

Que:- Describe Michelson-Morley experiment and explain the significance of negative result.

Ans:- The experiment was performed by Michelson and Morley to determine the relative velocity of light with respect to earth.

Experimental Arrangement:-

Let us suppose that a beam of light from a monochromatic source S falls upon a semi-silvered glass plate P placed at 45° to the beam and is partly reflected and partly transmitted. The reflected portion travels in a direction at right angles to that of initial beam falls normally at B on a mirror M_1 by which it is reflected back to P . The transmitted portion travels along the direction of the initial beam falls normally at A on another mirror M_2 and is reflected back to P . The two rays thus returned to P interfere on their final journey towards the telescope T , so that an interference pattern can be observed and studied with T . If this arrangement were at rest in either the

two rays would take the same time to return to P. But in the actual experiment the whole apparatus is moving with earth.

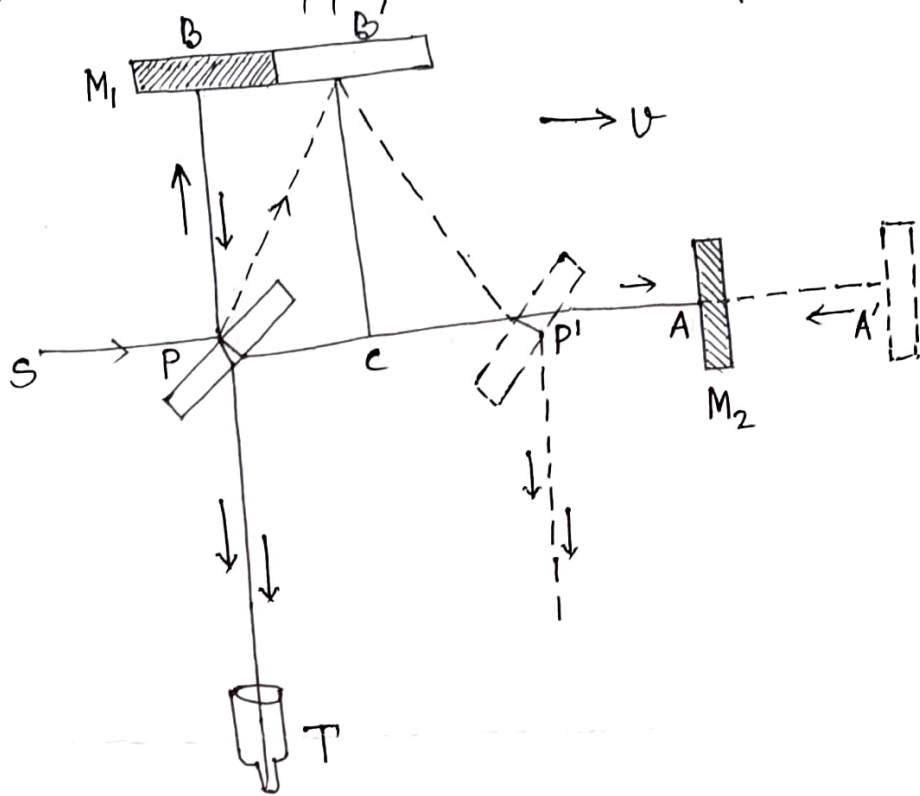


Fig: Michelson-Morley apparatus

Let us suppose the motion of direction of motion of earth coincides with the direction of the initial beam. Thus the path of the two rays and the time taken on their journey will no longer be equal.

Let c be the velocity of light, v be the velocity of the earth. Let $PA = PB = d$, The ray reflected from P and moving transversely will strike

the mirror M_1 not at B but at B' due to the motion of the earth. If t be the time taken by the ray starting from P to reach M_1 then

$$PB' = ct,$$

$$BB' = vt$$

The total path of the rays until it comes back to the plate is evidently $P, B'P', PP'$ being equal to $2PC = 2BB'$

$$\begin{aligned} \text{Also } PB'P' &= PB' + B'P' \\ &= 2PB', \text{ since } B'P = B'P' \end{aligned}$$

$$(PB')^2 = PC^2 + (CB')^2$$

$$\text{i.e. } c^2 t^2 = v^2 t^2 + d^2 \quad \text{since } CB' = PC$$

$$\therefore t = \frac{d}{[c^2 - v^2]^{1/2}}$$

If t_1 is the total time taken by the ray to travel the whole path $PB'P'$ then

$$\begin{aligned} t_1 &= 2t = \frac{2d}{[c^2 - v^2]^{1/2}} \\ &= \frac{2d}{c} \left(1 + \frac{v^2}{2c^2}\right) \end{aligned}$$

The ray transmitted through P and moving longitudinally towards M_2 has a velocity $(c-v)$ relative to the apparatus from P to A and $(c+v)$ on the return journey from

from A' to P' , assuming the other to be at rest. If t_2 is the total time taken by this ray get back to the plate.

$$t_2 = \frac{d}{c-v} + \frac{d}{c+v}, \text{ since } PA = P'A' = d$$

$$\therefore t_2 = \frac{2cd}{c^2 - v^2} = \frac{2d}{c} \left(1 + \frac{v^2}{c^2}\right)$$

Hence the difference between the time to travel of the longitudinal and transverse ray is

$$t_2 - t_1 = \frac{2d}{c} \cdot \frac{v^2}{2c^2}$$

and the effective optical path difference between the two rays is

$$\delta = \frac{c(t_2 - t_1)}{\lambda} = \frac{dv^2}{c^2\lambda} \text{ wave lengths.}$$

λ being the wavelength of the light used. The interference pattern would accordingly be shifted by the motion through $dv^2/c^2\lambda$ fringes.

If the whole apparatus is turned through 90° the difference in path will be in the opposite directions and consequently the effect will be doubled and displacement of fringes equal to $\frac{2dv^2}{c^2\lambda}$ will occur.

The experiment was repeated with multiple mirrors to increase the distance d but the result remains unchanged.