Michelson - Morley experiment
Emission theory vs postulate 2 of Special relativity

Nguyen Van Quang
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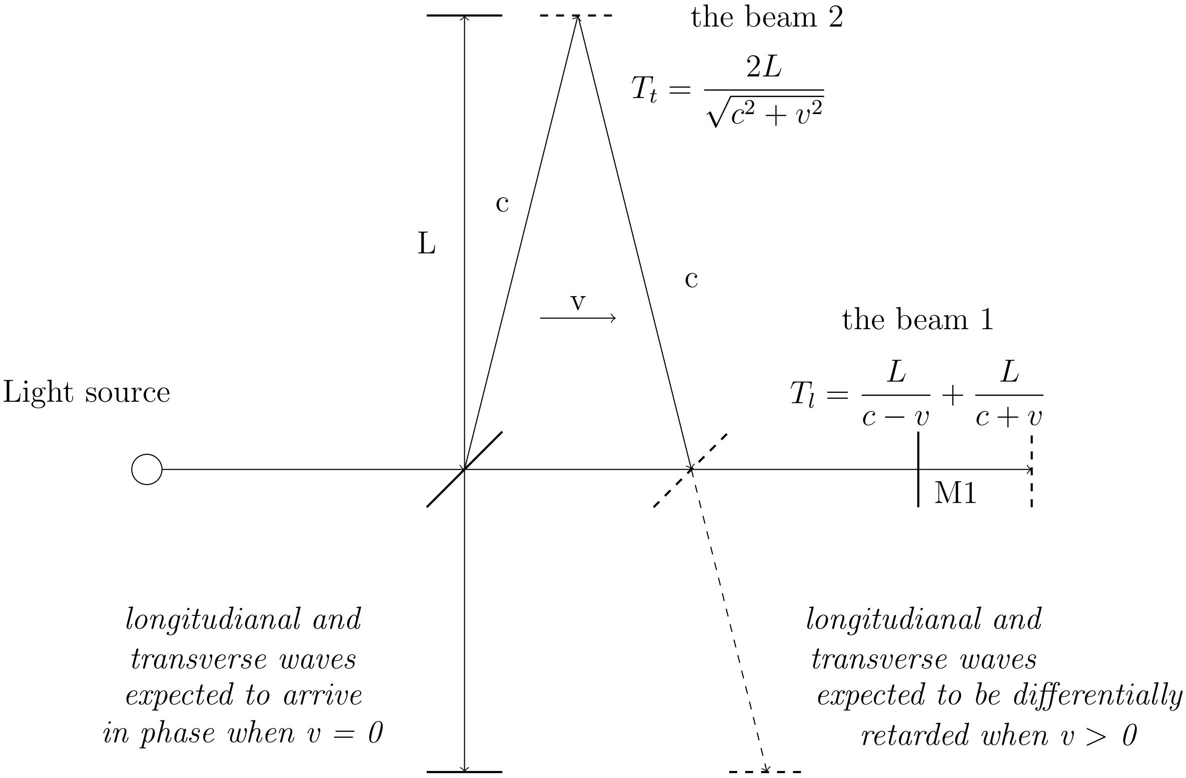
Abstract

Regarding the interference of the two light beams, we usually think of it as interference between two light beams of the same wavelength and frequency. However, if the interferometer of the Michelson - Morley experimental device accurately records the interference of the two light beams of the same wavelength , that is negative evidence for the correctness of the postulate 2 of special relativity.

1 Michelson - Morley experiment [1]



Expected differential phase shift between light travelling the longitudianal versus the transverse arms of the Michelson- Morley apparatus
Figure 1

The beam travel time in the longitudinal direction can be derived as follows: Light is sent from the source and propagates with the speed of light c in the aether. It passes through the half-silvered mirror at the origin at $T = 0$. The reflecting mirror is at that moment at distance L (the length of the interferometer arm) and is moving with velocity v. The beam hits the mirror at timeT_1 and thus travels the distance cT_1. At this time, the mirror has traveled the distance vT_1. Thus$cT_1 = L + vT_1$ and consequently the travel time $T_1 = L/(c - v)$. The same consideration applies to the backward journey, with the sign of$v$ reversed, resulting in

$cT_2 = L - vT_2$ and $T_2 = L/(c+v)$. The total travel time $T_\ell = T_1 + T_2$ is:

$$T_\ell = \frac{L}{c-v} + \frac{L}{c+v} = \frac{2L}{c}\frac{1}{1-\frac{v^2}{c^2}} \approx \frac{2L}{c}\left(1+\frac{v^2}{c^2}\right)$$

Michelson obtained this expression correctly in 1881, however, in transverse direction he obtained the incorrect expression

$$T_t = \frac{2L}{c},$$

because he overlooked the increase in path length in the rest frame of the aether. This was corrected by Alfred Potier (1882) and Hendrik Lorentz (1886). The derivation in the transverse direction can be given as follows (analogous to the derivation of time dilation using a light clock): The beam is propagating at the speed of light $c$and hits the mirror at time T_3, traveling the distance cT_3. At the same time, the mirror has traveled the distance vT_3 in the x direction. So in order to hit the mirror, the travel path of the beam is Lin the y direction (assuming equal-length arms) and vT_3in the x direction. This inclined travel path follows from the transformation from the interferometer rest frame to the aether rest frame. Therefore, the Pythagorean theorem gives the actual beam travel distance of $\sqrt{L^2 + (vT_3)^2}$. Thus $cT_3 = \sqrt{L^2 + (vT_3)^2}$ and consequently the travel time $T_3 = L/\sqrt{c^2 - v^2}$, , $T_t = 2T_3$is:

$$T_t = \frac{2L}{\sqrt{c^2 - v^2}} = \frac{2L}{c}\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \approx \frac{2L}{c}\left(1+\frac{v^2}{2c^2}\right)$$

The time difference between T_ℓ, T_t is given by

$$T_\ell - T_t = \frac{2L}{c}\left(\frac{1}{1-\frac{v^2}{c^2}} - \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\right)$$

To find the path difference, simply multiply by c;

$$\Delta\lambda = 2L\left(\frac{1}{1-\frac{v^2}{c^2}} - \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\right)$$

The path difference is denoted by $\Delta\lambda$because the beams are out of phase by a some number of wavelengths (λ). To visualise this, consider taking the two beam paths along the longitudinal and transverse plane, and lying them straight (an animation of this is shown at minute 11:00, The Mechanical Universe, episode 41). One path will be longer than the other, this distance is $\Delta\lambda$. Alternatively, consider the rearrangement of the speed of light formula $c\Delta T = \Delta\lambda$.

It can be seen from this derivation that aether wind manifests as a path difference.This derivation is true if the experiment is orientated by any factor of 90^0 with respect to the aether wind.If the path difference is a full number of wavelengths, constructive interference is observed (central fringe will be white).If the path difference is a full number of wavelengths plus one half, deconstructive interference is observed (central fringe will be black).

2 Emission theory vs postulate 2 of special relativity

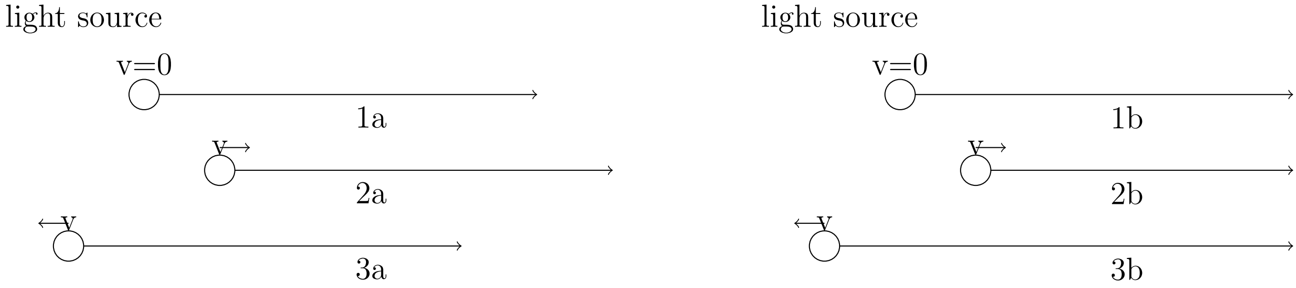
A. Emission theory [4], also called emitter theory or ballistic theory of light, was a competing theory for the special theory of relativity, explaining the results of the Michelson - Morley experiment of 1887. Emission theories obey the principle of relativity by having no preferred

frame for light transmission, but say that light is emitted at speed "c" relative to its source instead of applying the invariance postulate.
The name most often associated with emission theory is Isaac Newton. In his corpuscular theory Newton visualized light " corpuscles" being thrown off from hot bodies at a nominal speed of c with respect to the emitting object and obeying the usual laws of Newtonian mechanics, and we then expect light to be moving towards us with a speed that is offset by the speed of the distant emitter $(c \pm v)$.
It can explain the negative outcome of the Michelson - Morley experiment, since the speed of light in constant with respect to the interferometer in all frames of reference.

B. Postulate 2 [2]: The speed of light in vacuum is the same for all observers, regardless of the motion of light source, or observers,
Speed at which light waves propagate in vacuum is independent both of the wave source and of the inertial frame of reference of the observe. This invariance of the speed of light was postulated by Einstein in 1905 after being motivated by Maxwell 's theory of electromagnetism and the lack of evidence for the luminiferous aether [3].
Form formula for light speed: $c = \lambda f$, length of light beam $= n\lambda +$ out of phase,thus,

According to Emission theory, the wavelength and frequency of light beam are independent of the speed of the light source (a,figure 2).

According to postulate 2, the wavelength and frequency will change depending on the direction and speed of light source (b,figure 2).
Because the number of the waves emitted from the light source will remain the same during motion, so if the light source moves in the same direction as the light beam, the wave will be short (2b) ,frequency will increases, if it moves in the opposite direction to the light beam, the wave will be longer (3b), frequency will decreases.



a.Light beam moves according to the Emission theory

b.Light beam moves according to the postulate 2

figure 2:

Notes:

a.Light beam moves according to the Emission theory:

1a: Speed of light source $v = 0$, *speed of light* = *c*, *wavelength* = λ
2a : The light source moves in the same direction as the emitted light beam,speed of light = *c* + *v*, *wavelength* = λ

3a : The light source moves in the opposite direction of the emitted light beam,speed of light = c - v, wavelength = λ

b.Light beam moves according to the postulate 2:

1b: Speed of light source v = o, speed of light = c, wavelength = λ
2b : The light source moves in the same direction as the emitted light beam ,speed of light = c , wavelength $\lambda_1 = \dfrac{c-v}{c}\lambda$
3b : The light source moves in the opposite direction of the emitted light beam,speed of light = c , wavelength $\lambda_2 = \dfrac{c+v}{c}\lambda$

By postulate 2, for the Michelson - Morley experiment, the reflected beam from mirror M1 can be considered as the case 3b above. the interference must be:

The two light beams (the beam 1 and the beam 2 of Michelson - Morley experiment) arriving at the interferometer are of different wavelength, an interference occurs between two light beams of different wavelength and whose repetition period is not a wavelength, but a least common multiple of the two wavelength of the two beams.

References

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[2] Special relativity- Wikipedia

[3] Speed of light - Wikipedia

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Email:
nguyenvquang67@gmail.com
quangnhu67@yahoo.com.vn