# A Way to Understanding Michelson-Morley Experiment and its Consequence Regarding Luminiferous Aether / Ether (LE)

#### **Rabindranath Chattopadhyay**

Indian Association of Physics Teachers (India) and Institute of Science Education and Culture (Kolkata)

**Abstract:** As is well-known the trio, the Michelson-Morley (MM) Experiment, Experiment with Aberration and Fezau's Experiment forms the primary experimental basis as solid support to the Einstein's theory of absolute frame and Relativity. In this article especially the MM- experiment is considered for a point in its theoretical basis to be critically discussed.

Keywords: MM Experiment, Special Relativity, Ether

#### 1. Introduction

The concept of Aether came into consideration in the history of science after the discovery of undulatory nature of some features observed in the phenomena of propagation of light. Various provisional theories had been being proposed since Issac Newton including his own corpusculaular theory for explaining phenomena with light. Wave theory had been proposed by Huyge [1] and others gradually began to appreciate and modify the wave theory of light. Maxwell [2, 3, 4, 5] first time established his theory of electromagnetic nature of light and the light wave thenceforth. From then onward the concept of propagation of electromagnetic wave through a semi elastic hypothetical material medium called 'Aether' had been being carried forward by the scientific community. As a light bearing subtlest material medium with rather a typical combination of physical properties was hypothesized and had been being known as the 'Luminiferous Aether'(LE) from then on. But astronomical observation of stellar aberration and the related calculations showed that with the Earth's motion Aether need not be dragged with for explaining the aberration. Then Fizeau's [6] experiment of light's motion through moving material medium had to assume a formula for its explanation which got partial support from Lorentz-Fizerald [7] theory of contraction of length moving in this 'Aether' medium. Then came finally the most celebrated Michelson-Morley Experiment [8].

In their famous paper on their experiment on relative motion of Ether and the Earth Michelson and Morley(MM) mentioned that among two hypotheses the one of Fresnel's undulatory theory stating the LE to be at rest with respect to earth forms the basis of their experiment. The purpose of their experiment was to verify whether the hypothesis of LE at rest with respect to earth is true or not.

A brief discussion on the ultimate result of MM-experiment seems to be needed before going to theoretical analysis. Many books present it in many ways among which some are stated below; First of all in its mention about Aether Wikipedia , without mentioning the purpose of their experiment as presented by Michelson and Morley themselves in their original paper

states that "Hendrik Lorentz[9] and George Francis Fitzerald offered within the framework of Lorentz's Ether theory an explanation of how the Michelson Morley experiment could (2) have failed to detect motion through ether." This is somewhat misleading and may have meaning different from what it should have been. Similarly in many other textbooks on relativity authors do mention about the nonexistence of Ether as consequence directly from the Michelson-Morley experiment. This is not true and the experimenters do not mention this in their celebrated paper. But on the other hand in many good books authors do mention about it in proper manner what should really be. Robert Resnick [10] mentions in his book that experimental result obtained by Fizeau confirmed Fresnel's prediction about ether-drag coefficient. Repetition of the experiment by Michelson and Morley and by Zeeman [11] and others with greater precession of measurement strongly reaffirmed the Fresnel's drag coefficient. Bergman [12] mentions that ultimate conclusion in the M-M experiment is that 'Ether is dragged along with the Earth in its immediate neighborhood.' This inference along with the inference from Fizeau's experiment did not seem consistent with the inference from experiment with Aberration.

A proper justification in support of nonexistence of a material inertial medium like this Ether would be a set of three experimental consequences, namely Fizeau's Experiment along with Lorentz-Fizterald contraction ,aberration and M-M Experiment. In all the books and research papers that describes Michelson-Morley Experiment concluding the ethereal drag if 'Ether' exists at all , the expected result of the experiment as predetermined from simple Galilean transformation following classical dynamics is derived essentially in the very same way and this is no surprise at all until some doubts hit.

In this article the author would like to present his own view of understanding the result of M-M experiment and critically discuss a point in the derivation of theoretically expected result;

#### Theoretical Essentials and the Derivation:

It would be better to summarize all the main points as the assumptions and hypotheses about Ether are generally considered.

- 1) The need of a hypothetical medium named 'Ether' to carry light had been proposed and this concept had been being widely accepted and running almost contemporarily with Maxwell's discovery of undulatory nature of light as electromagnetic wave.
- 2) Fizeau's experiment with light's speed through moving water yielded result which could not be explained completely with the help of the then existing theories. Lorentz and Fitzerald came together in the rescue of the result and another hypothetical property had been associated with Ether and was attributed to a moving state contraction.
- 3) Then came Michelson and Morley with their famous experiment whilst observation on Stellar-light aberration was explained a-prior with no ether-drag as such with the Earth's motion. Michelson and Morley repeated their experiment several times over a long period of time with their interferometric setup having enhanced precession and came ultimately to the conclusion that Ether , if it does exist at all must have to be dragged with the Earth's motion.

Therefore it was finally a combination of Aberration and M-M experiment which inferred with utter contradiction faceto-face compelled the scientific community to believe in the nonexistence of as such a material medium like Ether that had been being advocated to be incorporated in the theory of light for long time by a group of renowned scientists.

(3) Ultimately the concept of field as 'space spanned by some kind of influence' had been established and well accepted since then. Field ,conceptually too has some typical properties among which the most intriguing is that being somewhat a non-matter continuum around a source which is matter itself ,at least the corresponding attributes are mandatorily associated with matter and similarly being intrinsically non-inertial can impart momentum to inertial mass while disturbed or rather undulated.

4) As the main objective of this article is with some points in the usual way of theoretical predetermination regarding the result of M-M experiment on Ether-drag some supposed physical properties of this Ether need being mentioned here. Comparing with sound-wave propagation through air and other such media 'light' was primarily supposed to be such a wave but its carrier was hypothesized to be a material medium with 1) inertial properties 2) all matter-penetrating property of pervasive nature ,3) having some type of correspondence with other physical properties , especially with optical properties and the like and 4) being inherently homogenous and isotropic in nature it carries light-wave with same speed in all possible directions and due to its inertial properties it obeys the rules of vectors while carrying light.

On the basis of the characteristic properties of 'Ether' mentioned above usually the formulae for lights motion and related phenomena are derived. Here also the necessary formulae are obtained on the ground of similar consideration but with a bit difference as are given below; (demonstrating figures are also provided below)

1)With no-drag condition the equations are,

$$cT - vT = D = cT' + vT'$$
 .....(1)  
{along the direction of  $v$ }

The total time of travel moving forward and return back along the original path of incidence of light and the direction with v the instantaneous velocity of earth in its orbit is then given by

{along the direction-support of v }

And along the perpendicular direction the similar equations are

$$T_1 = \frac{D}{c} = T_1^{'}$$
 .....(3)

{along the direction perpendicular to v }

and the total time of travel of light wave moving forward and return back along this direction is given by

Then the difference in total time of travel of light wave along these two mutually perpendicular paths (one along the direction of original incidence of light and return back and the other along its perpendicular,forward and return back) becomes, (4)

When the position of the mirrors gets a rotational shift of  $90^{\circ}$  the same time-difference is

obtained but with a negative sign ; 
$$\Delta \tau' = -\left\{\frac{2D}{c}\right\} \left[\frac{\left\{\frac{t^2}{c^2}\right\}}{\left(1-\frac{v^2}{c^2}\right)}\right]$$

Then the net shift of time-

difference becomes 
$$\delta \tau = \Delta \tau - \Delta \tau' = \{\frac{4D}{c}\} [\frac{\{\frac{b^2}{c^2}\}}{(1-\frac{b^2}{c^2})}]$$

As the Earth's orbital motion 'v' is approximately  $3X10^6$  cm./sec the  $(\frac{v}{c})$  ratio has a magnitude of about  $10^{-4}$  and hence the time-shift should have been approximately  $\delta \tau = \{\frac{4D}{c}\}(\frac{v^2}{c^2})$  and the corresponding fringe-shift will be about  $\{\frac{\Delta S}{S}\} = v\{\frac{4D}{c}\}(\frac{v^2}{c^2})$  ...(6)

For visible light  $(\frac{v}{c})$  is approximately  $2X10^4$  /cm and  $(\frac{v^2}{c^2})$  is approximately  $10^{-8}$  and *D* being considered to be as long as 10 meters then  $\frac{\Delta S}{S} = 0.8$ 

There are some specific points behind the above derivation for the total time of light's travel here which differs from the usual derivation that are given in all books on the theory of relativity.

In all books it is considered that with the passage of the apparatus-set in a particular direction the ray , reflected from the semitransparent reflector and deviated at  $90^{\circ}$  from the direction of its incidence its direction of propagation spontaneously changes or need being changed to get reflected from the perfect mirror( $M_2$ ) and similarly travel backward so as to meet the same point on the semitransparent mirror where it was originally incident. But this very assumption need not necessarily be incorporated into the derivation. As we consider a no- drag condition the ray cannot be dragged along with hypothesized Ether and even the Ether itself is not being dragged too. Even if we consider the wave-surface to reach the particular point of meeting for the interference to occur then a component of the light's velocity vector has to be considered because the point on the wave-surface where the light started moving (5)is then different from the point on the same wave-surface meeting the original point of its emanation. Moreover for

interference to occur it is not necessary that the divided rays (waves) meet at the same point as their emanation but just the meeting of the same two components of a single original wave. Hence the divided component may meet ultimately anywhere on the straight line along the direction of light's original incidence. Fig.1 to Fig.8 describe this scenario very well.





The plane of the perfect mirror  $M_2$  is parallel to the direction of motion of the apparatus-set. So if one just calculates the least amount of dimension of the mirror  $M_2$  needed to reflect light from itself and then to meet on the semitransparent mirror with its undeviated component reflected back from another perfect mirror  $M_1$  he gets the following;

$$T_1 = \frac{D}{c} \approx (\frac{10}{3}) X 10^{-8}$$
 secs.

The Earth's instantaneous orbital velocity is about  $3X10^6$  cms./sec.

Hence  $1 \approx vT = 0.1$ cm. The actual dimension of the mirrors used in MM experiment was much greater than 0.1cm. and even than  $\sqrt{2}$  cm. and therefore enough for the S-T mirror to come straight and light wave to get reflected back straight from mirror  $M_2$ . The only problem will be to observe interference the telescope has to be set in a position properly on the basis of this calculation and not straight over the original point of splitting of the original incident light on the semitransparent (S-T) mirror[Fig.9]. Hence what had been observed in this very experiment by different groups of experimenters might have been the fringe-shift in diffracted images of the real fringes.



No two curve lines can be parallel and so do curved planes too. Hence tangent to the part of the reflected wave surface that meet the other part's reflected wave surface in the direction of original incidence at the point of their splitting on semitransparent reflector(STR) is not exactly parallel to that to the wave surface that could have been directly sourced out from the point of reflection at mirror M<sub>2</sub> along the hypotenuse as usually thought to be. Now comes the question of geometry of wave surfaces because the time for waves travel to (7) yield interference-fringe would depend on that. Let us simply assume that the shape of wave surfaces are spherical and do not change in both nature and magnitude (i,e. the radius of curvature) with time and passage through Ether. Then where and when the transverse reflected wave (i,e. the reflected wave part after getting reflected at mirror M<sub>2</sub> at right angle to the original direction of light incidence) meet the reflected wave of the transmitted component along the line of original incidence will depend on the inequality

$$R_r \gtrless vT_1$$

For example if  $R_r > vT_1$  then  $cT_1 = D + \lambda$  [< $R_r$ ] Again if  $R_r = vT_1$  then  $cT_1 = D + R_r$  and when  $R_r < vT_1$ ,  $cT_1 = D - \lambda$ .

Hence we see that '  $T_1'$  differ in three cases and so does  $\tau$  too.

On the contrary if one considers the wave surface with same radius of curvature to be emanated from mirror  $M_2$  after reflection from it directed towards the hypotenuse that would be after time  $T_1$  from that then one gets

,2

$$cT_{1}^{'} = \sqrt{D^{2} + v^{2}T_{1}}$$
  
 $T_{1}^{'} = rac{D}{\sqrt{c^{2} - v^{2}}}$  .



Hence we see that  $T_1'$  does not depend on the abovementioned inequality and it appears the same as mentioned in books. But then  $T_1$  will not be equal to  $T_1'$  because the direction of wave surface propagation before reflection at mirror  $M_2$  will not be the same as that after reflection there. Law of reflection is to be obeyed everywhere and so also at the point of first incidence on STR the reflected component of the originally incident wave then will have to be directed towards the normal to the original line of incidence. Hence its path would not follow the then hypotenuse but straight to the perpendicular[Fig.10]. As a consequence  $T_1 \neq T_1'$ .

2) With an Ether-drag the derivation will be as follows;

For the wave along the line of original incidence

$$T(c+v) = D + vT , \qquad (8)$$

or,  $T = \frac{D}{c}$ .

On the return path T'(c-v) = D-vT' or,  $T' = \frac{D}{c} = T$ 

Total time of travel then becomes  $\tau = \frac{2D}{c}$ 

In the perpendicular direction then , both on forward and return path the same time of travel will be  $T_1 = T_1^{'} = \frac{D}{\sqrt{c^2 - v^2}}$  and thus the total time of travel in this direction will then be  $\tau^{'} = \frac{2D}{\sqrt{c^2 - v^2}}$ . The net difference in total travel-time will be given by

$$\Delta \tau = \tau - \tau = \left\{\frac{2D}{c}\right\} \left[\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}\right] \approx \left\{\frac{2D}{c}\right\} \left[1 + \frac{1}{2}\left(\frac{v^2}{c^2}\right) - 1\right] = 0$$

 $\left(\frac{D}{c}\right)\left(\frac{v^2}{c^2}\right)$ . Now when the whole set up is rotated through 90° the time-difference will then be  $\Delta \tau' = -\left(\frac{D}{c}\right)\left(\frac{v^2}{c^2}\right)$  and consequently the net shift of time-difference will then be  $\delta \tau = \left(\frac{2D}{c}\right)\left(\frac{v^2}{c^2}\right)$ .

The corresponding fringe-shift will be just half the value as obtained in no-drag case i,e. 0.4 for  $D \approx 10 \text{ m}$ . In this dragcase the line of propagation of reflected wave from S-T mirror in this perpendicular direction will swing like a rigid

#### Volume 12 Issue 6, June 2023

<u>www.ijsr.net</u>

Licensed Under Creative Commons Attribution CC BY

and

pendulum rod by the sweeping of the Ether medium (for drag-case) [Fig. 11].



Therefore it is being established here that even if we consider the Ether-drag the light- wave fringe-shift should have been produced instead of yielding a null result and thus contradict the observation in Michelson and Morley experiment.

An application to the case of a problem: A problem in the exercise section on the transformation in Michelson-Morley apparatus from P.G.Bergmann's book 'Introduction to the theory of relativity' reads as follows;

"Assuming that the Galilean transformation equations are applicable, derive the (9) rigorous expression for the time that a light ray needs to travel a measured distance l in both directions along a straight path in a Michelson-Morley apparatus, provided that the velocity of the apparatus relative to the privileged system is v and that the angle between the path and the direction of v is  $\alpha$ ."

# Solution in the conventional way as Bergmann's book follows;

Referred to Fig.(12) below the involved equations are given below;



$$(ct_1)^2 = (l + v \cos \alpha t_1)^2 + (v \sin \alpha t_1)^2$$

Or, 
$$t_1 = \frac{2lv\cos\alpha \pm \sqrt{4v^2 l^2 \cos^2\alpha + 4(c^2 - v^2)l^2}}{2(c^2 - v^2)}$$
 (6)

[Time for forward motion]

$$(ct_2)^2 = (l - v \cos \alpha t_2)^2 + (v \sin \alpha t_2)^2$$

Or,  $t_2 = \frac{-2lv\cos\alpha \pm \sqrt{4v^2 l^2 \cos^2\alpha + 4(c^2 - v^2)l^2}}{2(c^2 - v^2)}$  .....(7)

[Time for backward motion]

As the absolute value of time cannot be negative the total time taken by light ray to go forward and return back along the straight path will be given by addition of eq.(6) and Eq.(7);

$$t = t_1 + t_2 = \frac{\sqrt{4l^2 v^2 \cos^2 \alpha + 4(c^2 - v^2)l^2}}{(c^2 - v^2)} = \frac{2l\sqrt{1 - (\frac{v\sin\alpha}{c})^2}}{c(1 - (\frac{v}{c})^2)}$$
(8)

This is the solution obtained in the conventional way that is followed by everybody in general including Bergmann himself. Here if we put  $\alpha = 0^{c}$  then  $t = \frac{2l/c}{(1-(\frac{v}{c})^{2})^{2}}$  and if put  $\alpha = (\frac{\pi}{2})^{c}$  then  $t' = \frac{2l/c}{\sqrt{(1-(\frac{v}{c})^{2})^{2}}}$ . These are the results in

no-drag consideration for MM Experiment in straight along incident direction and perpendicular direction.

#### Solution in the nonconventional way as is newly proposed in this article:

Along the initial straight path the light wave takes a time  $t_1$  for which one can write,

 $l + v \cos \alpha \ t_1 = c \ t_1$  or  $t_1 = \frac{l}{c - v \cos \alpha}$  .....(9) and similarly

$$l - v \cos \alpha \ t_2 = c \ t_2$$
 or  $t_2 = \frac{l}{c + v \cos \alpha}$  .....(10)

Total time taken by the ray of light wave to travel forward and return back will then be (10)

given by 
$$t = t_1 + t_2 = \frac{(2l/c)}{(1 - (\frac{v \cos a}{c})^2)}$$
 .....(11)

For a comparison if we put  $\alpha = 0^c$  then  $t = \frac{\binom{2l}{c}}{(1 - \frac{v^2}{c^2})}$  for  $\alpha = (\frac{\pi}{2})^c$   $t = \frac{2l}{c}$  exactly the same result as in eqns. (3) and (4).

# 2. Discussion

In a detailed discussion between two ancient Indian sages on birds' flying long long ago the gist of the conclusion they conjointly reached was like this; If the Earth's atmosphere would not have been rotating along with the rotating Earth the birds in general that flew especially East in the morning in search of food could not return to their nests after the day break.

But the concept of Ether differs in this perspective. Atmosphere in general is excess fluid- surroundings of any naturally existing rigid body which evolved before the solidification of the body itself and remain associated with or rather clung to the respective bodies depending on their own gravitation and radiative transfer of heat with consequent temperature. But Ether, if it does exist at all, as its typical physical properties were postulated, was thought to be an all-pervading universal subtlest medium that could carry electromagnetic wave and energy the exact time of evolution of which could not be inferred.

# Volume 12 Issue 6, June 2023 www.ijsr.net

### Licensed Under Creative Commons Attribution CC BY

It exists everywhere and eternally which all matters and energies are moving through. And even it does not associate itself anyway with anybody or material entity and the like, only help pass through. However the most significant point worth-mentioning here is that the derivation of total traveltime in two mutually perpendicular directions differs from its conventional way and so does the corresponding result i,e. the delay-interval translated to the corresponding fringewidth except only the net delay-time interval for non-drag case. The last quantity mentioned above is the very same as is in conventional way of derivation.

# 3. Conclusion

Implications are many seemingly the most significant of which are as follows:

- 1) Experimental null-result does not match with the theoretically expected result as the theoretically calculated delay time is never zero in both the cases, drag or no drag.
- 2) This fact directly indicates that either there is no inertial medium like Ether as had been proposed or Ether has to have too much nontrivial enigmatic physical properties to cope with the other well established theories and observations. If it does not exist at all then it is clear from this article's consideration that M-M Experiment single handedly (11) establishes it and that without considering the result of aberration with this.
- 3) Thirdly if we ignore the existence of inertial medium like Ether and at the same time consider Maxwell's discovery of light being an electromagnetic wave then the wave has to travel through a continuum called 'field' (space spanned by some kind of influence). Then the wave is a kind of field-wave and this very concept of field is somewhat abstract.
- 4) While the subtlest material medium 'Ether' has been replaced by non-matter continuum called 'Field' it too has to have a few specific physical properties. The most fundamental two such properties are presumably as follows:
  - a) A field being continuum yet measurable needs to be discrete at the same time.
  - b) This field, inspite of being a non-matter entity can and do influence material entity and has inertia (dynamical state-sustainer).

# References

- [1] TREATISE ON LIGHT by CHRISTIAAN HUYGENS, rendered into English by SILVANUS P. THOMPSON, MACMILLAN AND CO. LIMITED, ST.MARTIN STREET, LONDON, MCMXII, 1690
- [2] On Faraday's Lines of Force by J.C.Maxwell, Cambridge Philosophical Transactions, Vol.X ,Part-1, Feb. 1856
- [3] XXV.On Physical Lines of Force; {Part I}: The Theory of Molecular Vortices Applied to Magnetic Phenomena, by J.C.Maxwell ,Philosophical Magazine and Journal of Science, [Fourth Series],March,1861, TheLondon, Edinburgh and Dublin.
- [4] XLIV.On Physical Lines of Force;{Part II}: The Theory of Molecular Vortices Applied to Electric Current, by J.C.Maxwell,Philosophical Magazine and

Journal of Science, [Fourth Series], March, 1861, The London, Edinburgh and Dublin.

- [5] XLIII.On Physical Lines of Force;{Part III}: The Theory of Molecular Vortices Applied to Statical Electricity, by J.C.Maxwell ,Philosophical Magazine and Journal of Science, [Fourth Series],April-May,1861, TheLondon,Edinburgh and Dublin.
- [6] XIV.On Physical Lines of Force; {Part IV}: The Theory of Molecular Vortices Applied to Action on Polarized Light, by J.C.Maxwell, Philosophical Magazine and Journal of Science, [Fourth Series], May, 1861, TheLondon, Edinburgh and Dublin.
- [7] On the Effect of a body upon the velocity with which it is traversed by the light by H.Fizeau ,Philosophical Magazine, 4<sup>th</sup> Series ,19, 245-260 (1860)
- [8] ART.XXXVI.-On the Relative Motion of the Earth and the Luminiferous Ether; by Albert A. Michelson and Edward W. Morley ,The American Journal of Science [Third Series]No.203 Novenber,1887
- [9] Electromagnetic Phenomena in a System Moving with any Velocity Smaller Than That of Light by Lorentz (1904), Koninklijke Akademie van Wetenschappen te Amsterdam, section of sciences, Proceedings 6, (1903-04),809-831
- [10] Introduction to Special Relativity by Robert Resnick ,wiley eastern Limited, New Delhi, Bangalore,Bombay, Calcutta,(First US Edition 1968 ,John Wiley and Sons Inc.,New York).
- [11] Direct Optical Measurement of the Velocity at the Axis in the Apparatus of Fizeau's Experiment by Zeeman, Proceedings 19 ,(1917) pp. 125-132
- [12] Introduction to the Theory of Relativity by Peter Gabriel Bergmann, EEE, Prentice Hall of India Pvt. Ltd., New Delhi110001, 1967