A corrected reanalysis of the two swimmers problem, as frequent model of Michelson's interferometric experiment.

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Summary

The article initially reviews various works describing the physical model (PM) of Michelson's interferometric experiment (ME) represented by the race between two swimmers Sw1, Sw2 (or boats, or planes, or sound signals etc.). The two swimmers must each swim the same distance, but Sw1 will go downstream the river flow, and Sw2 will go perpendicularly to this direction.

In all such works, it is considered that Sw2's path will require less time and that it will reach the first the start point. However, it is found that, in order to make this possible, Sw2 must not observe the orthogonality rule of his start direction, an action which is actually a deceit of the arbiters, and, hence, this will be a non-fair-play action towards Sw1.

The article proves by calculus that if the fair-play rules are observed, then the correct crosswise path is a right triangle instead of isosceles triangle considered by Michelson. And as consequence the two times shall be perfectly equal and the race ends in a tie, and the Sw2 myth of race winner shall be dashed to the ground. Note that the same result shall also be applicable to Michelson's interferometric experiment (ME) as well as to any similar experiment. As consequence, utilising the isosceles triangle for transversal path in PM and also in ME is an error.

Key words: Michelson experiment; two swimmers model; right triangle correct transversal path; error of isosceles triangle for transversal path.

<u>1. General presentation of physical models PMs</u> of Michelson's experiment (ME)

Many presentation works of Michelson's interferometric experiment (ME) use as physical (mechanical) model (PM), similarly to ME experiment and, at the same time, very suggestively, the (hypothetical) race between two swimmers, Sw1, Sw2 (alternatively, we may encounter the case of two boats, of two airplanes, of two sound signals, etc.) set to swim with the same own speed, *c*, the same distance, *l,* twice, go and return trip, in a river that flows with the speed *v*. However, for the first swimmer Sw1 who takes the path or the route $1_1=1_1'+1_1''$, it is required to cover the distance $1_1'$ that will aim right on the river flow direction, *v*. And, for the second swimmer, Sw2, who will take the path $1_2=1_2'+1''_2$ it is required to cover the same initial distance $l_2'=1_1'$, but perpendicularly aimed on the river flow direction *v* (Fig.1) and, thus, also perpendicularly on direction $1_1'$.

This orthogonality condition of the two initial paths, $1_2'$ and l_1' (Fig.2) is mandatory, in order to be able to admit the similarity between the two experiments, ME and PM, due to in Michelson's interferometric experiment, ME, the two initial light beams, 1' and 2', start mandatorily orthogonally between them. This is because the semi-transparent splitter, plate P, from which beams 1' and 2' go out, is 45^0 sloped against the incident ray, and the direct beam, 2', that permeates the splitter P and the beam 1', reflected by the splitter P, will form between them a 90^0 angle, according to the reflection laws of the geometrical optics.

However, it must also be mentioned that none of the physical (in fact mechanical) models (PMs) from the physics literature, establishes clearly and precisely the reference system (RF) that various displacements and movements from the PM, refer to. But from chosen RF, also essentially depends the accuracy of the analysis itself. This entanglement occurs because at least two local reference frames RF may be considered: the block-start or bank attached frame (BF) (the equivalent of ME interferometric device) and the water attached frame (WF) (the equivalent of ME aether).

And for the accurate analysis of any model PM one should specify from the beginning what is the adopted reference frame, RF. In our analysis, we will observe this rule in each and every figure or description.

However, here it must also be mentioned that in any and in all descriptions of the physical model PM encountered in the physics literature, one "demonstrate" that the time of running the transverse route is shorter than the longitudinal one, and that the swimmer Sw2 wins the race.

And this conclusion has become a myth for the young generation of high school or college graduates.

But in the next sections, we will demonstrate that, if the race would run "fair-play", the two swimmers, Sw1 and Sw2, would reach in the exact same time at the start point and this myth shall need to be corrected in this regard, „the race" ending „in a tie".

<u>2. Description of some physical models PMs from literature</u>

We will hereinafter describe details and observations regarding various presentations of the speciality literature for the physical model PM with the two swimmers, which is considered by their authors similar to the Michelson's interferometric experiment ME.

We have selected from the usual physics literature of average level, few such examples, from the Internet and from works addressed to young people. Young people could be deeper influenced by such examples (as I was too), that, if proven wrong, may have a negative impact with more profound consequences on future physicists.

i). Thus, in [1], Jurgen Freund says (referring to a boat, comparable with the swimmer): "When the boat is sailing at right angles to the banks it has to turn its bow slightly upstream and thus reaches the velocity $\sqrt{(c^2-v^2)}$ relative to the banks".

But we observe that the mention *turn its bow slightly upstream* indicates a clear lack of orthogonality in start direction of second boat.

ii). In [2] David Harrison says (referring to a raft and two markers, comparable with two banks): "Now the raft and markers are being towed to the left. In this case, the race will no longer be a tie. In fact is not too hard to show that swimmer 2 wins this race".

In an Annex is given the same transversal velocity $\sqrt{(c^2-v^2)}$ as in [1], which indicate a clear lack of orthogonality in start direction of second swimmer Sw2 including in an animated presentation of race.

iii). In [3] Austin Glesson says: "A stream of with D, is flowing with the speed v_0 from left to right. A swimmer whose speed is in still water v wants to swim across and back reaching the other bank at a point opposite the starting point. The resultant velocity which is directed across the creek is thus $\sqrt{(c^2-v^2)}$".

No mention is made about orthogonality of d1' and d2' paths, which condition is clearly absent.

iv). But, in [4] Michael Fowler says: "The swimmer going across the flow is trickier. It won't do simply to aim directly for the opposite bank, the flow will carry the swimmer downstream (Fig. 1). To succeed in going directly across, the swimmer must actually aim upstream at the correct angle".

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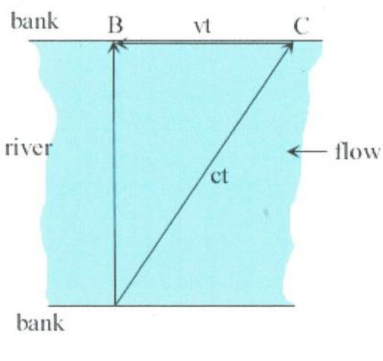

Figure 1: In time *t*, the swimmer has moved *ct* relative to the water, and been carried downstream a distance *vt*.

The swimmer going across the flow is trickier. It won't do simply to aim directly for the opposite bank-the flow will carry the swimmer downstream. To succeed in going directly across, the swimmer must actually aim upstream at the correct angle (of course, a real swimmer would do this automatically). Thus, the swimmer is going at 5 feet per second, at an angle, relative to the river, and being carried downstream at a rate of 3 feet per second. If the angle is correctly chosen so that the net movement is directly across, in one second the swimmer must have moved *four feet* across: the distances covered in one second will form a 3,4,5 triangle. So, at a crossing rate of 4 feet per second, the swimmer

Fig.1. The model with the swimmer Sw2 as trickier. According to Michael Fowler [Fig. 1, extracted from [4].

Here we observe a clear mention about the lack of orthogonality of paths d1' and d2' from mention *at the correct angle*. But Fowler associates the lack of orthogonality with even a kind of trick.

v). Although in [5] Bernard Jaffe does not specify the conditions in which „boater 2 crosses the water flow" but it chooses for the boater a path after the hypotenuse of the right triangle of the speeds v and *c*. And in the figure attached to the text, it shows that boater 2 runs the 27,5 m of the river width „perpendicularly to the water flow….".

But this last affirmation about orthogonality is untrue, because it refers to the route after the hypotenuse considered by the author, and without specifying the reference frame considered there by the author.

vi). However, in [6] George Gamow directly specifies: "In this case, the delay is due (on the transversal route of the river run by a motorboat) to the fact that the boat, in order to go from boat bridge 1 to boat bridge 3, it must advance slightly sidewise to compensate the current drift".

Thus, Gamow admits the path 2' shows sidewise advance and this is an acknowledgement that path 2' is not orthogonal to path 1'.

vii). In [7] D. Ciubotaru e. a. says: "The boat's movement speed (from which sound signals with sound speed v_s are emitted) may also be determined by having a reflecting area R_2, in such way that the arm $SR_2=l_2$ is perpendicularly on the boat's movement direction. From Fig. 4 one may determine the time τ_2 in which the sound covers the distance $S'R_2+R_2S$ … $\tau_2=2l_2/\sqrt{(v_s^2-v^2)}$".

But in Fig. 4 of [7], the sound's path is again an isosceles triangle, which indicates a clear lack of orthogonality in start direction of second sound signal (Sw2).

viii). Finally here, in [8] Thomas D. Le says: "To compensate, Boat 2 has to head into the current (upstream from the work) at a certain angle so that the combined effect of *c* and *v* would allow it to reach Pier B".

And in Fig. from page 23 of [8] the boat's path is the hypotenuse of the right triangle, which indicates a clear lack of orthogonality in start direction of Boat 2 (Sw2).

And such analyses in which the lack of orthogonality in start direction of second swimmer Sw2 may comprise all published works on the above PM model subject.

3. Findings and Observations on previous physical models PM

Going further we will show important details and observations regarding some of the physical models PMs, previously described in Sec. 2.

We notice here that practically in every previous description of the mechanical models PMs of the ME experiment, with the two swimmers Sw1 and Sw2, in the respective authors' works of description and analysis of the two paths, l1 and l2, an error has slipped, consisting of disrespect of complete similarity between the two experiments, ME and PM.

By similarity disrespect, we mean how the direction of start path l2' was selected within PM, when we observe that initial path l2' of swimmer Sw2 is allowed to deviate from the orthogonal direction to the water speed direction *v*, because Sw2 starts at a small angle β against the exact orthogonal direction. Such path deviation constitutes a trick and a non fair play towards Sw1.

It must be mentioned that the angle β is not explicitly notified before the start to swimmer Sw2, but only indirectly (a trick), because it is said that Sw2 should aim at a point C from the opposite bank, but situated outside the orthogonal direction.

But this aiming of initial path l2' is impossible within and in the conditions of ME experiment, when the opposite M2 mirror does not include reference points for orienting the light, which is not intelligent in order to consent to a trick and it will start l2' exactly at 90^0.

And in the PM experiment, on the opposite bank, no personnel, and no orientation sign for Sw2 is found there, that can indicate him the angle β.

Thus, the model PM of ME experiment, may only succeed in practice as Michelson and authors (mentioned in Sec. 2) proposed, only if somehow Sw2 can benefit of the indication of the angle β, exactly at the start-up moment, but this would be the case of a trickier towards Sw1.

If the model PM would deploy in the conditions of an official race or even of an Olympic contest, the organizers would not allow such deviation from the orthogonality rule of paths l_1' and l_2' offering to Sw2 the β angle before starting.

This means that swimmer Sw2 assigned on path l_2' should also start orthogonally on blockstart, thus perpendicularly on path l_1' including perpendicularly on water speed direction *v*. This situation obviously is possible, only without particularly indicating to Sw2 a shifted reference from the opposite bank and without indicating him the angle β. As a matter of fact, the angle β also depends on the river flow speed, *v*, that should not be known by any of the contestants.

We notice that Michael Fowler uses a rough characterization of the swimmer Sw2, that of trickier, and we must agree that M. Fowler is perfectly right. This is because this swimmer Sw2 benefits from information which is not allowed in a fair play contest.

Meaning that Sw2 benefits of indirect knowledge of the river speed *v*, and of permission of his start-up after a non-orthogonal direction to speed *v*, and, hence, non-orthogonal to the movement direction of contestant Sw1.

But the basic rule as ordinary peoples understand such a contest, is that the two swimmers, Sw1 and Sw2, must start from blockstart, on orthogonal directions between them, as light beams start from the semitransparent splitter in ME.

Therefore, the correct path in PM model of ME experiment must take this rule of paths orthogonality into account. In this case in WF frame the correct complete crosswise path of Sw2 is a right triangle instead of isosceles triangle as it is demonstrated in Sec.5.

Here we define such deviation of l_2' of Sw2 from orthogonal directions an essential error in involved analyses.

Fowler's characterization of tricker for the swimmer Sw2 is perfectly applicable to the other contestants Sw2 of the examples above and others, including the boaters or airplane pilots, that may be found in other description works of PM model of EM experiment.

We must emphasize that the above-indicated error from PM model, was also taken over, by Michelson in the analysis of his ME experiment [9, 10, 11]. But here we will limit ourselves to the correct analysis of PM model only.

4. Correct reanalysis of the two swimmers physical model PM

This reanalysis shall refer to the physical model PM of ME experiment, model that shall consist, for simplification, of the race between the two swimmers, Sw1 and Sw2.

The following analysis is based on the important observation of the Sec. 3., meaning that the start-up mode of Sw2 must observe the rule of fair play. This means that Sw2 should not benefit before start-up of the prior knowledge of angle β or river speed *v*, nor it should apply such angle β to his start direction l_2'.

But Sw2 should start according to the inferred and unanimously accepted rule by the ordinary people, of such contest, meaning that the two swimmers should start from their blockstarts after <u>two orthogonal directions between them</u>.

However, it should also be specified here an aspect which is very important to any cinematic analysis: meaning that it must clearly indicate the reference frame, RF of the space, to which the movements of the relevant bodies, objects, refer to.

This means that the object or the body that RF is attached to, should be clearly indicated. In case of PM of the two swimmers, Sw1 and Sw2, the most useful reference frames shall be the water attached frame (moving with the speed *v* against the bank) WF, and the blockstart or bank attached frame, BF.

One may notice that all of the previous analyses, either referring to the physical model PM or to the Michelson's experiment ME, do not approach this aspect and, thus, do not specify or write down in the figures of the relevant texts, which is the reference frame of the space, WF or BF, that was considered by the respective authors.

And for this reason, in many cases both reference frames, WF and BF are involved, which leads to misunderstandings and errors in the phenomena's analysis, as the error of the start direction of Sw2 has systematically slipped in.

In this analysis, we will indicate which RF is adopted and we will even clearly mark in the attached figures, which will be the reference frame RF of the space chosen for each and every analysis, also being indicated the related Ox, Oy coordinates.

We would also like to mention here that for the reference frame of time *t*, RFT, the unique frame with one uniform flow speed of the unique time *t*, according to classical physics, shall be adopted in all our analyses. The reference moment as $t = 0$, could be taken either moment of the time *t* of the experiment, provided to have the above condition of even time *t* flow.

5. Correct reanalysis of the physical model PM of the two swimmers in the WF frame

5.1. Presentation of the physical model PM of the two swimmers

The correct paths or routes in the physical model PM for two boats, B_1 and B_2, was described previously by us in [9, 10, 11].

And the same paths for the two boats, but applied to two swimmers, Sw1 and Sw2, are shown in Fig. 2 and in Fig.3. which represent de physical model PM of the two swimmers which will be analysed.

It should be specified that in Fig. 2 and in Fig.3, the selected reference frame is $x_1O_1y_1$, as the water frame WF, with the axis O_1x_1 aimed reversely to water speed *v*. Here point O_1 was taken the point coinciding with the block-start BS right corner, and the initial time moment with t=0 is the moment of the contest start-up.

In this PM model, we will consider that the water flows with the speed *v* towards the left side of the observer O_1 of Fig. 2. But in the water frame, WF selected here, in Fig. 2 and in Fig.3, the block-start BS and the two river banks RB1 and RB2 will shift to the right side of the drawing, with the speed *v*, the water remaining still.

5.2. Analysis of model PM in case of crosswise direction

In $x_1O_1y_1$ frame at the time t=0, the swimmer Sw2 will leave from the point O_1 in the direction y_1 which is perpendicular to the block-start (and to the river bank RB1), and it shall run his initial path 2' between the point O_1 and the point A_2 located oppositely on the opposed bank RB2 located at the orthogonal distance l_2 (Fig.2).

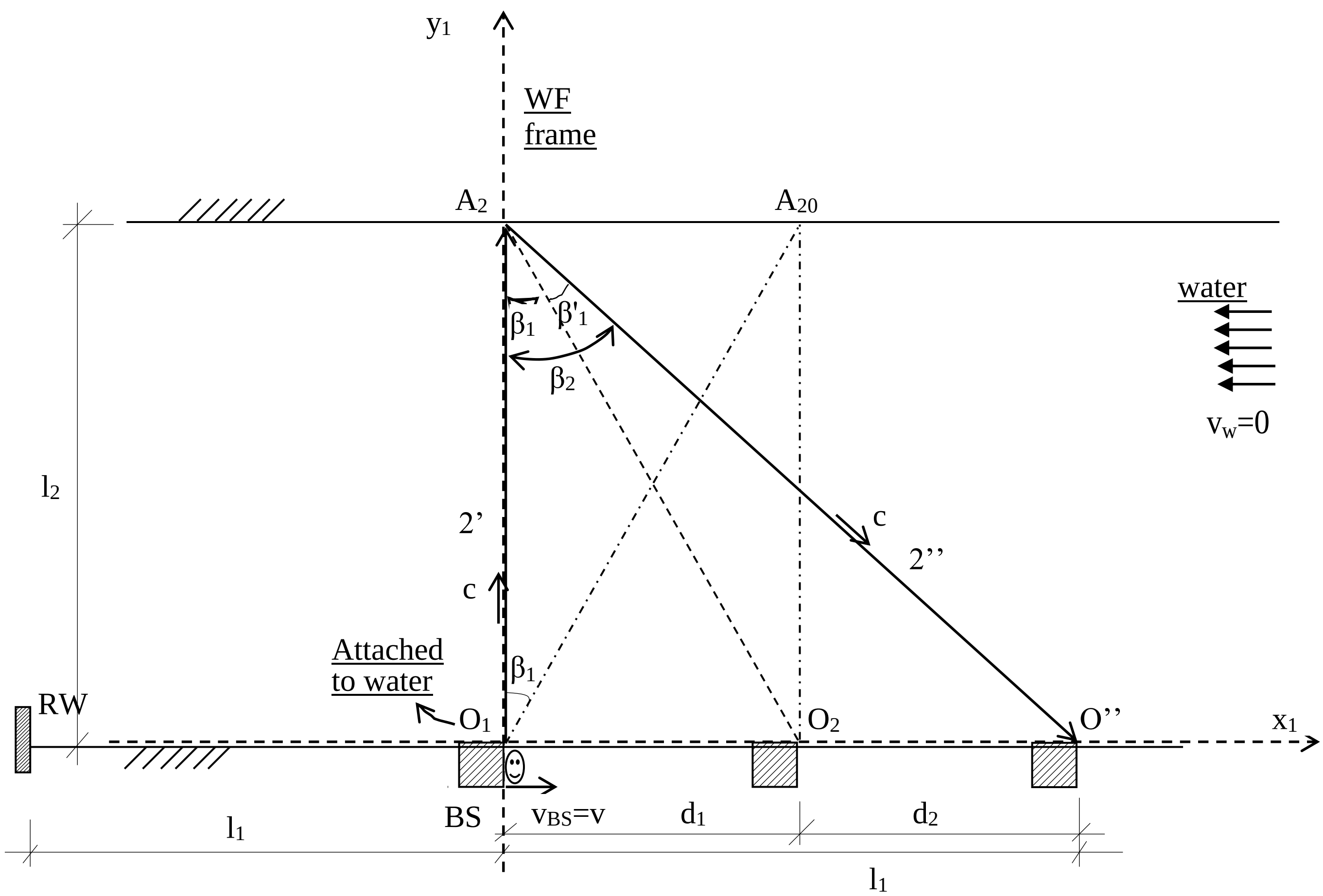

Fig. 2. Model with two swimmers Sw1 and Sw2 in WF frame. The case of Sw2 in crosswise path 2'+2''as right triangle.

The time needed to cover the path 2'= O_1A_2 shall be t'_2 corresponding to running the path 2' by the swimmer Sw2 with his own speed *c* against a still water. It may be noticed that point A_2 does not coincide with point A_{20} that was corresponding at the time t=0, with the point on the RB2. This point A_{20} is directly opposite to O_1 at that time t=0, because the opposite bank shifted to right with the speed *v* in this timeframe t'_2 on a distance d_1 (Fig. 2).

At the same time, when Sw2 reaches point A_2 he can observe that the block-start BS shifted with the distance d_1 to the point O_2 (the point which is orthogonally opposite to point A_{20}) (fig.2), and that BS continues to shift in the same direction x_1 with the speed *v*.

Therefore, Sw2 to be sure that it reaches the exact meeting with BS at return to point O'', Sw2 will have to swim also with the speed *c* to the estimated point of meeting O'' located at distance $d_2 \approx d_1$ but still slightly longer than d_1 due to time t''_2 is for the return path 2'' that will be sloped, thus longer than 2' path (orthogonally on 1' path, in FW) (Fig.2).

Note that this correct and fair play route 2'-2" of swimmer Sw2 in water frame WF has the shape of a right triangle O_1A_2O'' in Fig. 2 and not of a isosceles triangle as considered by authors from Sec. 2 and by Michelson.

Now we will determine firstly these two times, t'_2 and t''_2.

But we must remind here that first calculus concerning the two times, t'_2 and t''_2, was performed by us in [9, 10, 11], but there t'_2, t''_2 being the times spent by the light in their paths in ME experiment, and performed in two distinct sections, with separate meanings.

In order to better understand the final result of our calculus which is $t_2=t_1$, we will resume here the calculus from [9, 10, 11] of time t_2 performed in the transversal path, and of time t_1 performed in the longitudinal path by two swimmers Sw2 and Sw1 in corresponding unique PM model from Fig. 2 and Fig.3.

But here we will improve some our first calculus operations, and bringing together on the same model PM, the two previous sections from [11]. Also, the appearance of small fonts of indices from formulae, was improved compared with [11].

Now we will determine firstly the two times, t'_2 and t''_2, with the geometrical elements of Fig. 2., from which it results that:

$$t'_2 = \frac{l_2}{c} = \frac{O_1A_2}{c}; \quad t''_2 = \frac{A_2O''}{c} \tag{1}$$

$$t_2 = t'_2 + t''_2 \quad O_1O'' = vt_2 \tag{2}$$

From the right triangle O_1A_2O'' of Fig. 2 it results that:

$$\left(O_1A_2\right)^2 + \left(O_1O''\right)^2 = \left(A_2O''\right)^2 \tag{3}$$

Introducing (1) and (2) in (3) we obtain:

$$\left(t'_2c\right)^2 + \left(vt_2\right)^2 = \left(t''_2c\right)^2 \tag{4}$$

Replacing t_2 from (2) into (4) we obtain:

$$\left(t_2'c\right)^2+\left(v\left(t_2'+t_2''\right)\right)^2=\left(t_2''c\right)^2 \tag{5}$$

After making the calculations between the brackets and regrouping the terms we obtain:

$$\left(t_2''\right)^2\left(c^2-v^2\right)-2v^2t_2't_2''-\left(t_2'\right)^2\left(c^2+v^2\right)=0 \tag{6}$$

By solving the second-degree equation of (6) we obtain the result:

$$t_2''=\frac{2v^2t_2'+\sqrt{4v^4\left(t_2'\right)^2+4\left(c^2+v^2\right)\left(c^2-v^2\right)\left(t_2'\right)^2}}{2\left(c^2-v^2\right)}=\frac{v^2t_2'+t_2'\sqrt{v^4+\left(c^2+v^2\right)\left(c^2-v^2\right)}}{c^2-v^2} \tag{7}$$

Due to the solution $t_2''=0$ obtained for sign (-) in front of the root sign of (7) would be inutile, we have chosen the sign (+) in front of the root of (7).

By introducing (1) and (7) in (2) we obtain:

$$t_2=\frac{l_2}{c}+\frac{\frac{v^2l_2}{c}+\frac{l_2}{c}\sqrt{v^4+c^4-v^4}}{c^2-v^2}=\frac{l_2}{c}+\frac{\frac{v^2l_2}{c}+\frac{c^2l_2}{c}}{c^2-v^2}=\frac{l_2c^2-l_2v^2+v^2l_2+c^2l_2}{c\left(c^2-v^2\right)} \tag{8}$$

And from (8) we finally obtain for the time t_2 of the crosswise route 2'-2":

$$t_2=\frac{2l_2c^2}{c\left(c^2-v^2\right)}=\frac{2l_2}{c}\frac{1}{1-v^2/c^2}=\frac{2l_2}{c}\frac{1}{\alpha^2} \qquad with\ \ \alpha=\sqrt{1-v^2/c^2} \tag{9}$$

<u>5.3. Analysis of model PM in case of longitudinal direction</u>

For the longitudinal direction, the path run by Sw1 is shown in Fig. 3. It must be specified that in Fig. 3 also, the selected reference frame is $x_1O_1y_1$, the water frame WF is attached to water, with the axis O_1 x_1 aimed reversely to water speed *v*. And here we have taken the point O_1 of the initial moment t=0 of the race start, coinciding with the same right corner of the blockstart BS.

In Fig. 3 at the time t = 0, swimmer Sw1 will leave from point O_1 in the direction reversed to x_1 and parallel to block-start BS (and to the RB1) and it shall run in his own go time t_1' his initial path 1' between the point O_1 and the point A_1, located in the already shifted position of the return wall RW (Fig. 3). The return wall RW, was initially, at the time t = 0, situated in the point A_{10} of the same bank RB1, being initially located at distance l_1.

The movement distance b_1 of RW in time t_1' and the movement distance d_1 of Sw1 in the same timeframe 0......t_1' shall be (Fig. 3):

$$b_1=vt_1'; \quad d_1=l_1-b_1=l_1-vt_1' \tag{10}$$

The time covered by Sw1 when going out and the covered distance shall be from (10):

$$t_1'=\frac{d_1}{c}; \quad d_1=l_1-v\frac{d_1}{c}; \tag{11}$$

From (11), after grouping the terms, it results d_1:

$$d_1\left(1+\frac{v}{c}\right)-l_1=0; \quad \rightarrow d_1=\frac{l_1}{1+v/c} \tag{12}$$

And the time t_1' corresponding to path d_1 run with the speed *c* shall be:

$$t_1' = \frac{d_1}{c} = \frac{l_1}{c+v} \tag{13}$$

For the return path t_1" of Sw1, the movement distance b_2 of RW and the movement distance d_2 of Sw1 shall become (Fig. 3):

$$b_2 = vt_1''; \quad d_2 = l_1 + b_2 = l_1 + vt_1'' \tag{14}$$

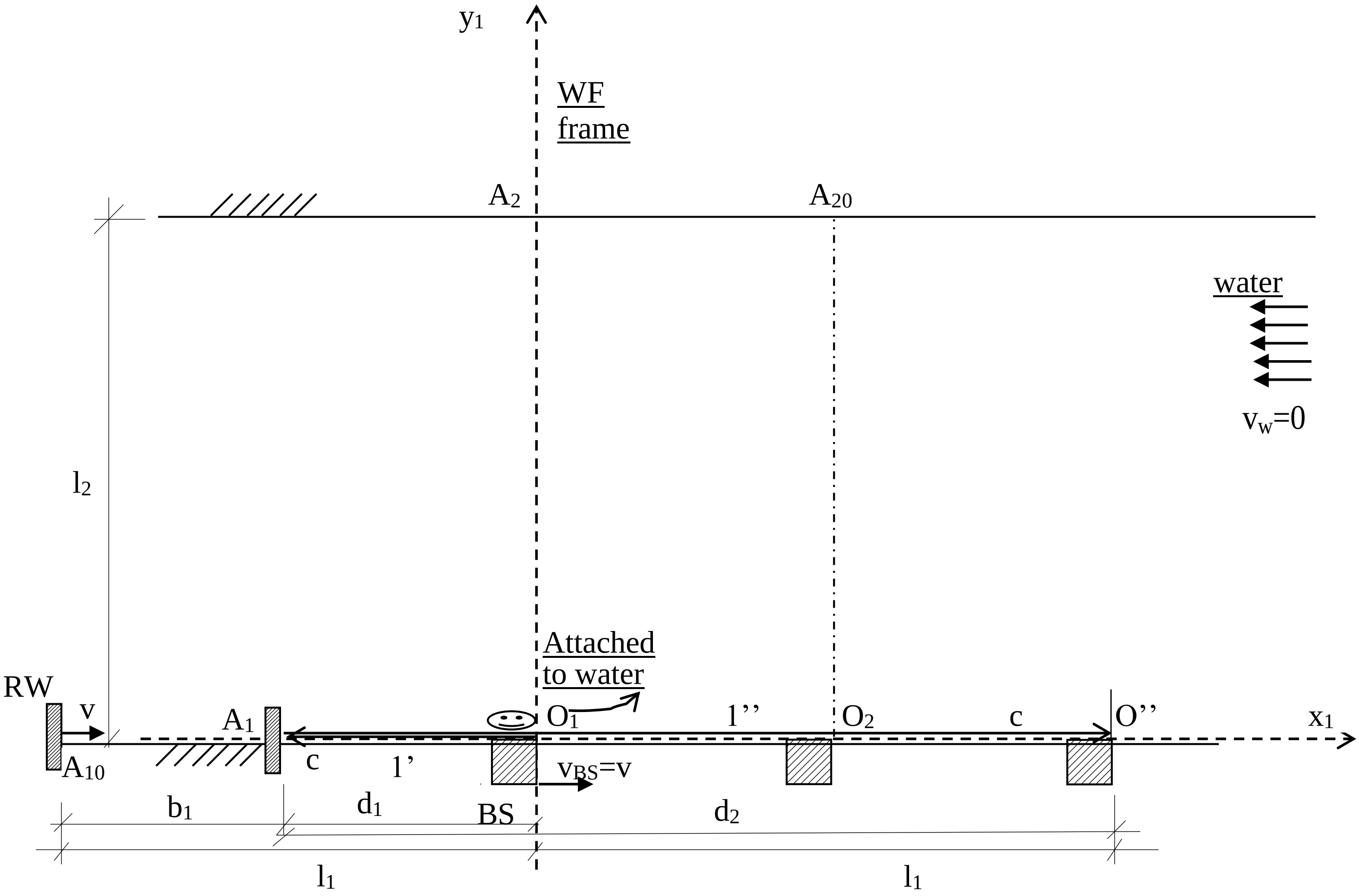

Fig.3 Model with two swimmers Sw1 and SW2, in WF frame. The case of Sw1 in longitudinal path 1'+1"

The time t_1" covered by Sw1 when returning and the covered distance d_2, shall be from (14):

$$t_1'' = \frac{d_2}{c}; \quad d_2 = l_1 + v\frac{d_2}{c}; \tag{15}$$

From (15), after grouping the terms, it results d_2:

$$d_2\left(1 - \frac{v}{c}\right) + l_1 = 0; \quad \rightarrow d_2 = \frac{l_1}{1 - v/c} \tag{16}$$

And time t_1'' corresponding to returning route d_2 covered with speed *c* shall become:

$$t_1'' = \frac{d_2}{c} = \frac{l_1}{c-v} \tag{17}$$

Therefore, total time t_1 shall be from (13) and (17):

$$t_1 = t_1' + t_1'' = \frac{l_1}{c+v} + \frac{l_1}{c-v} = \frac{2l_1 c}{c^2 - v^2} = \frac{2l_1}{c}\frac{1}{\alpha^2} \tag{18}$$

Note that in (18) the same result was obtained as in (9) except for lengths l_1 and l_2.

Hence, in case of length equality $l_1 = l_2$, it results from (9) and from (18):

$$t_2 = t_1; \quad ;and \quad \Delta t = t_2 - t_1 = 0 \tag{19}$$

Therefore, the two swimmers, Sw1 and Sw2, shall arrive at the same time, if at their departure the fair play of orthogonality of start-up direction of the two swimmers will be also respected for Sw2, and their race shall end in a tie, without any winner whatsoever (just hypothetically because there are no data or proofs that such race would have been practically performed).

Moreover, any intermediary start direction of 1' path with start angle $\alpha \neq 0$ of Sw1, may be considered as also obtainable from the overlapping of the two cases from 0^0 and 90^0 analysed above, but with the results of times *t* applied in percentages appropriate for α., And such one results that the obtained equality of the two times, $t_2 = t_1$ shall be obtained for any pair of paths in which the paths 1' and 2' will be aimed at 90^0 between them, independently of the start angle α of Sw1.

6. Correct reanalysis of the physical model PM in BF frame

6.1. Presentation of the physical model PM of the two swimmers in BF frame

Also such a path or route, within the physical model PM of the two boats in the BF reference frame, correctly and fair play run, according to the appropriate rules described in Sec. 1, was described previously by us in [9, 10, 11].

And even a such path for the two boats, but applied to two swimmers, Sw1 and Sw2, is shown in Fig. 4. Now, in Fig. 4, the selected reference frame is xOy, the one attached to block-start, BF frame, with the axis Ox aimed reversely to water speed *v*.

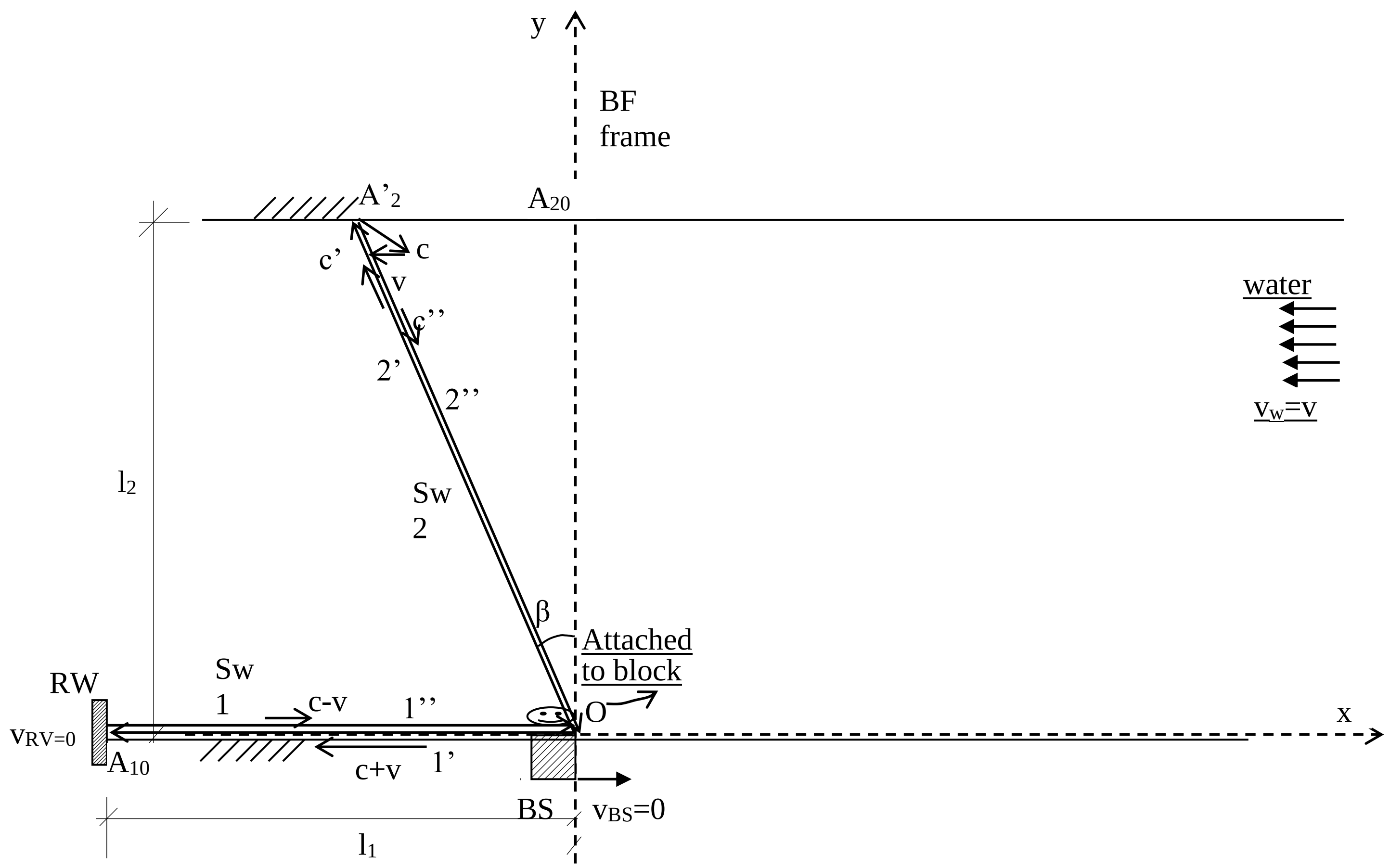

Fig. 4. Model with two swimmers Sw1 and Sw2 in BF frame. The case of longitudinal path 1'+1" and crosswise/transversal path 2'+2" inclined with β double line.

Here also, point O, the one of the initial time t=0 of the race start, coincides with the block-start BS right corner. In this model, we will consider that the water flows with the speed *v* to the left side of the observer O from Fig. 4., while the blockstart BS and the two river banks RB1, RB2, including the return walls RW shall remain still for the observer from the BF frame.

6.2. Analysis of model PM in case of crosswise direction

In Fig. 4, at the time t=0, swimmer Sw2 leaves from point O with his speed *c* in the direction y, perpendicular to the block-start BS (and to the RB1 bank).

But, because he swims in the water, he will be carried over by the water with the water speed *v*, and, therefore, the speed of Sw2 against block-start BS shall be *c'* with an angle β, depending also on the velocity polygon [9, 10, 11].

The simmer Sw2 shall cover his initial path 2' between point O and point A'_2 located on the opposite bank RB2 (Fig. 4) but located at a distance d_1 given by angle β in BF, $d_1=OA'_2$. Swimmer Sw2 shall cover this distance $d_1 = l_2.v/c$ within the timeframe t'_2.

Note that point A'_2 does not coincide with point A_{20} (Fig. 4), which was corresponding at the initial time t=0, to the point of the RB2 bank, which was directly opposite to O point at that time.

Now, Sw2, to make sure, when returning, it reaches exactly the start point O (Fig. 4), it shall have to swim with his own speed, *c*, but angled against axis Oy, at an angle ε depending on the velocity polygon [9, 10, 11] in such way that, under the water speed's *v* influence, the resulting speed *c''* is aimed towards the point O, that Sw2 is able to see right from the time of his return from A_2' point (Fig. 4), without breaking any fair play rule. And hence, Sw2 shall return to point O after the timeframe t_2''.

So the complete transversal/crosswise path in BF frame takes the shape of an inclined with angle β double line (Fig. 4).

Because the model PM as physical phenomenon involved, or even the real contest is unique in reality, in any selected reference frame WF or BF, the total time $t_2 = t'_2 + t''_2$ of running the above path 2'-2'', must be equal to the calculated time t_2 of eq. (9) and it does not require new calculation here.

It is logical that such calculation performed for the path 2'-2'' from Fig. 4 shall give the result of the eq. (9). Including the timeframes t'_2 and t''_2 of the two frames WF and BF, shall have to be equal between them.

6.3. Analysis of model PM in case of the longitudinal direction

For the longitudinal direction, the path 1'+1" covered by Sw1 is also shown in Fig. 4. Here, we have taken the point O of the initial time *t*=0, of the race start, coinciding with the same block-start BS right corner.

In Fig. 4, at the time t=0, when going out, swimmer Sw1 shall leave from point O, in direction reversed to Ox, parallel to block-start (and to RB1) and it shall cover his initial path 1' between point O and point A_{10} located also in the initial position of the return wall RW, in BF (Fig. 4).

And for the return path 1'', swimmer Sw1 shall start from point A_{10} in the direction of O where it shall arrive in the position O, still the initial one, in BF (Fig. 4). Sw1 shall return to point O after total timeframe $t_1=t'_1+t''_1$.

But the rule of times t_2 from the end of Sec. 6.2. shall also apply to this go-return race, regarding the equivalence of the times t_1 covered in the two reference frames BF and WF. Therefore, total time $t_1=t'_1+t''_1$ for running the path 1'-1'' of Fig. 4 above, must be equal to the calculated time t_1 of eq. (18) and it does not require new calculation here in BF. Including the partial timeframes, t'_1 and t''_1, of the two cases WF and BF, shall have to be equal between them and do not require neither of them a new calculation.

7. Conclusions and consequences

From the above presented situations of PM model, it results that, following detailed analysis of the path to be run by the swimmer Sw2 in crosswise direction of the river flow in the water reference frame WF, such path must take the shape of a right triangle, unlike the shape of isosceles triangle considered by many authors and by Michelson, probably also in WF, in the analytical interpretation of his experiment ME.

And in case of considering the shape of a right triangle of the path covered by Sw2 in WF, the two times of the two swimmers Sw1 and Sw2 shall be equal: $t_1=t_2$ and their race shall end in a tie.

In the BF frame the crosswise path takes the shape of an inclined with β double line, but the times t_1 and t_2 must remain the same as in WF frame. As consequence, utilising the isosceles triangle for transversal path in PM is an error also here.

Obviously, this result shall also have to be applied to the analysis of Michelson's experiment ME, as well as of the other similar experiments. And therefore, the aether's presence remains possible after ME experiment and thus, aether should not be removed from physics, as Einstein did based on ME experiment.

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