The Error in the Michelson-Morley Experiment That Precipitated Einstein's Theory of Relativity

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Abstract

In order to explain the mechanics of the famous Michelson-Morley experiment of 1887, designed to detect the ether and the ether wind, Albert Michelson compared it to two swimmers racing in a river. One swimmer travelled across the river and back to the starting point and the other travelled the same distance with the same speed downstream and back to the same starting point. He believed that such a comparative model is equivalent to the mechanics of his experiment.

In the swimmers' model, however, the swimmer that travels across the current must change his direction of travel slightly upstream in order to swim straight across the current. The angle between the ***initial*** directions of travel of the two swimmers is greater than 90^0, while the angle between the ***initial*** direction of travel of the two light beams in the MM experiment is fixed, 90^0, and cannot be altered. Therefore, the two models are not equivalent. This non-equivalence produced different travel times in the two models, which invalidate Michelson's calculations and all subsequent interpretations of this experiment that are found in physics textbooks and physics literature.

This error had a great role in the emergence of Einstein's theory of relativity.

The beginning of the great confusion

At the end of the 19th century, most physicists believed that all empty space on earth and interplanetary space was filled with the substance called the ether. This elusive substance was needed in order to explain the wave nature of light. It was reasoned that because sound waves require air for their propagation as waves, a similar substance would have to exist for light to propagate as waves. Physicists firmly believed in ether's existence and searched for a way of detecting it.

An interesting phenomenon puzzled physicists at that time. It was observed that it took longer to swim in a river to point C *(Fig. 1)* 50 yards downstream and back to point A than to point B, 50 yards across-stream and back to A. In other words, swimmers traveled with the same speeds V, yet the down-stream swimmer took longer to swim the same distance. That is, the parallel time T_P was longer than the vertical time T_V.

Swimmers racing in a river current

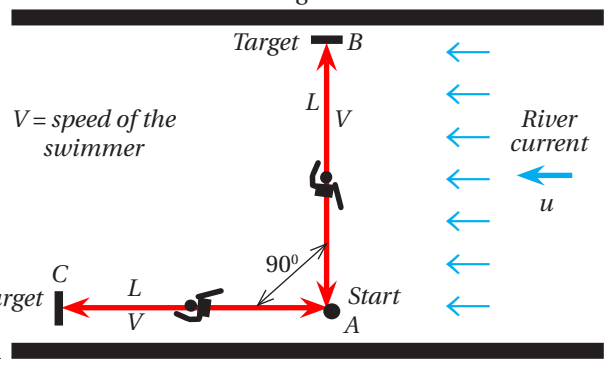

Fig. 1

$$T_V = \frac{2L}{V\sqrt{1-u^2/V^2}} \qquad T_P = \frac{2L}{V(1-u^2/V^2)}$$

Two beams racing in the ether wind - Earth and lab at rest

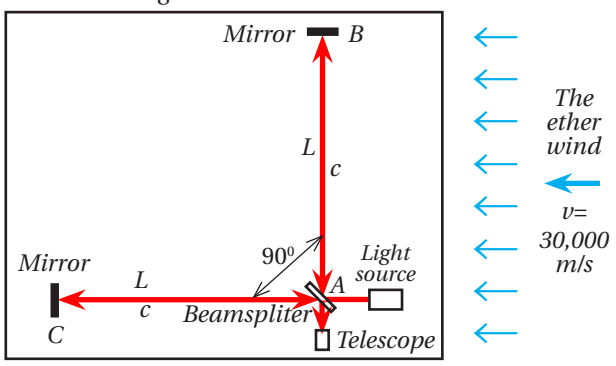

Fig. 2

$$T_V = \frac{2L}{c\sqrt{1-v^2/c^2}} \qquad T_P = \frac{2L}{c(1-v^2/c^2)}$$

Albert Michelson was inspired by the outcome in the race of the two swimmers in *Fig. 1* to construct an interferometer *(Fig. 2)* where the two light beams would be racing, while the ether wind was blowing through the laboratory, the way the current did in the river. [1] If the times of travel were different, there would be a fringe shift in the experiment due to the ether wind. The experiment is known as the Michelson-Morley (MM) experiment.

In the experiment, a light beam was split by a beamsplitter at A into two beams *(Fig. 2)*. One travelled across the ether wind to a mirror at B, then bounced back to the beamsplitter at A, while the other beam travelled the same distance downstream to another mirror at C, then traveled back to the beamsplitter at A; the same way the swimmers traveled in the river to the corresponding targets and back to the starting point at A.

At first glance, the two mechanical system in *Figs. 1* and *2* do indeed ***appear*** to be identical.

Michelson and physicists of that time, as well as textbook writers, including current ones, believed that they were identical, and that the times of travel of the two swimmers and the two beams would also be identical. The different times of travel in the ether model *(Fig. 2)* would produce fringe shift when the beams are reassembled at the beamslplitter and are sent to a viewing screen (a telescope). Thus, the existence of the ether and the ether wind would have been confirmed.

So, where is the error?

The error

In order to swim straight across the current at speed V and reach the target at B in *Fig. 1*, the swimmer must ***change*** his direction of travel and swim slightly upstream in the direction of B', shown in red in *Fig. 3*. The angle between the initial direction of travel of the two swimmers is ***greater*** than 90⁰. Thus, the swimmer travels along AB, that is the ***side*** of a triangle of speeds, ABB', at speed $\sqrt{V^2-u^2}$. The swimmer swimming downstream travels at its own speed V plus the speed of the current u $(V+u)$ and at speed $V-u$ on the way back. The travel times of the two swimmers are different.

Swimmers racing in a river current

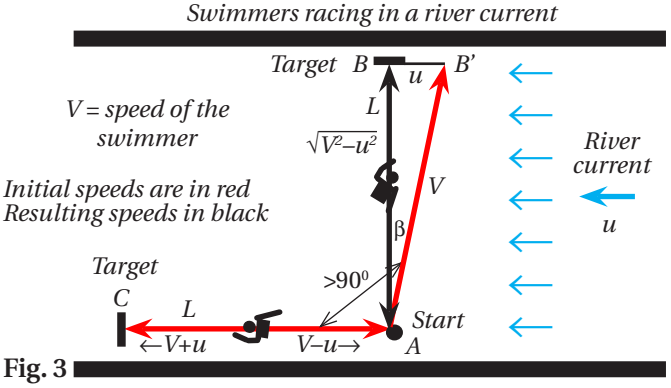

Fig. 3

$$T_V = \frac{2L}{\sqrt{V^2-u^2}} \qquad T_P = \frac{L}{V+u} + \frac{L}{V-u} = \frac{2LV}{(V^2-u^2)}$$

$$T_V = \frac{2L}{V\sqrt{1-u^2/V^2}} \qquad T_P = \frac{2L}{V(1-u^2/V^2)}$$

Two beams racing in the ether wind - Earth and lab at rest

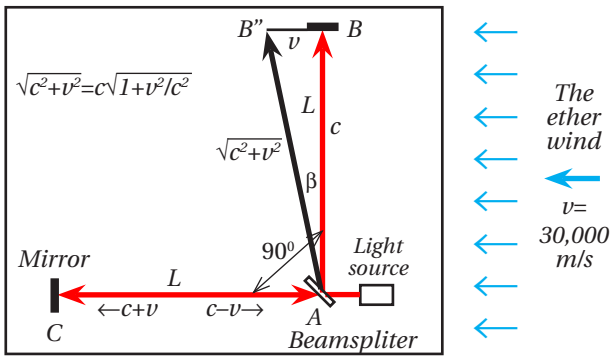

Fig. 4

$$T_V = \frac{2L}{c} \qquad T_P = \frac{L}{c+v} + \frac{L}{c-v} = \frac{2Lc}{(c^2-v^2)}$$

Initial speeds are in red, final in black

$$T_P = \frac{2L}{c(1-v^2/c^2)}$$

In the actual MM experiment *(Fig. 4)*, a beam of light is split into two beams by a beamsplitter at A. One beam is projected perpendicularly to the ether wind and the other one parallel to the wind, forming a 90⁰ angle. The initial direction of the two light beams and the 90⁰ angle between the two beams are dictated by the beamsplitter's design, and cannot be altered. Everything in the experimental setup is firmly fastened to the optical table and cannot move independently.

The vertical beam has no means to change its initial direction of travel or its initial aim.

The ether wind will then displace the vertical beam to the left and travel along AB", which is the ***hypotenuse*** of the triangle of speeds ABB", at speed $\sqrt{c^2+v^2}$ and in time L/c, which is different than the vertical time in the swimmers' model.

The travel times in the two models in *Figs. 3* and *4* are calculated *in the same manner*, using Newton's mechanics of addition or subtraction of speeds for the parallel and vertical beams and the Pythagorean theorem for the vertical beams.

The essence of Michelson's error is this: ***The swimmers' model and the actual model of the MM experiment are not equivalent.*** Thus, the travel times in the swimmers' model cannot be used as the beams' travel times in the actual experiment, the way it was done by Michelson and Morley and by all physics' textbook writers since.

Proof of the error

1. In the swimmers' model, there are two changes in the swimmer's directions of travel across the current: One is by the swimmer, the other is by the river current. In the actual experiment, however, only the ether wind can change beams' direction of travel.

2. If the speed of the river current is increased, the swimmer traveling across the current would simply increase his angle of travel and again arrive at *B (Fig. 3)*. However, when the Earth increases its orbital speed around the Sun, the vertical beam in the actual experiment has no means to change its initial angle of travel relative to the parallel beam, The initial direction of the beams' travels is dictated by the beamsplitter's design and cannot be changed.

3. If we angle the vertical beam in the actual experiment, as was done in the swimmers's model, we would have to angle the entire setup of the MM experiment and recalculate the parallel time, which has never been done.

The drawings of the first Michelson's experimental setup of 1881 *(Fig. 5)* and the one performed with Edward Morley in 1887 *(Fig. 6)* show the fixed nature of the experimental setups and the fixed and unchangeable initial angle of 90⁰ between the parallel and vertical beams. During the rotation of both apparatuses, nothing in the setups was moved or changed.

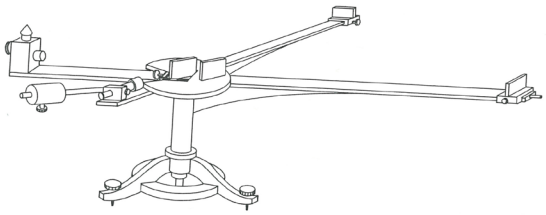

Fig. 5

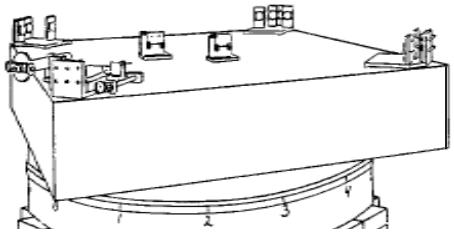

Fig. 6

A separate work titled *Proofs of the Error,* that includes the error in Richard Feynman's unique interpretation of the MM experiment in his *Lectures on Physics*, are shown on the website: EinsteinsFirstErrors.com. *Proofs of the Error* presents a great reassurance that the error described in this paper is real and beyond any doubt.

One error precipitated others

Because the direction of travel of the vertical beam in the actual MM experiment in *Fig. 4* must be along the hypotenuse, not the side of a triangle of speeds ABB', this error precipitated new ones:

1. Vertical speed must be $\sqrt{c^2+v^2}$, not $\sqrt{c^2-v^2}$
2. Vertical time must be: $T_V=2L/c$, not $2L/c\sqrt{1-v^2/c^2}$.
3. Contraction factor must be $(1-v^2/c^2)$, *not* $\sqrt{1-v^2/c^2}$, for the vertical and parallel times to be equal.
4. Wrong contraction factor led to errors in all of Lorentz's transformation equations, which are the backbone of all of Einstein's equations of the special theory of relativity.

Contraction theory to the rescue

When the MM experiment showed the negative result, that is, no fringe shift, the physics community was stunned by the results. Michelson almost had a nervous breakdown. Everyone expected that the fringe shift would be the result of the experiment and confirm the existence of the ether and the ether wind, as the Earth moved though the ether.

Thus, a new puzzle immerged: How to explain the negative results?

In order to salvage the ether theory, two physicists, George E. Fitzgerald and Hendrik Lorentz proposed that the stone platform on which the experimental setup was arranged contracted along the parallel dimensions due to the ether wind, by the right degree so that the vertical and parallel beams traveled in equal times and thus explained the absence of fringe shift in the actual experiment.

Lorentz reasoned that if in the parallel time in *Fig. 2*, $T_P=2L/c(1-v^2/c^2)$, the parallel length L is contracted by the square root factor to $L\sqrt{1-v^2/c^2}$, and the term in the denominator of the parallel time $(1-v^2/c^2)$ is expanded to two square root terms, $\sqrt{1-v^2/c^2}\sqrt{1-v^2/c^2}$, so that one square root term cancels the one in the nominator, the total parallel time would become equal to the total vertical time, $T_P=T_V=2L/c\sqrt{1-v^2/c^2}$. Lorentz believed that equal times would cause no fringe shift, and in agreement with the actual null results of the MM experiment.

That is how the theory of the existence of the ether was thought to be salvaged and how the theory of contraction of the parallel length of any body in motion by the square root factor $\sqrt{1-v^2/c^2}$ was born.

Consequences of the error

Michelson's error has not been discovered to the present time. His calculations of the vertical time in the ether setting are considered correct by every physics textbook and every manual on the theory of relativity.

Every presentation and every diagram of the motion of the light beams in the MM experiment mimic the swimmers' model. With the swimmers' model, conceived more than a century and a quarter ago, Michelson set the pattern for all future interpretations of his experiment. Only *Figs. 1, 2* and *3* are seen in physics textbooks, but never *Fig. 4*, the correct one.

Referring to the MM experiment, Einstein wrote: *"This was the first path which led me to the special theory of relativity."* [2] However, Einstein did not notice the error in the interpretation of the MM experiment or the error in the magnitude of Lorentz's contraction needed to explain the null results of this experiment.

Einstein incorporated Lorentz's faulty theory of contractions and his now meaningless transformation equations, which Einstein called "epoch-making," also known as Lorentz-Einstein transformation equations, into his theory of relativity.

The newly discovered error calls for the reexamination of the MM experiment and open a discussion about the error and its possible consequences.

References

[1] Albert A. Michelson and Edward W. Morley, *On the Relative Motion of the Earth and the Luminiferous Ether*. Amer. J. of Sci. Volume XXXIV, Nov. 1887, pp. 333-341

[2] Albert Einstein, *How I Created the Theory of Relativity*, Physics Today, Vol., 8. p. 45-47

Please note:

Paper #2 titled: "*Michelson-Morley Experiment is the Experimental Proof Against the Constancy of the Speed of Light and Einstein's Theory of Relativity,"* presented on the website EinsteinsFirstErrors.com, is of enormous importance.

It shows that the beams' equal times, made possible by the Lorentz-Einstein's theory of contraction along the parallel dimensions, are not sufficient to explain the null results of this experiment. A more important fact is ***where*** on the beamsplitter the two beams reunite when the apparatus is rotated. If its not always in the same place—the fringe shift would occur.

According to Einstein's mechanics, the travel times when the apparatus is in motion are different than when the apparatus is at rest, contradicting the principle of relativity. These different times guarantee that the beams will not reunite at the same place on the beamsplitter when the apparatus is rotated, predicting the fringe shift that did not occur in the actual experiment.

This can only be seen in the new and unique drawings of the MM experiment using single waves the length of the arms of the apparatus or the distance between the beamsplitter and the mirrors.