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Identification of Michelson's Errors in his 1881/87 Experiments and their re-analysis

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Research Article

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ABSTRACT

The Michelson-Morley experiment was an attempt to detect the existence of the luminiferous aether, a supposed medium permeating space that was thought to be the carrier of light waves. First are highlighted the errors committed by Michelson in the analysis of experiments of 1881/87 by reanalysing his faithful physical model, the contest between two swimmers (SW). Are provided evidences showing that Michelson designed his interferometer based on an analogy with this swimming contest, considering the SW2 winner. Is also provided evidence that in 1892, Lorenz expressed doubts about the correctness of Michelson's 1887 analysis, without finding errors.

Michelson's errors consisted of assuming the transverse path of SW2 to be an isosceles triangle, and thus calculating the wrong result, $t_2 < t_1$.

We logically demonstrate, that under fair play conditions, the correct path for SW2 is a right triangle, and the correctly calculated times are $t_2 = t_1$, or $\Delta t = 0$

It is shown that an initial error was committed by Michelson in 1881 analysis by superposing paths for SW2 and in incorrect calculations of t_2 and Δt, an error communicated to him by Potier which indicated $\Delta t = 0$

In 1887 analysis, Michelson acknowledged this error, modified the path to isosceles triangle, and made new calculation; however, he reduced the $\Delta t = t_1 - t_2 \neq 0$ by only half, compared to Δt in 1881, meaning that the basic error in Δt (ERM87) has persisted until today.

This ERM87 in Δt and the isosceles path has been reported by the present authors since 2000".

We emphasize that error ERM87 is repeatedly printed and is being appeared in all college physics textbooks around the world, exemplifying by presenting excerpts from textbooks of US and Canada. A correction to ERM87 and a reconsideration of special relativity theory is required, following which the ether can be reintroduced into physics with multiple favorable consequences.

INTRODUCTION TO THE PROBLEM OF MICHELSON'S ERRORS FROM 1881/87

ERM81/87 is the double scientific error that occurred in the theoretical analysis of the experiments carried out by Michelson that became ingrained in the minds of physicists all around the world from 1881-87, when Michelson's first interferometry experiments (ME81/87) took place [1,2]. These involved two light beams, starting at 90° to each other and returning to the same observation point **Figure 1a and 1b**. Michelson's incorrect theoretical analysis of this experiment marked the beginning of the questioning of the existence of the ether by physicists.

Although ERM81/87 has persisted continuously from 1881 to today, its impact was strongest in 1905, when ERM81/87 was taken over and developed by Einstein was creating his Special Relativity Theory (SRT) [3]. This theory took ME81/87 as its basis, including ERM81/87, which gave rise to the more complex mistake of SRT itself. Through the popular theory of SRT, the ERM81/87 error has intoxicated the thinking of physicists and has led to the total removal of the ether from physics.

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The origin of this error ERM81/87, lay in analysis and incorrect logical judgment by Michelson regarding a problem/contest that appears simple and insightful but which has an essential subtlety. It concerns a contest (a hypothetical contest or thought experiment, since this never took place in reality) between two boats with rowers, located on the bank of a flowing river. Later on, the initial scenario involving rowers was altered, sometimes becoming the problem of two ships, two swimmers, two watchmen, or two planes, for example. For clarity, we will examine the case of two swimmers, SW1 and SW2, as Michelson did in his justification for his experiments **(Figure 2a)**.

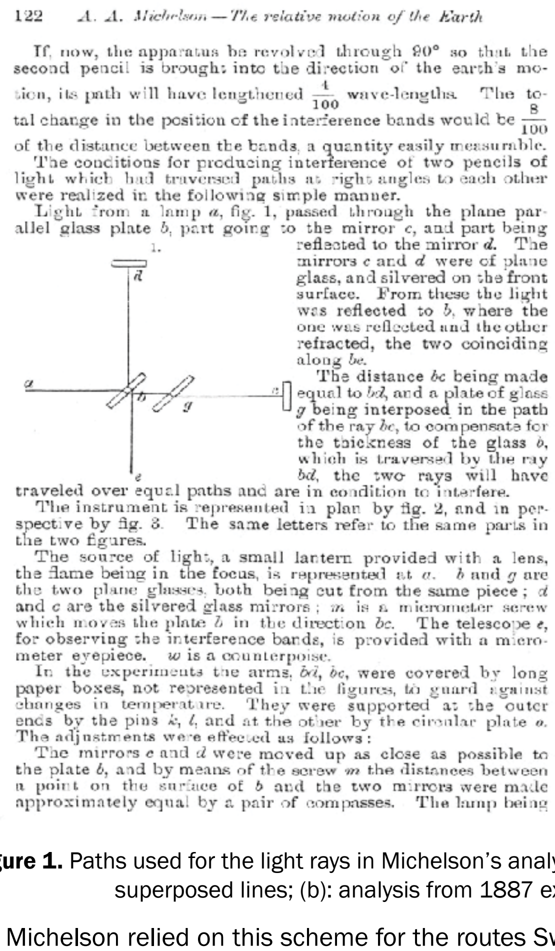
Here, we briefly summarise the problem of the two swimmers contest, with its own basic rules, and placed it in real condition.

The contest involves the question of which of two Swimmers (SW1 and SW2) will arrive back at the starting block first, under the following conditions:

- The starting block is on the bank of a river of width L, which flows with constant speed v (these data are unknown to the two swimmers before the race)
- Both swimmers swim at the same speed c
- Swimmer SW1 travels a distance L along a route Sw1 in a direction parallel to the current v, along the river bank, while swimmer SW2 follows the route Sw2, also a distance L, but in a direction transverse to the river
- Both swimmers start from the same block, located on one of the river banks

In his analysis of the ME81/87 experiments, Michelson calculated the times t_1 and t_2 in 1881 (and recalculated them in 1887) for the longitudinal and transversal directions in his device or for the swimmers SW1 and SW2 in the thought contest, and obtained the result that $t_2 < t_1$. He therefore concluded that SW2 will return before SW1 to the starting block. The times t_1 and t_2 were calculated in Michelson's analyses based on his own geometric schemes for the routes Sw1 and Sw2. For the route Sw1, Michelson used a scheme with two overlapping lines, both in 1881 and in 1887, but for the route Sw2, he used two overlapping lines in Michelson AA [1] **(Figure 1a)** and an isosceles triangle shape in Michelson AA, et al. [2] **(Figure 1b)**.

a)



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If, now, the apparatus be revolved through 90° so that the second pencil is brought into the direction of the earth's motion, its path will have lengthened $\frac{4}{100}$ wave-lengths. The total change in the position of the interference bands would be $\frac{8}{100}$ of the distance between the bands, a quantity easily measurable.

The conditions for producing interference of two pencils of light which had traversed paths at right angles to each other were realized in the following simple manner.

Light from a lamp *a*, fig. 1, passed through the plane parallel glass plate *b*, part going to the mirror *c*, and part being reflected to the mirror *d*. The mirrors *c* and *d* were of plane glass, and silvered on the front surface. From these the light was reflected to *b*, where the one was reflected and the other refracted, the two coinciding along *be*.

The distance *bc* being made equal to *bd*, and a plate of glass *g* being interposed in the path of the ray *bc*, to compensate for the thickness of the glass *b*, which is traversed by the ray *bd*, the two rays will have traveled over equal paths and are in condition to interfere.

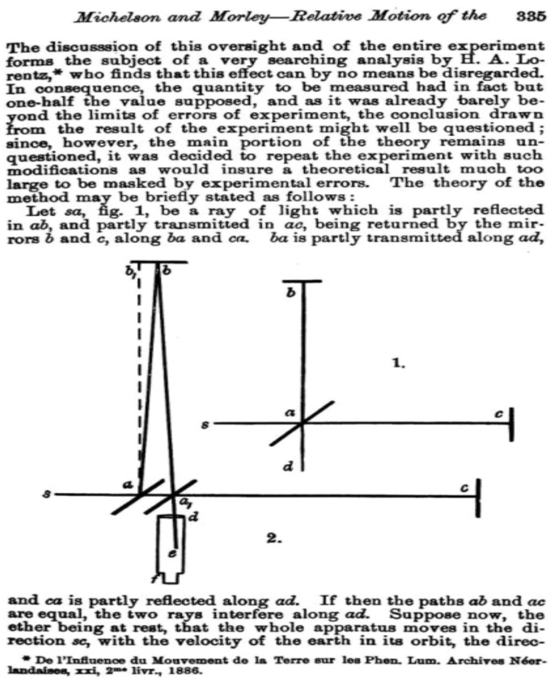
The instrument is represented in plan by fig. 2, and in perspective by fig. 3. The same letters refer to the same parts in the two figures.

The source of light, a small lantern provided with a lens, the flame being in the focus, is represented at *a*. *b* and *g* are the two plane glasses, both being cut from the same piece; *d* and *c* are the silvered glass mirrors; *m* is a micrometer screw which moves the plate *b* in the direction *bc*. The telescope *e*, for observing the interference bands, is provided with a micrometer eyepiece. *w* is a counterpoise.

In the experiments the arms, *bd*, *bc*, were covered by long paper boxes, not represented in the figures, to guard against changes in temperature. They were supported at the outer ends by the pins *k*, *l*, and at the other by the circular plate *o*. The adjustments were effected as follows:

The mirrors *c* and *d* were moved up as close as possible to the plate *b*, and by means of the screw *m* the distances between a point on the surface of *b* and the two mirrors were made approximately equal by a pair of compasses. The lamp being

b)



Michelson and Morley—Relative Motion of the 335

The discusssion of this oversight and of the entire experiment forms the subject of a very searching analysis by H. A. Lorentz,* who finds that this effect can by no means be disregarded. In consequence, the quantity to be measured had in fact but one-half the value supposed, and as it was already barely beyond the limits of errors of experiment, the conclusion drawn from the result of the experiment might well be questioned; since, however, the main portion of the theory remains unquestioned, it was decided to repeat the experiment with such modifications as would insure a theoretical result much too large to be masked by experimental errors. The theory of the method may be briefly stated as follows:

Let *sa*, fig. 1, be a ray of light which is partly reflected in *ab*, and partly transmitted in *ac*, being returned by the mirrors *b* and *c*, along *ba* and *ca*. *ba* is partly transmitted along *ad*, and *ca* is partly reflected along *ad*. If then the paths *ab* and *ac* are equal, the two rays interfere along *ad*. Suppose now, the ether being at rest, that the whole apparatus moves in the direction *sc*, with the velocity of the earth in its orbit, the direc-

* De l'Influence du Mouvement de la Terre sur les Phen. Lum. Archives Néerlandaises, xxi, 2me livr., 1886.

Figure 1. Paths used for the light rays in Michelson's analysis (a): analysis from 1881experiment, with both paths Sw2 shown as incorrect superposed lines; (b): analysis from 1887 experiment, with an incorrect isosceles triangle used for path Sw2.

Michelson relied on this scheme for the routes Sw1 and Sw2 used by the two swimmers in the contest, as shown in **Figure 2a**, when he designed and made his interferometric device, through which he sought to demonstrate the movement of the earth in its orbit through the cosmic ether, which was considered at that time to be a real form of a stationary matter as light support, by many physicists.

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In 1905, when Einstein developed his SRT, he also relied on the scheme used by Michelson in ME87 for the light paths [2] **(Figure 1b)**, i.e. a double linear path Sw1 and a path Sw2 in the shape of an isosceles triangle in the swimmers contest **(Figure 2a and 2b)**. This scheme was then adopted by most other physicists, who accepted SRT as valid, including the great Lorenz.

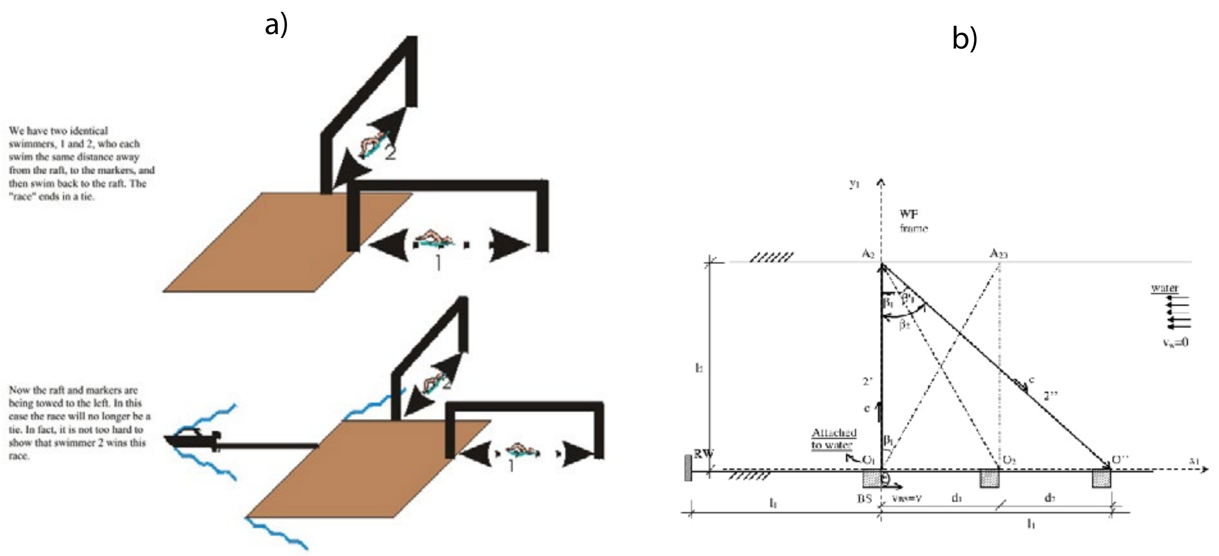

Figure 2. The ‘two swimmers’ model of Michelson’s interferometer (a): generic physical model with a contest between two swimmers; (b): physical model of two swimmers with the correct right triangle O_1A_2O'' for path Sw2, proposed by the authors in 2020.`

However, there are indications that Lorenz expressed doubts about the correctness of the Michelson’s interpretation/theory of ME/87, since he asked in an 1892 letter to Michelson LD [4].

“Can there be some point in the theory of Mr. Michelson’s experiment which has as yet been overseen?” (sic)

Unfortunately for physics in general, he failed to confirm this suspicion by identifying Michelson’s errors. We can therefore say that by discovering Michelson's error in Has I [5], after more than 100 years, we have confirmed Lorenz’s legitimate suspicion of ME/87.

Michelson’s analysis of his experiments from 1881/87

We first observe from his analyses of 1881/87 in which Michelson calculated some parameters of his interferometer device, which considered to be movable with the earth in the ether, without indicating the Referential Frame (RF) he used for the earth/ether.

This ambiguity can have negative consequences on the logical judgment and development of the analysed phenomenon. This lack of RF means that some errors may slip into the calculations or the logic adopted, which was the case in Michelson's analyses.

In all our analyses, starting with our paper of Has I [5], we have specified precisely in which RF has been used, either by indicating the speed v=0 of the body/part, or by positioning the origin Oxyz of the Cartesian coordinate system on the reference body. This rule should be applied in all analyses and analytical calculations in the natural sciences, to provide clarity for readers and to ensure the correctness of the calculations and analyses.

On pg. 336 of ME/87 [2], Michelson notes that for a velocity of light V, velocity of the earth v, D distance ab or ac **(Figure 1b)**, a time T is required for light to pass from a to c, and a time T1 for light to pass from c to a1. He then calculated the longitudinal time as follows:

$$T + T_1 = \frac{D}{V - v} + \frac{D}{V + v} = 2D\frac{V}{V^2 - v^2} \tag{1}$$

From (1), Michelson calculated the longitudinal distance by multiplying in (1) by V, as follows:

$$2D\frac{V}{V^2 - v^2} \approx 2D\left(1 + \frac{v^2}{V^2}\right)` \tag{2}$$

Michelson did not calculate the transversal distance or time, simply indicating briefly that the distance corresponding to the isosceles triangle ab_{a1} from **Figure 1b** is:

$$2D\sqrt{\left(1+\frac{v^2}{V^2}\right)} \tag{3}$$

But we can see that in (3), the distance indicated by Michelson, resulting from the isosceles triangle aba1 shown in **Figure 1b**, is not correct.

Later researchers established the correct formula for the path ab_{a1}, calculating it from two right triangles ab_{a0} [6], resulting in the correct distance ab_{a1} (from the corresponding time T):

$$2D\frac{1}{\sqrt{\left(1-\frac{v^2}{V^2}\right)}} \tag{4}$$

It should be noted that the result of a simplified calculation based on a linear approximation of the expressions in Equation (3) and (4) gives the same result for distance ab_{a1} indicated by Michelson in the end:

$$2D\left(1+\frac{v^2}{2V^2}\right) \tag{5}$$

However, the above formal error from 1887 analysis remains, which together with the error in Δt from his ME81 analysis, which was discovered and noted by Potier in 1881, indicate an inconsistency in Michelson's analyses of his experiments ME81/87.

Thus from Equation (2) and (4), doubling the distance result from Equation (5), due to the rotation of the interferometer by 90°, the difference in the distance between the two paths resulted in Michelson's ME87:

$$2D\left(\frac{v^2}{V^2}\right) \tag{6}$$

which represents for Michelson, 0.04 interference fringes.

By dividing the distance in Equation (6) by V, we can also obtain the time difference between the two paths, as usually discussed in SRT [6-8]:

$$\Delta t = 2(t_1 - t_2) = \frac{2l}{c}\frac{v^2}{c^2} = \frac{2l}{c}\beta^2 \neq 0 \tag{7}$$

The shape of the isosceles triangle for Sw2 after Michelson's ME87 and relation Equation (7) put in the form $t_2<t_1$ was used consistently after 1905, and is still used today in calculations of Δt in Equation (7) by many physicists to justify the validity of SRT, including Kittel et al., Jaffe, Rosser, Feynman, Prokhovnik, Taylor and Wheeler, Tipler and Llewellyn, Sivoukine, Serway et al., Gamow, Nolan , Schwartz et al., Shalowtz, Teller et al., [9-22].

Similarity Between Michelson's Experiments ME81/87 and the 'Two Swimmers Contest', Correctly Analysed and Calculated by Us

Actual situation of our analysis of swimmers contest

From the beginning of this analysis, I emphasise the longstanding situation in physics in which the correspondence of the paths Sw1 and Sw2 of the two swimmers SW1 and SW2 with the light rays 1/1′ and 2/2′, respectively, from ME81/87, was and is unanimously recognised in Physics, and the model for the contest of the two swimmers was indirectly assumed by Michelson in ME81/87.

Thus, a detailed analysis of the thought experiment of the contest between two swimmers can be admitted as faithfully representing the interferometric device of Michelson from 1881/87.

It should be noted that Michelson did not directly refer in his articles to the model of the boatmen/swimmers; however, there are family testimonies to confirm that Michelson knew in advance about the problem of the two swimmers, saying to his children:

"Two beams of light race against each other, like two swimmers, one struggling upstream and back, while the other covering the same distance, just crosses the river and returns. The second swimmer will always win, if there is any current in the river" after Livingstone [4].

We can see that before or during his ME81/87, Michelson chose the wrong final answer, with SW2 as the winner. In his papers from ME81/87, he does not present a logical analysis of the contest, its final outcome, or a mathematical calculation for t_2, as we did in our article [5].

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However, we state now, as in our important article [5], that the scheme for the paths Sw1 and Sw2 proposed by Michelson in ME87 contained from the beginning a hidden error in the form of a double error: in the composition of the path of Sw2 as an isosceles triangle, and in the relation $t_2<t_1$.

This is because, the route Sw2 as an isosceles triangle does not correspond to the real conditions of the competition if it were to take place in reality, on the bank of a real river, in the presence of all the protagonists involved and assuming the existence of written, detailed regulations for conducting the contest and validating the results.

Needless to say, a real contest of this type never took place, the one that would have been the competent court to validate the result of the contest problem, no matter what that result was. The problem was actually a thought experiment, but this non-existence of a real contest did not prevent Michelson from considering it as a real fact (including the adoption of the path Sw2 as an isosceles triangle), and assuming that it represented what would actually happen, which was not the case.

In our article [5] and in our subsequent work [23-27] on the competition between SW1 and SW2, we specified from the beginning the RF adopted in our analysis.

We mention that the path Sw1 with two overlapping lines adopted by Michelson is also correct, if the water reference frame (WF, or ether frame EF) is adopted **(Figure 2b)** leading to a total round trip time of [26,27]:

$$t_1 = t_1' + t_1'' = \frac{2l_1 c}{c^2 - v^2} = \frac{2l_1}{c}\frac{1}{\alpha^2}; with \quad \alpha = \sqrt{1 - v^2 / c^2} \tag{8}$$

We first determined the two times and based on the geometrical elements of the physical model (PM) in **Figure 2**, from which it results that:

$$t_2' = \frac{l_2}{c} = \frac{O_1A_2}{c}; \quad t_2'' = \frac{A_2O''}{c} \tag{9}$$

$$t_2 = t_2' + t_2'' \quad O_1O'' = vt_2 \tag{10}$$

From the right triangle O1A2O″ of **Figure 2**, we get:

$$\left(O_1A_2\right)^2 + \left(O_1O''\right)^2 = \left(A_2O''\right)^2 \tag{11}$$

Introducing (9) and (10) into (11) gives:

$$\left(t_2'c\right)^2 + \left(vt_2\right)^2 = \left(t_2''c\right)^2 \tag{12}$$

By replacing t_2 from (10) in (12), we obtain:

$$\left(t_2'c\right)^2 + \left(v\left(t_2' + t_2''\right)\right)^2 = \left(t_2''c\right)^2 \tag{13}$$

Carrying out the calculations in the brackets and regrouping the terms gives:

$$\left(t_2''\right)^2\left(c^2 - v^2\right) - 2v^2 t_2' t_2'' - \left(t_2'\right)^2\left(c^2 + v^2\right) = 0 \tag{14}$$

By solving the second-degree equation in (14), we obtain the result:

$$t_2'' = \frac{2v^2t_2' + \sqrt{4v^4\left(t_2'\right)^2 + 4\left(c^2+v^2\right)\left(c^2-v^2\right)\left(t_2'\right)^2}}{2\left(c^2-v^2\right)} = \frac{v^2t_2' + t_2'\sqrt{v^4 + \left(c^2+v^2\right)\left(c^2-v^2\right)}}{c^2-v^2} \tag{15}$$

Due to the solution , the (–) sign in front of the square root in Equation (15) is pointless, and we use only the (+) sign.

By introducing Equation (9) and (15) into (10), we obtain:

$$t_2 = \frac{l_2}{c} + \frac{\frac{v^2l_2}{c} + \frac{l_2}{c}\sqrt{v^4 + c^4 - v^4}}{c^2 - v^2} = \frac{l_2}{c} + \frac{\frac{v^2l_2}{c} + \frac{c^2l_2}{c}}{c^2 - v^2} = \frac{l_2c^2 - l_2v^2 + v^2l_2 + c^2l_2}{c\left(c^2 - v^2\right)} \tag{16}$$

From (16), we finally obtain for the time t_2 of the crosswise route 2′–2″:

$$t_2 = \frac{2l_2c^2}{c\left(c^2 - v^2\right)} = \frac{2l_2}{c}\frac{1}{1 - v^2/c^2} = \frac{2l_2}{c}\frac{1}{\alpha^2} \qquad (17)$$

Note that in (17), the same result was obtained as in Eq. (8) except for the lengths l1 and l2. Hence, in case where $l_1 = l_2$, we see from Equation (8) and (17):

$$t_2 = t_1; \quad ;and \quad \Delta t = t_2 - t_1 = 0 \qquad (18)$$

Hence, the swimmers SW1 and SW2 arrive at the same time if the 'fair play' rule of orthogonality for their initial direction at their departure is also respected for Sw2. Their race would therefore end in a tie, as demonstrated above. There is no winner in this hypothetical race. But indeed a real such a contest would be clearer for the disputed result.

Anyone who has doubts about this calculation and the results presented above can verify these by organising a real contest. I have no doubt of the outcome.

New developments of our analysis of swimmers contest

In order to bring additional arguments for the above result Equation (18) of equality between SW1 and SW2 in classical contest, we will generalize below, the classical contest, with 1' path parallel to v, by admitting any direction α, for starting of SW1 from the blockstart.

So we will demonstrate here that any intermediary starting direction of the road/path 1′, with starting angle α ≠ 0, obtained by rotating with angle α>0 the blockstart (but with β=0 permanently), may be considered as also obtainable from the overlapping of the two classical cases A and B, both with α=0, and β=0 **(Figure 3)**.

Case A corresponds to the projection of the inclined road 1' on the Ox axis, and of the projection of the road 2' on the Oy axis (the path/road in green in **Figure 3c)**.

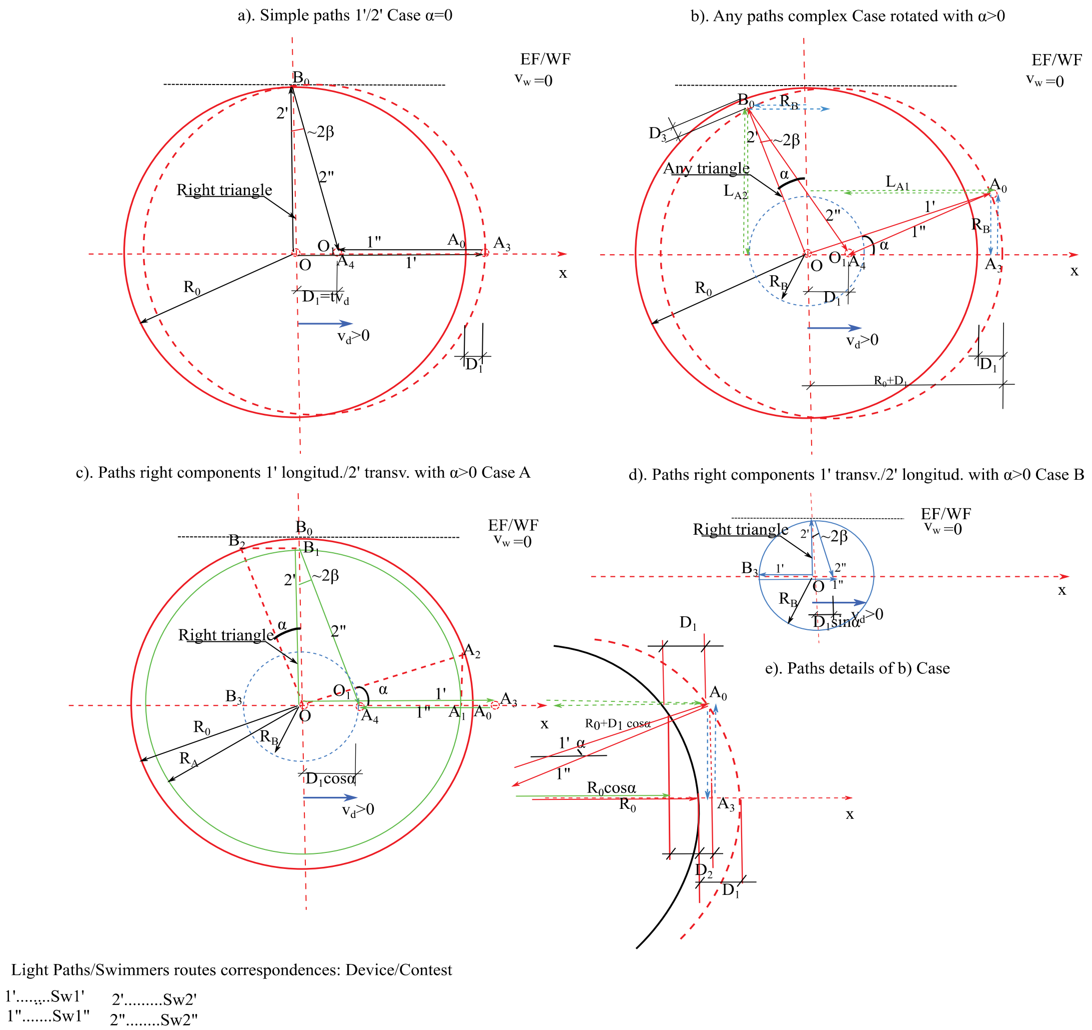

Figure 3. Representation of the general Michelson contest free of path/road errors (a): Contest rotated at an angle α; (b): Paths components at 0°; (c): Paths components at 90°; (d): All with the corresponding circles for various paths components. Details of returning paths 1'-1" zone from b, e.

Case B, corresponds to the projection of road 1′ on the Oy axis and of the projection of the road 2′, on the Ox axis (the road in blue in **Figure3d)**.

In each of these cases A and B, it will be possible to apply equation (18), resulting in $t_{2A} = t_{1A}$ and $t_{1B} = t_{2B}$, as below.

Equality of the two total times $t_2=t_1$ as above is obtained for any case of the contest, A/B in which paths 1′ and 2′ start with path 1′ inclined at angle α, and paths 2′ and 1′ are oriented at angle of 90°, each other **(Figure 3b)**.

In Case A, with α=0.0, SW1 leaves on the distance $La_1=(R_0 + D_2)$, on the road 1', and SW2 leaves on the distance $La_2=(R_0-D_3)$ cos α on the road 2' **(Figure 3b and 3c)**. Here R_0 is the circle radius of classical contest with α=0 **(Figure 3a)**.

In Case B, with α=-1800, SW1 leaves on the distance $-L_{a3} = L_{a2}$ tg α, on road 1' and SW2 leaves on the distance $L_{a3}=L_{a1}$ tg α on road 2' **(Figure 3b and 3d)**.

But any return roads 1" and 2" or L_{xy}, are obligatory those to return to the starting point O, moved to its final position O' according to the speed v and the time t_1, an unique point for both swimmers **(Figure 3b and 3d).**

From **Figure 3e** we can write:

$D_1=vt_1$ with $t_1=(R_0+D_1)/c$ (19)

And finally the quantities D_1, D_2, D_3, result from (19) and from **Figure 3e**:

$$D_1 = \frac{(R_0\ tg\beta)}{(1-tg\beta)} \quad (20)$$

$$D_2 = R_0 \left[\frac{tg\beta}{(1-tg\beta)} + cos\alpha - 1\right] \quad (21)$$

$$D_3 = D_1\ sin\alpha \quad (22)$$

From the vector composition at right angle, $R_a+R_b=R_0$, we can see the equivalence of the roads, from **Figure 3b** with those of **Figure 3c and 3d**.

But the cases in **Figure 3c and 3d**, are classic contest cases, in which $t_{1a}=t_{2a}$ and $t_{1b}=t_{2b}$, and their sum gives us:

$t_{1a}+t_{1b}=t_{2a}+t_{2b}$ (23)

The relation (23) is equivalent to $t_{10}=t_{20}$, for the classical case from **Figure 3a**, so there is the equivalence of the contest case with α =0.0, with the combination/overlap of the two cases A and B, with α=0.0/180^0.

This conclusion can also be supported by a second observation, that for the special case with α=450 **Figure 3b**, roads 1' and 2' are situated in perfectly identical positions with respect to the direction of velocity v of water/ether. And so the relation $t_2=t_1$ must be physically/mechanically fulfilled, and so the relation Equation (18) will have to result from analytical calculations: $t_2=t_1$.

We can also find third correspondence between the general case of the contest in **Figure 3b**, with the calculation of the areas of the circles with the radii afferent to cases A and B, when we can write from **Figure 3b, 3c and 3d**:

$$R_A = R_0\ cos\alpha\ and\ R_B = R_0\ sin\alpha \quad (24)$$

From equation (24) the relation between the areas of the 3 circles results:

$$A_t = A_A + A_B = \pi\left(R_0^2\ cos\alpha^2 + R_0^2\ \ sin\alpha^2\ \right) = \pi R_0^2\left(R_0^2\ cos\alpha^2 + R_0^2\ \ sin\alpha^2\ \right) = \pi R_0^2 \quad (25)$$

This relationship from equation (25) between the total areas of the two circles corresponding to cases A and B, leads to the conclusion that between the respective total return times $t_t=t_1+t_2$, there must be similar relations:

$t_{tA}+t_{tB}=t_{t0}$ (26)

From equation (26) above, it follows the possibility of the existence of generalized contests with any α=0.0 .... 900., in which the condition $t_2=t_1$ is permanently fulfilled, including the particular case of Michelson's classic contest with α=0.

In this situation, we see that the case of the contest of the two swimmers, with SW1 swimming parallel to the direction of water flow, as assumed by Michelson, can be generalised to the departure of SW1 at a certain angle α, where the directions Sw1′ and Sw2′ are always orthogonal **(Figure 4)**, as in our solution above, in Equation (18).

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Similarity Between Michelson's Experiment ME81/87 and the 'Two Swimmers Contest', Calculated According to Followers of Michelson

In this section, we present a detailed analysis and calculation of the times taken in the contest between two swimmers, although here we consider a competition between two planes, using a model taken from a recent physics textbook by Serway et al. [28], whose author is a faithful follower of Michelson. The textbook presents a calculation that was corrected (compared to Michelson's simplistic calculation in Section 2) immediately after 1905 by Michelson's first followers. Here we consider the case of two planes, flying at speed c in a wind with speed v, along runways with length L **(Figure 5)**, conditions that are completely equivalent to swimmers moving along a river, as shown in **Figure 2**.

Under these conditions, the total round trip time in the longitudinal direction I of the wind, above author calculated as follows from right and left times:

Under these conditions, the total round trip time in the longitudinal direction I of the wind, above author calculated as follows from right and left times:

$$t_1 = t_R + t_L = \frac{L}{(c+v)} + \frac{L}{(c-v)} = \frac{2Lc}{(c^2 - v^2)} = \frac{2L/c}{\left(1-\frac{v^2}{c^2}\right)} \quad (27)$$

In the calculation of the transverse time II, the pilot must point the plane towards the wind at a certain angle given by vectors c and v, (Figure 4a) which obviously must be given to the pilot by the organiser (non fair-play, fraudulent action). Applying Pythagoras' theorem to the vector triangles, one obtained the speeds:

$$\mathrm{v}_u = \mathrm{v}_d = \sqrt{c^2 - v^2} = c\sqrt{\left(1-\frac{v^2}{c^2}\right)} \quad (28)$$

For the transversal path II, for departure and return, one obtained the time:

$$t_2 = \frac{L}{v_u} + \frac{L}{v_d} = \frac{L}{c\sqrt{1-\frac{v^2}{c^2}}} + \frac{L}{c\sqrt{1-\frac{v^2}{c^2}}} = \frac{2L}{c\sqrt{1-\frac{v^2}{c^2}}} \quad (29)$$

By comparing Equations (27) and (29), author concluded that the airplane flying along route II wins the race.

The difference in flight times is given by:

$$\Delta t = t_1 - t_2 = \frac{2L}{c}\left[\frac{1}{\left(1-\frac{v^2}{c^2}\right)} - \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\right] \quad (30)$$

This expression can be simplified taking into account that the ratio v/c is usually much smaller than one, and by using the binomial development formula in v/c and neglecting the terms of order higher than two, we obtain:

$$\left(1-\frac{v^2}{c^2}\right)^{-1} = 1+\frac{v^2}{c^2} \text{ and } \left(1-\frac{v^2}{c^2}\right)^{-1/2} = 1+\frac{1}{2}\frac{v^2}{c^2} \quad (31)$$

The difference in light times is:

$\Delta t=(Lv^2)/c^3$ for $v/c <<1.0$ (32)

A perfect analogy is observed between the competition between planes or swimmers and the paths of the light rays in the interferometer in ME81/87.

There is also an analogy between the final results, in which the winner of the race is shown to be the plane flying along the transverse route II to the wind, which is similar to the ray of transverse light travelling in a direction normal to the movement of the earth/ether, for which Michelson finds a shorter time. This result is due to the two errors committed by Michelson mentioned above: the isosceles triangle and the angle $\beta \neq 0$.

Identification of Michelson's Errors in his Analysis of ME1881/87 by our Logical Analysis of the Contest between two Swimmers

Even under the general conditions of the thought experiment/contest indirectly assumed by Michelson, it can be found from the following detailed logical analysis, which is based on fair play, that the route Sw2 which was assumed by Michelson in ME87 to have the form of an isosceles triangle does not correspond to the general contest conditions, nor does it respect the rules of fair play, for the reasons listed below.

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1(a). Error 1: SW2 starting at an inclined direction

The main error in the analysis of ME87 relating to the route Sw2 (OA′2O′ for Boat 2 in **Figure 2a**, SW2 in **Figure 2b**, or aba1 in **Figure 1b**) is that the initial route from the starting block, Sw2', is not orthogonal to the direction of the river bank, nor is it orthogonal to the starting direction Sw1' of SW1 in **Figures 1b and 2b**. The route Sw2' was assumed by Michelson to be inclined at an angle β to the orthogonal direction, in the direction of the water current v in **Figure 1b**. This inclination of the route Sw2' was clearly against the regulations of the contest, because the two swimmers SW1 and SW2 must start from mutually orthogonal directions (crossing the river is considered orthogonal to river bank, based on common sense). Under real competition conditions, the referees would not allow this deviation in the route Sw2' with angle β. And even on the basis of this error of an inclination with angle β of the route Sw2', Michelson obtained in ME81/87 the complete route as an isosceles triangle which gave him the wrong result that $t_2<t_1$. This error was achieved by the first fraud of SW2, and constitutes a lack of fair play between SW2 and SW1.

1(b). Error 2: The form of an isosceles triangle for Sw2 route with result $t_2<t_1$

Here, we state again that another error was made in Michelson's article of 1887, since the path chosen there was in the form of an isosceles triangle. Michelson obtained in ME81/87 the complete route as an isosceles triangle which gave him the wrong result that $t_2<t_1$. And from the proposed isosceles triangle, Michelson obtained his convenient but erroneous result that $t_2<t_1$. This isosceles route is incorrect **(Figure 1b);** as shown in our article [5], the correct path for Sw2 is a right triangle **(Figure 2b)** as demonstrated.

2(a). Lack of orthogonality between Sw2' and Sw1' (following from Error 1)

We mention here that the condition of orthogonality between Sw2' and Sw1' is in accordance with the real operation of Michelson's interferometer, in which two light rays 1' and 2' start perfectly orthogonal to each other, due to splitting by a semi-transparent plate P inclined at 45° **(Figure 1a and 1b)**. Hence, the path Sw2', which is inclined at an angle of 90°+β as proposed in Michelson **(Figure 1b)**, stands in contradiction to the correct path 2' used in Michelson's apparatus, in which the rays were arranged at exactly at 90° **(Figures 1a and b)**. This error due to the lack of orthogonality of the two routes is a sequel of the first error.

2(b). Starting direction of SW2 at angle β (associated with Error 1)

A second aspect of the first error in the analysis of ME87, which constitutes an aditional fraud, was introduced by Michelson, in that the starting direction Sw2' of SW2 is inclined at precisely angle β with respect to the correct orthogonal direction **Figure 1b**; however, the angle β depends directly on the velocities v and c (i.e. tgβ = v/c).

In the simple competition problem, swimmer SW2 does not know the speed of the water v in advance, and hence does not know angle β before the start of the race. A knowledge of the speeds v and c, and hence of angle β, by SW2 alone, would imply a violation of fair play by SW2. This action is obviously only possible through prior fraud by the organisers/referees, by divulging secret information on the angle of β. This error, which involves tilting Sw2' at exactly the angle β, also constitutes a fraud or lack of fair play by SW2 in this contest. We remind the reader that this path Sw2 by SW2, results in an isosceles triangle, precisely due to this error/fraud. Based on this error/fraud regarding the angle β **(Figure 1b)** and the resulting isosceles triangle, Michelson obtained his convenient but erroneous result that $t_2<t_1$. This error due to the angle β in the path Sw2′ forms part of the first error, and constitutes a fraud and a lack of fair play by SW2.

2(c). A right triangle path gives the best coherence

We mention here that the right triangle condition for the route Sw2', proposed in our article [5] **(Figures 2b and 3a)**, is the real/correct path, with angle β=0, and $t_1=t_2$ corresponding to the maximum intensity of fringes, i.e. the real ones that are observable at the returning point O. This maximum fringe intensity appears because for $t_1=t_2$, we obtain the maximum coherence of the rays 1" and 2″ in the interferometer, those of return in point O in **Figures 2b, 3a and 3b**. This maximum fringe visibility for $t_1=t_2$ happens to the detriment of any other combinations of times $t_1 \neq t_2$, and even for $t_2<t_1$. Thus, the real fringes observed by Michelson in EM81/87 must have been those produced by the path Sw2' as a right triangle, as proposed in our article [5].

In the case where path Sw2' is correctly angled at 90°, after SW2 reaches the opposite bank and turns through 180°, he or she will see the position of the starting block directly. SW2 will always aim for the starting block on the way back along path Sw2", which will therefore have a direction correctly inclined at an angle of approx. 2β **(Figure 2b)**, but without SW2 knowing the angle β, so without SW2 violating the rules of competition and of fair play.

In this way, the path Sw2" will form the hypotenuse of a right triangle, with the legs of the triangle having directions c and v.

The same path Sw2", at an angle of approx. 2β, will also be travelled in the interferometer by the returning ray 2", after reflection at the mirror through 900+2β, but based on the Huygens principle, applied to the reflected light as a new source in multiple directions, in the wave hypothesis of light. Alternatively, we obtain ray 2" above, based on the spatial re-emission of photons from the light ray in multiple directions in the corpuscular hypothesis of light. This path 2" will be inclined to the hypotenuse at an angle of approx. 2β, thus forming a right triangle, giving $t_1=t_2$. This will ensure the best coherence and hence the optimal visibility of the real, observable fringes, so the ray 2" inclined at approx. 2β will be the real path in the device.

3(a). First double error in t_2 produced in ME81

It is useful to note here that a larger double error in the analysis of ME81, consisting in the superposition of routes Sw2′ and Sw2″ **(Figure 1a)**. This was followed by an incorrect calculation of t2, and therefore of the measurable Δt, when Michelson found a value of

$$\tau_2=2T_0\ (v^2/V^2) \qquad (33)$$

for the difference in measurement times (in fact, he noted $\tau_2=\Delta t$ and V=c), by using the wrong path, including overlapping straight lines for Sw2 in **(Figure 1a)**.

This error was communicated to him verbally by Potier on the occasion of Michelson's 1881 visit to Paris; Potier indicated that the correct result would be Δt=0 but did not give a justification, as Mark shows [28].

As a result, in his 1887 analysis, Michelson clearly acknowledged this error and changed the calculation to:

$$\tau_2=2T_0\ (v^2/V^2) \qquad (34)$$

However, this reduces only by half the time difference $\Delta t=t_1-t_2$, compared to $\Delta t=\tau_2$ in 1881; this means that the basic error in Δt persisted after 1887, since Michelson never analysed Potier's suggestion of Δt=0.

We can therefore suppose that the error in ME81, which was pointed out by Potier, was the real reason for resuming the experiment in 1887, when Michelson adopted a new route for Sw2 in the form of an isosceles triangle in **Figure 1a and 1b**, obtaining τ_2 as shown in equation (34).

Discovery of Michelson's errors in his analysis of experiments of 1881/87, as reported in our papers of 2000 and later, based on the model of a contest between two swimmers

We should mention that these two errors, i.e. the use of an isosceles triangle for *Sw2* and the wrong relationship $t_2<t_1$, which are explained in Sec.5, points i.a), i.b), ii.a), ii.b), ii.c), and iii.a), and which appeared in Michelson's analysis of his ME81/87 experiments, were initially reported in our important article of 2000 in the journal *Romanian Reports in Physics* [5]. We attach two pages from this article for confirmation (Fig. 4)."

We later published our analysis of Michelson's errors in similar, improved articles, in other journals that were open to new ideas [23-27].

However, these new articles of ours were unfortunately rejected by several other journals that are considered to represent mainstream physics, although no verifier or editor indicated the existence of possible errors in our articles. This rejection was motivated by the fact that the articles did not correspond to the physics principles of these journals, which are aligned with the main stream in physics, devoted to SRT. We must therefore consider our articles and analyses mentioned above, to be correct until proven otherwise.

In our first important article [5], in which we re-examined Michelson's analysis of his ME87 experiments and in which Michelson's errors were revealed regarding the route Sw2, as discussed above in Sec. 5, points i.a), i.b), ii.a), ii.b), ii.c), and iii.a), we also indicated the correct route for Sw2, which was essentially a path in the form of a right triangle (for Boat 2, in the reference water/ether referential system, as clearly specified **Figure 4**.

In this article, were calculated the two times t_1, t_2 for paths Sw1 and Sw2, but corrected them for Michelson's errors, adopting a right triangle path for Sw2'. In this way, we obtained the correct relation $t_1=t_2$, indicating that a fair competition between SW1 and SW2 ends in a draw.

In fact, common sense and correct logic would give us the same result of the equality $t_1=t_2$ between the two swimmers SW1 and SW2.

However, Michelson's logic did not give the same results as above, **Figure 4 a Fig. 4b** in which the contest ends in a draw (but told him the opposite, that SW2 arrives before SW1), since in the case of a tie, he would not have had to build his interferometer, as the device would not have been useful. Such a device would not have been useful to Michelson because it could not provide the desired result pursued by him, that of identifying the real movement of the earth through the ether, based on the difference between t_1 and t_2.

The correct result of the equality in the times of arrival $t_1=t_2$ of the two swimmers, as reported in our 2000 article, indicates/ confirms when applied to ME81/87 that the existence of the ether should not be denied in physics based on this experiment.

As a consequence, if the correct result $t_1=t_2$ had been adopted by Micherlson, there would have been no valid arguments for Einstein to remove the ether from physics in 1905 by promoting SRT, including on the basis of the experiment ME81/87, which was misinterpreted by Michelson. If the correct relation $t_1=t_2$ had been adopted by Einstein, SRT would then not have had its starting point in 1905 (with wrong relationship $t_2<t_1$), by invoking the results of such experiments as those of Michelson and then

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of Michelson and Morley.

It is therefore logical that if the error in the relationship $t_2<t_1$ reported in our article of 2000 in the analysis of ME81/87 is a real error, then SRT should now be replaced by other realistic theories, without the contraction of time and space, and without the need for a speed of light that is constant regardless of the speed of the observer.

As a result, it will be necessary to create a New Physics, based on a new ether, the basis for which we have proposed [30] through our HM16 model of the ether; this was later developed further and new features was added in other articles [31,32], and is waiting to be improved by the recovered community of physicists.

The New Physics also includes our new theory of gravitation, which is based on interaction between electrical dipoles, the basis for which was created [32] which we developed in Has I et al. [33]; this was also extended in other article [34,35], and must be further developed due to the presence of the HM16 ether model.

Current Consequences of Perpetuating Michelson's Errors

Two errors has been discussed at Items 1(a), 1(b), 2(a), 2(b), 2(c) and 3(a) briefly along with demonstration of Michelson's incorrect analysis for the results of ME81/87, in which the path Sw2 is an isosceles triangle and that $t_2<t_1$. These errors have not been discovered and reported by physicists for over a century, and have therefore been accepted in a dogmatic or compulsory way within mainstream physics, till date.

It is outrageous to see how today's young generation of future physicists is still intoxicated with this error, which wrongly indicates that $t_2<t_1$ starting from the incorrect path of an isosceles triangle; these errors are still contained in official textbooks in all countries, instead of the correct path of a right triangle and the correct relation $t_2=t_1$.

As relatively recent examples of the promotion of these two errors, we give extracts from some physics handbooks for high schools and colleges. We attach two pages **(Figure 5)**, from a 2006 college physics textbook from the USA by Sarway et al. [17], where instead of swimmers, two planes are considered.

Here, the route Sw2′ is again shown as an isosceles triangle, and the time difference is calculated as $\Delta t=Lv_2/c_3$, which gives the same incorrect results as in Michelson's analysis, $t_2<t_1$

a)

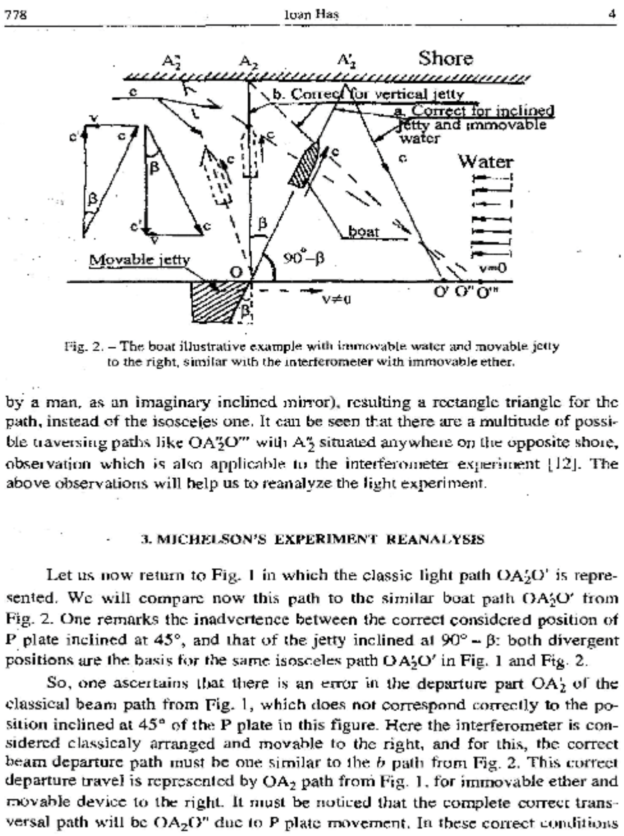
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Fig. 2. – The boat illustrative example with immovable water and movable jetty to the right, similar with the interferometer with immovable ether.

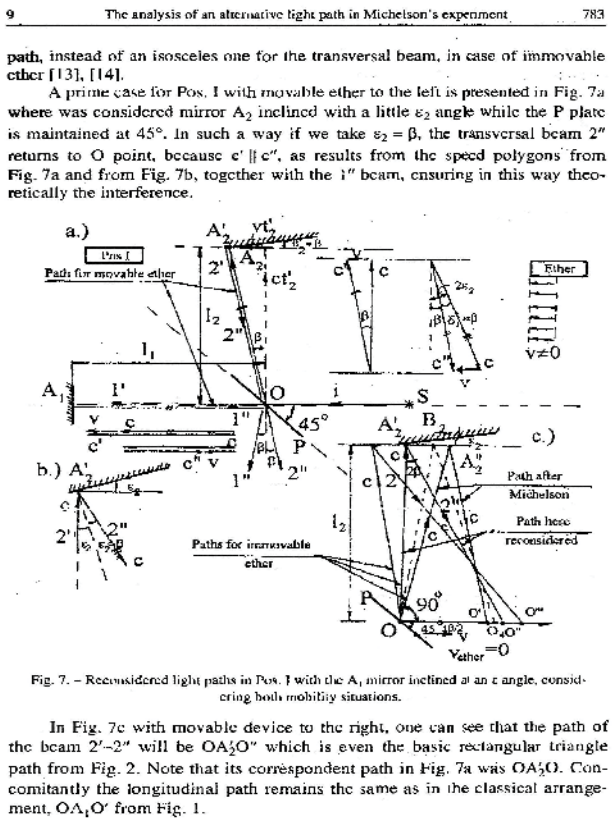
by a man, as an imaginary inclined mirror), resulting a rectangle triangle for the path, instead of the isosceles one. It can be seen that there are a multitude of possible traversing paths like $OA_2'''O'''$ with A_2''' situated anywhere on the opposite shore, observation which is also applicable to the interferometer experiment [12]. The above observations will help us to reanalyze the light experiment.

3. MICHELSON'S EXPERIMENT REANALYSIS

Let us now return to Fig. 1 in which the classic light path $OA_2'O'$ is represented. We will compare now this path to the similar boat path $OA_2'O'$ from Fig. 2. One remarks the inadvertence between the correct considered position of P plate inclined at 45°, and that of the jetty inclined at $90° - \beta$: both divergent positions are the basis for the same isosceles path $OA_2'O'$ in Fig. 1 and Fig. 2.

So, one ascertains that there is an error in the departure part OA_2' of the classical beam path from Fig. 1, which does not correspond correctly to the position inclined at 45° of the P plate in this figure. Here the interferometer is considered classicaly arranged and movable to the right, and for this, the correct beam departure path must be one similar to the *b* path from Fig. 2. This correct departure travel is represented by OA_2 path from Fig. 1, for immovable ether and movable device to the right. It must be noticed that the complete correct transversal path will be OA_2O'' due to P plate movement. In these correct conditions

b)


9 The analysis of an alternative light path in Michelson's experiment 783

path, instead of an isosceles one for the transversal beam, in case of immovable ether [13], [14].

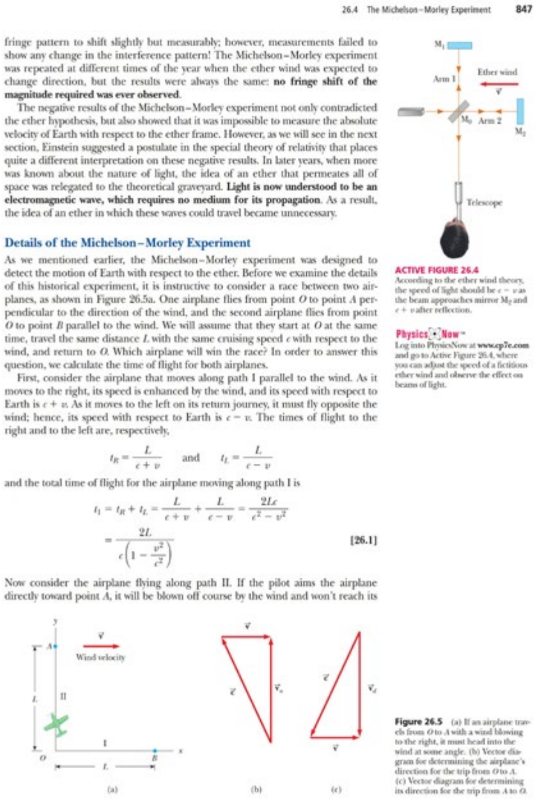
A prime case for Pos. I with movable ether to the left is presented in Fig. 7a where was considered mirror A_2 inclined with a little ε_2 angle while the P plate is maintained at 45°. In such a way if we take $\varepsilon_2 = \beta$, the transversal beam 2″ returns to O point, because c′ ∥ c″, as results from the speed polygons from Fig. 7a and from Fig. 7b, together with the 1″ beam, ensuring in this way theoretically the interference.

Fig. 7. – Reconsidered light paths in Pos. I with the A_1 mirror inclined at an ε angle, considering both mobility situations.

In Fig. 7c with movable device to the right, one can see that the path of the beam 2′–2″ will be $OA_2'O''$ which is even the basic rectangular triangle path from Fig. 2. Note that its correspondent path in Fig. 7a wais $OA_2'O$. Concomitantly the longitudinal path remains the same as in the classical arrangement, OA_1O' from Fig. 1.

Figure 4. Correct analysis by I. Has [5], with a right triangle path for Sw2 (a): excerpt from the author's 2000 paper, with the transversal paths of the boat as the correct right triangle in the reference frame of the water, WR; (b) excerpt from 2000 paper showing the transversal paths of the light rays as the correct right triangle in the reference frame of the ether, ER.

a)



b)

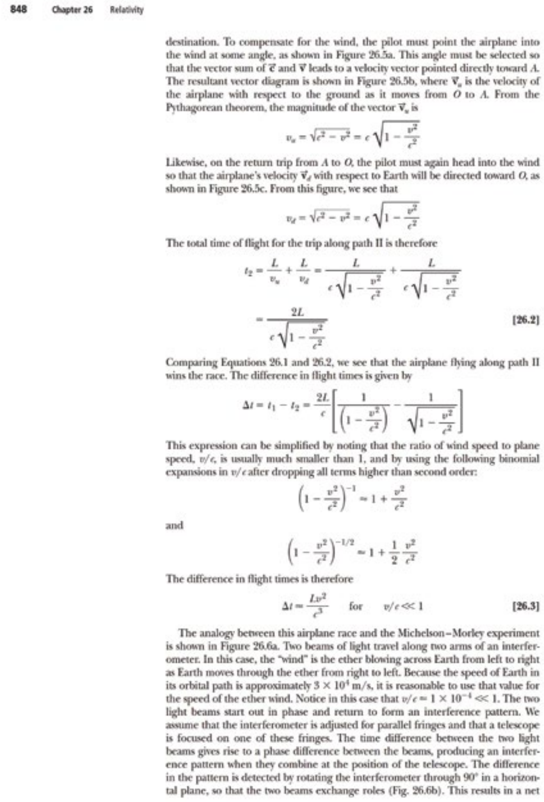
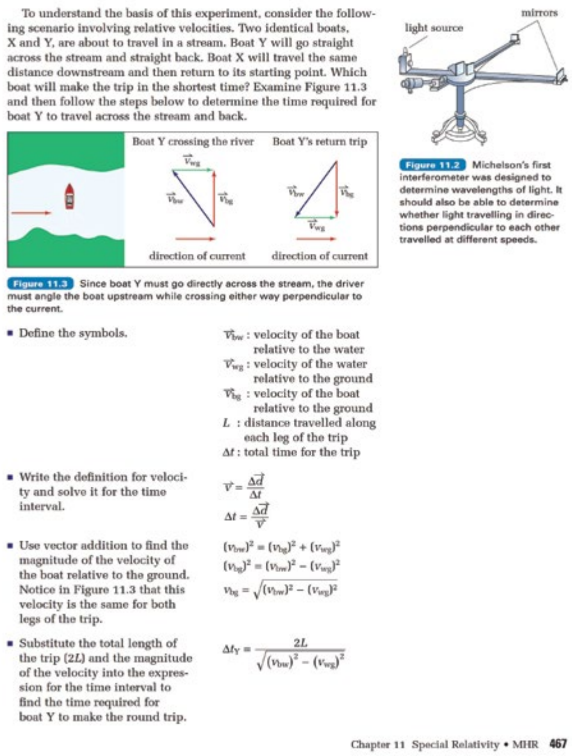


Figure 5. Example of an incorrect analysis of two planes in a USA college physics textbook from 2000, with an isosceles triangle for Plane 2 and the result $t_2<t_1$.

a)



b)

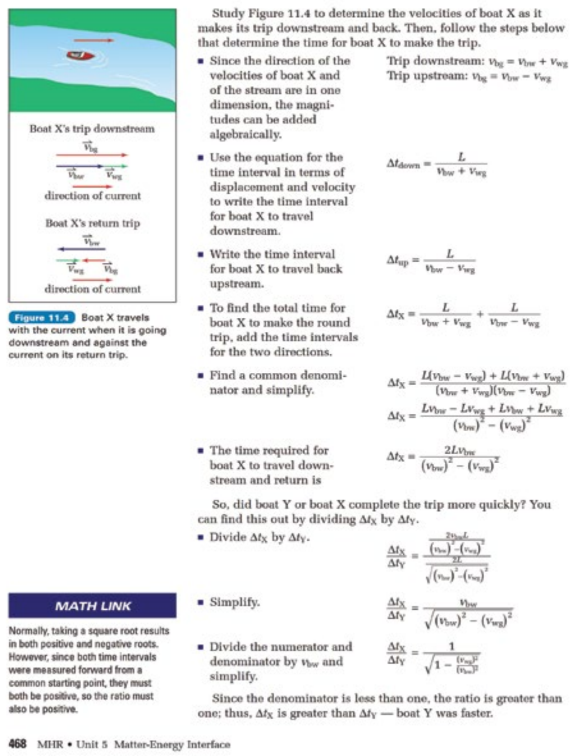


Figure 6. Example of incorrect analysis of Boats X and Y in a Canadian-American college physics textbook from 2019, with an isosceles triangle for Boat Y and the result t2<t1

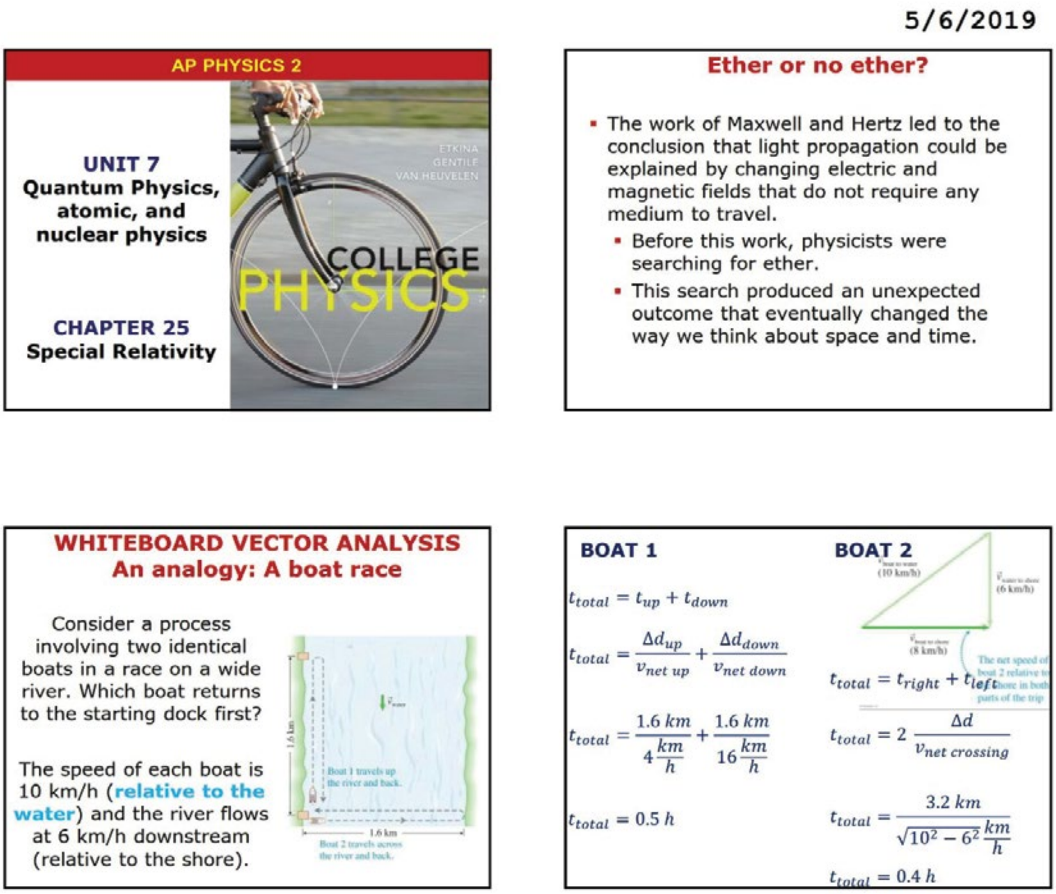


Figure 7. Example of incorrect analysis of Boats 1 and 2 in a synthesis from a USA college physics textbook from 2000, with an isosceles triangle for Boat 2 and $t_2<t_1$.

We also attach a page **(Figure 6)** from a high school physics textbook from the 2000s from Canada (where education is organised in a similar way to the USA).

In this example, the role of the swimmers is played by two boats, Boat X and Boat Y, and the incorrect analysis of Michelson's path Sw2 as an isosceles triangle is repeated. Here, the route of Boat Y is analysed in the incorrect form of the isosceles triangle, and the mathematical calculation of times again wrongly results in $t_2<t_1$.

Finally, we attach a page **(Figure 7)** from an American college physics textbook from 2019, where instead of swimmers, two boats (Boats 1 and 2) are presented. Here, the mathematical calculation of times gives t_1=0.5 h and t_2=0.4 h, again wrongly resulting in $t_2<t_1$!

Incorrect examples such as these in physics textbooks can be found in large numbers in any country.

However, worse still is the fact that at present, in many such textbooks, examples and justifications of SRT such as those above (based on a physical model such as swimmers, boats, ships, etc.) are not even given, which would offer younger students the chance to analyse the model themselves and to draw their own conclusions. Instead, SRT is directly introduced in many textbooks, without justification, by stating the two related "principles" that were proposed.

The presence of these errors, which were introduced by Michelson in his ME81/87 analysis, allowed for the promotion and acceptance of SRT in physics from 1905 onwards, and the neglect of the possible real presence of the ether in physics and in nature.

This also means that in 1905, along with SRT, a current in physics began in the wrong direction (since it is based on two errors), which is now referred to as mainstream physics, a direction that does not accept the presence of the ether. It supports the promotion of a set of new theories, mathematical creations that can be invented in unlimited numbers, since this is a self-reproductive field of theories without any correspondence to the real three-dimensional world. These new theories provide large numbers of jobs for physicists and other scientists, starting with the theory of general relativity and continuing with theories of the big bang, black holes, non-Euclidean spaces, dark matter, dark energy, quantum "mechanics" without physical/mechanical support, all floating in a "vacuum" that is not considered a vacuum, etc.

I think I can assure any reader that he/she will find above, and especially in Section 5, an analysis of the incorrect interpretation of the competition between swimmers SW1 and SW2 proposed by Michelson in his ME81/87 analysis.

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Conclusions and proposals for future action to address the situation created by the presence of errors introduced into physics by Michelson through ME81/87 analysis.

The complete styudy was conducted with an aim to show and convince readers that Michelson's analysis of ME81/87 is wrong, due to the two errors that crept into the path of SW2 from the starting block. These errors in the path of SW2, in the form of an isosceles triangle, as proposed by Michelson in 1881/87, gave the wrong result that $t_2<t_1$, when in fact the correct relation between times is $t_2=t_1$ and the correct path of SW2 is a right triangle; however, these errors went unnoticed by physicists all the times.

These errors have been incorporated into mainstream physics all round the world since 1905, a current that is manifested/ materialised based on SRT, a theory that includes as the basis of its arguments, precisely these two errors proposed by Michelson in the path of SW2 as an isosceles triangle, with $t_2<t_1$, instead of the correct right triangle path and the correct relationship $t_2=t_1$.

An open discussion by the community of physicists or by public can be done on these two errors performed by Michelson's incorrect analysis of ME81/87 and can be formulated based on presented evidence/ discussion in the above study. Discussion can be started by reanalysing our 2000 article [5] followed by the following papers as these papers will help in reaching certain conclusions reported by us in these works.

Publication of our articles since 2000 [23,25,26] in journals without significant impact, and the rejection of these articles by high-impact journals (obviously due to their devotion to mainstream physics based on ME81/87 and SRT, without the ether), means that this work failed to resonate with physicists in the mainstream of physics, and will not discuss other causes for this lack of reaction, making a big reason for writing this study, which is addressed to all physicists and society as a whole, in order to obtain a wider, immediate resonance of the problems of Michelson's errors and of the existence of the ether in physics and in nature.

I am now primarily concerned with determining measures or actions that can be taken in the immediate future to address this inadequate state of affairs in physics, which does not reflect the truth, and to reinstate the truth in regard to the status of the ether in physics. This has been severely affected by the errors that slipped into Michelson's EM81/87 analysis, regarding the isosceles triangle path and the incorrect relationship $t_2<t_1$.

At the same time, it will be necessary to include in this debate the issue of the current foundations of SRT, a theory that is unfortunately based on Michelson's ME81/87 erroneous analysis, meaning that SRT will need to be deeply re-analysed and reformed.

These two main analyses should be accompanied by a debate on the content of physics textbooks at the primary school, high school and university levels, regarding Michelson's incorrect analysis of ME81/87, with the isosceles triangle path and the relation $t_2<t_1$, instead of the correct right triangle and the result $t_2=t_1$, in the problem of the two swimmers/boats that appears in these textbooks as a model to follow.

Due to the immense importance of this subject and its future consequences, this analysis should take place at a high level, i.e. at the level of the Presidency, the Government, the Ministry of Education, the Academy, and other responsible institutions, responsible media, etc., of each country.

This can only be achieved if, based on the above text/material, we can convince the President/Prime Minister/Ministry of Education/President of the Academy and other responsible people of the existence of this error in ME81/87 analysis, with isosceles triangle path for Sw2 and $t_2< t_1$, instead of right triangle and $t_2=t_1$.

As a result of the above presentation, we will find room for the fight against the wrong analysis of ME81/87, and hence for a debate about the justification of SRT and a reconsideration of the ether in physics, which will have profound consequences.

ACKNOWLEDGEMENT

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