The Meaning of the Michelson-Morley Experiment

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Abstract The Null result of the Michelson-Morley experiment, that ruled out the existence of an immobile Aether, is unexpected only in terms of Galilean Physics.

In Special Relativity, that Null result is fully expected, and does not rule out the existence of any Aether.

Since textbooks present the Michelson Morley experiment only in terms of Galilean Physics, its meaning is distorted, and misleading.

In particular, the Michelson-Morley Experiment cannot, and does not rule out an immobile Aether, or any Aether.

Furthermore, the Michelson Morley experiment is not an anomaly explained away by Lorentz contraction, but the most solid confirmation for Relativistic Kinematics.

Precision tests of the experiment validate further the formulas of velocity transformations in Special Relativity, and confirm Special Relativity.

keywords Michelson-Morley, Interferometer, Aether, Lorentz Transformations, Velocity Transformations, Special Relativity, Galilean Transformations

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Introduction

Electrodynamics was visualized by analogy with the Mechanics of Fluids. Thus, the Aether, as a medium that permeates the universe and enables electro-magnetic waves to propagate, was visualized as water at rest.

The Immobile Aether Hypothesis contradicts the reality of Molecular Brownian Motion, and the fact that all matter, including its sub-particles, participates in some harmonic motion.

A more credible candidate for an Aether would be the Neutrinos, or the photons of Zero Point Energy that permeate the universe, and move at light speed, or other unknown-yet particles.

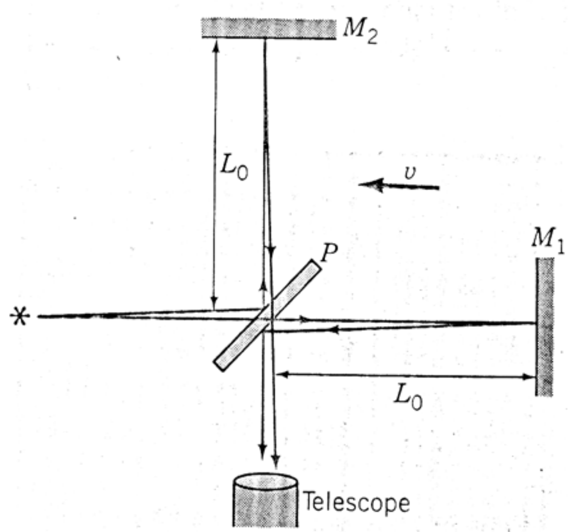
Nevertheless, the Michelson-Morley Experiment was set up to detect the speed of the earth, in an immobile Aether.

The motion of the earth in the Aether at speed v generates an "Aether wind" with velocity $-v$.

A light beam that travels time T_1, parallel to the earth's motion, interferes with a light-beam that travels time T_2, perpendicular to the motion.

The time-travel difference results in a wave-phase difference, and an interference pattern at the telescope.

A rotation of the Interferometer will shift the interference fringes, by an amount determined by v.



The measured shift indicated $v \approx 0$, and no immobile Aether.

But Michelson-Morley estimates for the time difference $T_1 - T_2$, were Galilean.

The speed of the beam to the mirror M_1, was taken as $c - v$

The speed of the beam returning from M_1, was taken as $c + v$

The Galilean distance in both directions is L_0,

and the Galilean time interval is

$$T_1 = \frac{L_0}{c - v} + \frac{L_0}{c + v} = \frac{2L_0}{c} \frac{1}{1 - \frac{v^2}{c^2}}$$

In a right angle triangle where c is the hypotenuse, and v is one of the sides of the triangle, the speed of the beam to the mirror M_2, and back is $\sqrt{c^2 - v^2}$,

the Galilean distance in both directions is L_0,

and the Galilean time interval is

$$T_2 = \frac{L_0}{\sqrt{c^2 - v^2}} + \frac{L_0}{\sqrt{c^2 - v^2}} = \frac{2L_0}{c}\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

The Galilean time difference is

$$T_1 - T_2 = \frac{2L_0}{c}\left(\frac{1}{1 - \frac{v^2}{c^2}} - \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}\right)$$

and for $v \ll c$,

$$\approx \frac{2L_0}{c}\left\{(1 + \tfrac{v^2}{c^2}) - (1 + \tfrac{1}{2}\tfrac{v^2}{c^2})\right\} = \frac{L_0}{c}\frac{v^2}{c^2}.$$

To explain the null result, Lorentz suggested that the distance L_0 contracts in the direction of the motion by a factor of

$$\sqrt{1 - \tfrac{v^2}{c^2}}.$$

Consequently,

$$T_1 = \frac{L_0\sqrt{1 - \frac{v^2}{c^2}}}{c - v} + \frac{L_0\sqrt{1 - \frac{v^2}{c^2}}}{c + v} = \frac{2L_0}{c}\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}},$$

and

$$T_1 - T_2 = \frac{2L_0}{c}\left(\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} - \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\right) = 0.$$

Feynman [Feynman, I-15-5] notes that

> *…Although the contraction hypothesis successfully accounted for the negative result of the experiment, it was open to the objection that it was invented for the express purpose of explaining away the difficulty, and was too artificial…*

Indeed, the Lorenz contraction alone allows the velocities transformation to be Galilean.

Is it believable that the velocities are

$$c - v, \quad \text{and} \quad c + v?$$

Feynman proceeds to justify the null time with arguments adapted from Einstein's Special Relativity.

At the end, the purpose of the Michelson Morley experiment to establish the existence of the Aether is forgotten.

The Aether existence remains unresolved, and more precise Michelson Morley experiments serve as further proof to the non-existence of the Aether.

The significance of the experiment to the confirmation of relativistic kinematics, and special relativity goes unnoticed in the Textbooks.

The most solid experimental confirmation of Special Relativity is not presented as such.

Our purpose here is to elucidate and clarify the meaning of the Michelson Morley experiment.

By casting the experiment in terms of special relativity, we aim to establish that

- Michelson-Morley Experiment cannot, and does not rule out an immobile Aether, or any Aether.
- the Michelson Morley Experiment validates the formulas of velocity transformations in Special Relativity, and confirms Special Relativity.
- Any greater precision in the null result of the experiment, puts Special Relativity on a firmer basis.

We proceed to set up the Michelson-Morley Experiment in Lorentz Coordinate Transformations terms.

1.

Michelson-Morley in Special Relativity

In the interferometer system S',

the speed of the Aether wind is $-v$.

The speed of the beam to the mirror M_1 is

$$u_x' = c.$$

Thus, the speed of the beam to the mirror M_1 in the observer system S is

$$u_x = \frac{c - v}{1 + \frac{c(-v)}{c^2}} = c.$$

The distance traveled to M_1 in the observer system S is

$$\frac{L_0 - v\Delta t'}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Therefore, the beam travel-time to M_1 in the observer system S is

$$\frac{L_0 - v\Delta t'}{c\sqrt{1 - \frac{v^2}{c^2}}}$$

The speed of the beam returning from the mirror M_1 is

$$u_x' = -c.$$

Thus, the speed of the beam returning from the mirror M_1 in the observer system S is

$$u_x = \frac{-c - v}{1 + \frac{(-c)(-v)}{c^2}} = -c\,.$$

The distance traveled from M_1 in the observer system S is

$$\frac{-L_0 - v\Delta t'}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Therefore, the beam travel-time return from M_1 in the observer system S is

$$\frac{L_0 + v\Delta t'}{c\sqrt{1 - \frac{v^2}{c^2}}}$$

Consequently, the beam time interval to go to M_1, and return from M_1, in the observer system S is

$$T_1 = \frac{L_0 - v\Delta t'}{c\sqrt{1 - \frac{v^2}{c^2}}} + \frac{L_0 + v\Delta t'}{c\sqrt{1 - \frac{v^2}{c^2}}}$$

$$= \frac{2L_0}{c}\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}\,.$$

Therefore, according to Special Relativity, Michelson-Morley's Galilean time interval , $\frac{2L_0}{c}\frac{1}{1 - \frac{v^2}{c^2}}$, is incorrect.

Regarding the path to the 2^{nd} mirror , the speed of the beam to the mirror M_2 is

$$u_y' = c\,.$$

Thus, the speed of the beam to the mirror M_2 in the observer system S is

$$u_y = \frac{c}{1+\frac{c(-v)}{c^2}}\sqrt{1-\frac{v^2}{c^2}} = c\frac{\sqrt{c^2-v^2}}{c-v}.$$

The distance traveled to M_2 in the observer system S is L_0

Therefore, the beam travel-time to M_2 in the observer system S is

$$\frac{L_0}{c\sqrt{c^2-v^2}}(c-v)$$

The speed of the beam returning from the mirror M_2 is

$$u_y^{'} = -c.$$

Thus, the speed of the beam returning from the mirror M_2 in the observer system S is

$$u_y = \frac{-c}{1+\frac{(-c)(-v)}{c^2}}\sqrt{1-\frac{v^2}{c^2}} = -c\frac{\sqrt{c^2-v^2}}{c+v}.$$

The distance traveled from M_2 in the observer system S is $-L_0$

Therefore, the beam travel-time from M_2 in the observer system S is

$$\frac{L_0}{c\sqrt{c^2-v^2}}(c+v)$$

Consequently, the beam time interval to go to M_2, and return from M_2, in the observer system S is

$$T_2 = \frac{L_0}{c\sqrt{c^2 - v^2}}(c - v) + \frac{L_0}{c\sqrt{c^2 - v^2}}(c + v)$$

$$= \frac{2L_0}{c\sqrt{1 - \frac{v^2}{c^2}}}.$$

Therefore, according to Special Relativity, Michelson-Morley's Galilean time interval $\frac{2L_0}{c}\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ is correct.

Finally, the time difference in special relativity is

$$T_1 - T_2 = \frac{2L_0}{c}\left(\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} - \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}\right) = 0$$

In conclusion, in special relativity, the time difference does not depend on the speed of the Aether wind, and no shift should be expected.

Thus, the null results of the Michelson-Morley experiment validate Relativistic kinematics, and confirm Special Relativity.

In particular, the Michelson-Morley Experiment does not rule out immobile Aether, or any Aether.

References

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