind evidentierea eterului, Buletin stiintific (Matematica- Fizica-Chimie), Institutul de subingineri, Suceava.
5. D Olenici (1990) Teoria eterului si experienta lui Michelson, Revista de Fizică si Chimie, Anul XXVII, iulie-august 7-8.
6. D Olenici, the kinematic reflection, a new method of standing out the existence of the ether, Proceedings the III-rd Conference on theoretical physics, general relativity and gravitation, held 1993 in Bistrita, Romania 3.
7. D Olenici, St B Olenici (2009) The existence of the ether and earth rotation demonstrated by the aberration of terrestrial light and kinematic reflection, Anuarul Complexului Muzeal Bucovina, M XXXIV – XXXV-XXXVI, 2007-2008-2009 Suceava.
8. D Olenici, the kinematic reflection on a spherical mirror and possible implications in astronomy, Proceedings of the IV-th and V-th Conferences on theoretical physics, general relativity and gravitation, held in May 1994 and 1995 in Bistrita, Romania 4-5.