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Michelson-Morley Experiment and the Theory of Special Relativity

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Abstract

The paper considers Michelson-Morley experiment, conducted to detect a luminiferous ether in space. Light from a source was transmitted and reflected in two perpendicular arms of the same length *L*, moving with velocity **v**. Using an interferometer, no difference was detected in the times taken for the transmitted and reflected rays to cover the length *2L* in the longitudinal and transverse directions. The theory of special relativity explained the null result through conceptions of length contraction, by *sqrt(1 – v^2/c^2)* in the longitudinal arm, and time dilation in the transverse arm, by Lorentz factor *1/{sqrt(1 – v^2/c^2)}*, where *c* is the speed of light in a vacuum. This makes the times taken, for the round trips of length *2L*, in both arms, to be equal as *2L/c{sqrt(1 – v^2/c^2)}*. This paper argues that with no relative motion between components of the apparatus, where the observer moves at the same velocity **v**, as the light source, the result of the experiment should always be a null. The null result influenced the contention of special relativity, that the speed of light is independent of motion of the observers and that ether did not exist. If ether moved along with velocity **v** as the apparatus, it could not be detected. The Lorentz factor, length contraction, time dilation and mass expansion, are misconceptions in special relativity, which this paper seeks to address.

Keywords: Fringe Shift, Interferometer, Length, Light, Mirror, Plate, Reflection, Refraction, Time, Velocity, Wavelength

1. Introduction

Speed of light features prominently in this paper. In 1865, the great Scottish mathematician and physicist, James C. Maxwell, gave the speed of light *c* in a vacuum, as [1]:

$$c = \sqrt{1/\mu_o \varepsilon_o} = 299\ 792\ 458 \text{ meters per second} \quad (1)$$

where μ_o is the magnetic permeability and ε_o the electric permittivity of electric field in a vacuum. This speed is the most measured and most accurately known quantity in physics. In the theory of special relativity, speed of light *c* is taken a constant relative to all observers. This paper proposes speed of light *c*, in a vacuum, as a constant relative to the source only. The variation of speed of light with direction of motion or rotation of reflecting mirrors, was tested in the Michelson-Morley of 1887, Sagnac experiment of 1913 and other experiments [2 – 6].

The author showed that speed of light *c* is the maximum to which a charged particle may be accelerated by an electric field, because accelerating force decreases with speed, reducing to *0* at speed *c*. Lorentz factor has nothing to do with mass, but the result of motion of a charged particle perpendicular to an electric field [7 - 10].

The famous Michelson-Morley experiment was conducted by the Americans Albert Michelson and Edward Morley. The purpose was to detect the presence of a medium called ether, for propagation of light.

A diagram of Michelson-Morley (MM) experiment is shown in Figure 1. The apparatus consisted of light source *S*, half-silvered glass plate *A* at angle of 45°, mirrors *B* and *C* on perpendicular arms of equal length *L* and interferometer as detector *D*. The whole apparatus was placed on a turntable that could be swung round by 90°.

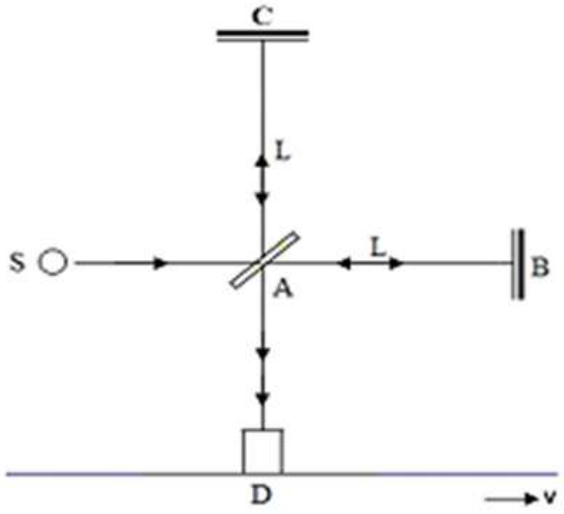

Figure 1: Apparatus of Michelson-Morley Experiment at velocity **v** of revolution of the Earth round the Sun.

In Figure 1, the transmitted light went on to mirror B and the reflected beam to mirror C, each through perpendicular arms of equal length L. The reflected lights, from B and C, were returned to the half-silvered plate A where they were again half-reflected and half-transmitted. The recombined rays of light travelled behind the half-silvered plate A to reach the detector D, where interference patterns could be observed or recorded. If there was any difference (Δt) in the transit time between the two rays of the same frequency f, it should show as interference patterns, with maxima and minima of the same period $1/f$, in the interferometer D.

For two waves with transit time difference (Δt), phase difference $2\pi f(\Delta t) = (2\pi c/\lambda)(\Delta t) = 2\pi\delta$, where $\delta = (c/\lambda)(\Delta t)$ is the fringe shift. The interferometer, in the MM experiment, was sensitive enough to detect this shift if present. However, the shift obtained was 0.00 ± 0.01, indicating a null result, within limits of experimental error. With reference to Figure 1, the experiment found no difference in the times taken for the transmitted and reflected rays to cover the distances ABA and ACA, each of length $2L$ in the perpendicular arms. The relativistic and non-relativistic explanations of the results of MM experiment are given.

2. Relativistic Explanations of the Results of MM Experiment

The relativistic argument is that as light moves from plate A to reach a mirror B in time t, the mirror would have moved a distance vt. The relative speed between light leaving plate A with speed c and mirror B moving with speed v, in the same direction, is $(c - v)$. This 'relative speed' means that mirror B could be regarded as 'stationary' while light from plate A moved with speed $(c - v)$ to reach it within distance L in time $L/(c - v)$. Similarly, the relative speed between light leaving mirror B with speed c and plate A moving with speed v, in the opposite direction, would be $(c + v)$. So, for a given distance, light took longer to reach a target moving in the direction of propagation. Total transit time t_1 of light in the longitudinal round trip ABA, becomes:

$$t_1 = \frac{L}{c-v} + \frac{L}{c+v} = \frac{2cL}{c^2 - v^2} = \frac{2L}{c\left(1 - v^2/c^2\right)} \tag{2}$$

With the line AC moving at speed v in a perpendicular direction, speed of light going from A to C and from C to A is put, according to special relativity, as $c\sqrt{\left(1 - v^2/c^2\right)}$. Transit time t_2 taken in the transverse round trip ACA, of total length $2L$, becomes:

$$t_2 = \frac{2L}{c\sqrt{\left(1 - v^2/c^2\right)}} \tag{3}$$

If MM experiment gave a null result, then t_1, in equation (2), should be equal to t_2 in equation (3). But how could the two transit times be equal? George Fitzgerald in 1889 and Hendrik Lorentz in 1892 came forth with a brilliant mathematical answer by suggesting that the length L of the longitudinal arm (AB), in equation (2), somehow, suffered a contraction by a factor $1/\gamma$ to become L/γ, where γ, Lorentz factor, is:

$$\gamma = 1/\sqrt{\left(1 - v^2/c^2\right)} \tag{4}$$

The transverse arm (AC) somehow suffered a time dilation by a factor γ to become γt_2. This is the genesis of relativistic length contraction and time dilation, carried over to relativistic mass expansion. However, relativistic length contraction and relativistic time dilation do not occur simultaneously, on the same path.

Equation (3) gives speed of light v_2, with relativistic time dilation, in the transvers arm, as:

$$v_2 = \pm c\sqrt{\left(1 - v^2/c^2\right)} = \pm c/\gamma \tag{5}$$

Equation (5), where v_2 becomes zero, at a point in space, and no transmission, as $v \rightarrow c$, is questionable.

3. Non-relativistic explanation of the result of MM experiment

In the MM experiment (Figure 1) there was no relative motion between the components of the apparatus (light source, reflecting/refracting plate, the mirrors, the detector and the observer). Bodies moving with the same velocity **v**, in this case, velocity of revolution of the Earth round the Sun, are stationary relative to each other. But the individual bodies may move relative to one another.

The length L of each arm remains constant while the rays are transmitted and reflected at speed of light c. With no time difference between the rays in perpendicular arms, covering the same distance $2L$, the result should always be a null. The point here is that the observer, also moving with **v**, sees no change in relativity.

4. Results and Discussion

- An experiment, like the MM experiment, does not lie, but interpretation of the results may be wrong.
- Length contraction and time dilation are not from the results of Michelson-Morley experiment, but mathematical designs to explain the null result of the experiment.
- In Figure 1, for the apparatus, with light source, moving at speed v relative to an observer, putting (c – v) as the speed of light in the direction (AB) of motion and (c + v) in the opposite direction (BA), contradicts the relativistic principle of constancy of speed of light.
- Making speed of light in the perpendicular direction as $\pm c\sqrt{\left(1-v^2/c^2\right)}$, which reduces to *0*, at a point in space, as $v \rightarrow c$, and giving Lorentz factor as $\gamma = 1/\sqrt{\left(1-v^2/c^2\right)}$, cannot possibly be correct.
- The luminiferous aether should exist as an electric field medium that is carried along with the equipment of an apparatus.
- Relative velocity, between two bodies, is the difference of their respective velocities, irrespective of a frame of reference.
- If the speed of light were that constant for all observer, stationary or moving, it would never have been measured, umpteen times, in different directions and distances.
- Lawrentz transformation is not required.
- The MM experiment, with no relative motion between the components of the apparatus, should be compared to Sagnac experiment of 1913, where there was relative motion between rotating mirrors and the centre of rotation, resulting in observation of fringe shift.

5. Conclusions

- Interpretation of null result of Michelson Morley experiment, as due to length contraction in the direction of motion, and time dilation in the transverse direction, relative to an observer, is a misconception.
- The result of Michelson-Morley experiment should always be a null as there is no relative motion between the components of apparatus and observer, moving with the same velocity **v** of revolution of the Earth.

6. Recommendation

Results of the Michelson-Morley experiment should be reviewed in consideration of the apparatus, including the light source, and the observer, moving at the same velocity **v** of revolution of the Earth.

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