Michelson - Morley Experiment :-

→ **Concept of ether** - In nineteenth century, Physicists thought that electromagnetic wave also required a medium through which they could propagate. The medium is called Ether. it was assumed that, this medium present everywhere, even in free space. The ether have unusual properties That it is mass less but rigid medium

The Experiment performed in 1887 by A.A. Michelson and E.W. Morley given negative result. which contradict the ether hypothesis.

→ **Negative result of Michelson-Morley Experiment :-**

1- Michelson-Morley experiment discards the idea of any privileged frame of of reference or ether.

2- The speed of light in vacuum should be the same (c) in all the inertial frame. It does not depend upon the motion of the observer or the Source.

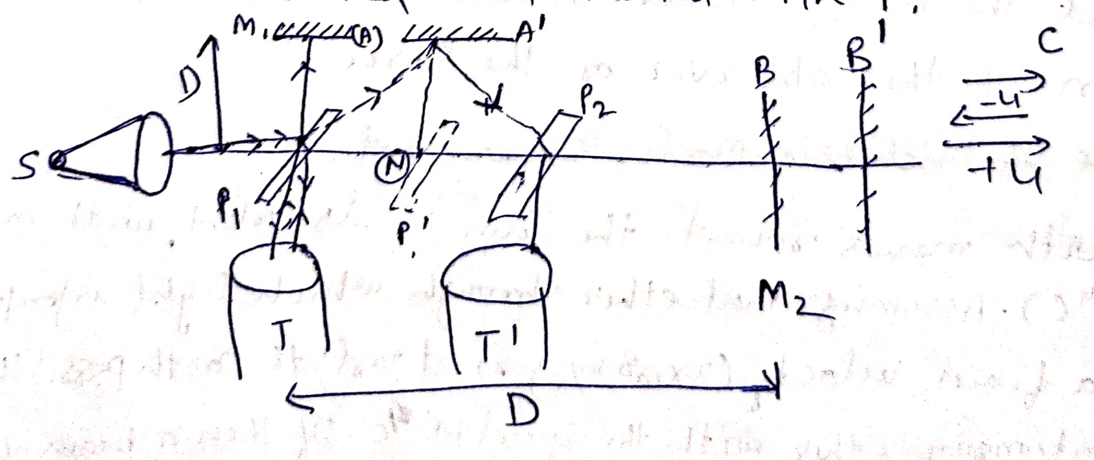
→ **Purpose of Michelson-Morley Experiment :-**

The Earth moves round the sun in its orbit, with 30 km/sec ($\simeq 10^{-4}c$). Assuming that ether through which light is propagated with a fixed velocity (3×10^8 m/s) is at rest, the earth passes through This stationary ether with the speed $10^{-4}c$. If then a beam of light is sent from a source to an observer on the earth in the same direction as the earth's Motion, it should take more time to complete the Journey than if sent in the opposite direction, since the observer is moving away from the advancing light wave when later is in the same direction, as the earth's motion, whereas observer is moving towards the advancing wave in the reverse direction.

The purpose of the experiment was to measure this time difference from which the velocity of the earth relative to the ether frame can be calculated.

Experimental Setup -

The apparatus consists of a michelson's interferometer in which a beam of light from a monochromatic source falls on a Semi silvered plate P placed at 45° to the beam and is partly reflected and partly transmitted. The plate is semisilvered on the back surface, so that half of intensity is reflected back and half is transmitted. The reflected portion travel in a direction at right angles to the incident beam and falls normal at A on the plane mirror M_1 and is reflected back to P_1.
The transmitted ray travelling along the incident ray, fall normally at "B" on the plane mirror M_2 and is reflected back towards the telescope T, so that an interference pattern can be observed and studied with "T".



The ray coming from the Source S and entering into the Telescope T after being reflected from the mirror M_1 traverse the plate "p" Three times, while that reflected from M_2 traverse

Through it only once. Hence the optical path of two interfering rays are not equal. They are made the same by placing a compensating plate of the same thickness and material as P_1 between P_2 and M_2.

The distance between mirror M_1 and M_2 from plate(P_1) kept same, say D here. If the whole apparatus were at rest in ether, the two rays would take the same time to return to P_1. But since the experiment was performed on earth and earth is rotating from west to east, so in actual experiment the whole apparatus is moving with earth. Let us assume that the direction for motion of the earth coincides with the direction of the incident beam of light.

The time of travel for the two journey in the L-frame

1- Lateral or transverse Journey P_1A, AP_2 :- That is journey perpendicular to the direction of earth's motion.

2. Longitudinal Journey P_1B, BP_2 :- That is journey along the direction of earth's motion will no longer be equal.

The difference between these times can be calculated as follow

→ Time taken to cover distance D from P_1 to B

$$t_1 = \frac{D}{c-u} \quad \text{— (A)}$$

and on the return journey from B to P_1, the relative velocity of light is $c+u$, so time taken is

$$t_2 = \frac{D}{c+u} \quad \text{— (B)}$$

Total time $$t = t_1 + t_2 = \frac{D}{c-u} + \frac{D}{c+u} = \frac{2cD}{c^2-u^2} = \frac{2D/c}{\left(1-\frac{u^2}{c^2}\right)} \quad \text{— (1)}$$

→ Now the time taken to cover the distance D. from P_1 to A and return will be same and since as

$$t_1' = \frac{D}{\sqrt{c^2-u^2}} \quad \text{and} \quad t_2' = \frac{D}{\sqrt{c^2-u^2}}$$

so $t_1' = t_2'$

Total time $t' = 2t_1' = \frac{2D}{\sqrt{c^2-u^2}} = \frac{2D/c}{\sqrt{1-u^2/c^2}}$ — (2)

– As $t' < t$

Thus the time difference between the time of the longitudinal and transverse ray is

$$\Delta t = t - t' = \frac{2D/c}{1-\frac{u^2}{c^2}} - \frac{2D/c}{\left(1-\frac{u^2}{c^2}\right)^{1/2}}$$

$$= \frac{2D}{c}\left[\left(1-\frac{u^2}{c^2}\right)^{-1} - \left(1-\frac{u^2}{c^2}\right)^{-1/2}\right]$$

$$= \frac{2D}{c}\left[\left(1+\frac{u^2}{c^2}\right) - \left(1+\frac{1}{2}\frac{u^2}{c^2}\right)\right]$$

[Expanding binomial and neglecting higher term, $u \ll c$.]

$$\boxed{\Delta t = \frac{2D}{c}\left[\frac{u^2}{2c^2}\right] = \frac{Du^2}{c^3}} \quad \text{— (3)}$$

→ Distance covered by light in time $\Delta t = \Delta t \times c = \frac{Du^2}{c^2}$.

So the optical path P_1B is longer by $\frac{Du^2}{c^2}$ than the optical path P_1A and so this is the path difference introduced between the two parts of the incident beam reflected from mirrors M_1 and M_2 respectively due to motion of the apparatus.

Unit - 05

Special theory of Relativity →

The two fundamental postulates of special theory of relativity are given below -

① All the laws of physics have the same form in all inertial systems moving with constant velocity to one - another.

② The speed of light in vaccum is constant in every inertial system.

[The Ist pastulate is the Galilian hypothesis of invariance or Newtonion principle of relativity. while the 2nd postulate is an experimental fact]