# Detection of Luminiferous Ether by Michelson-Morley Experiment

PHY 102 Project Report
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**Abstract**

*This experiment is the recreation of Michelson-Morley Experiment, 1887 [1]. In this experiment, by using lasers, mirrors, and beam splitter, an interference pattern was observed that remained constant when the direction of the experimental setup was changed. The result disproved the existence of ether and also validated the postulate of the theory of relativity that one can not measure the speed of itself.*

# Contents

# 1 Objectives

The aim of the Michelson-Morley experiment is to detect the hypothetical ether relative to which light waves travel at a constant speed. The present paper aims to answer the question of existence of ether experimentally.

# 2 Introduction

During the 19th century, it was believed that just like a normal wave requires a medium to propagate the energy, for example, in water when the molecules vibrate while transferring the energy, light ways also must need a medium to travel through [2]. It was assumed that since light can travel through vacuum as well, the medium must exist in the vacuum as well and in every space around. This medium was considered to be ether which was friction-less.
The hypothesises considered at that time were that either the ether is stationary and is partially dragged by Earth or the ether is completely dragged by Earth. According to the first hypothesis, Earth and ether are in relative motion so an "ether wind" should exist. Due to the direction and the speed of the motion, Earth can not always be in rest with respect to the motion of the ether. So, through an experiment the aim was to test the relative speed of light with respect to Earth at different directions and times of the day.

# 3 Mathematical Background

The wave theory of light explained nearly all observed phenomenon of light observed so far in the early 19th century using a wave equation:

$$\ddot{u} - c^2\nabla^2 u(\vec{r}, t) = s(\vec{r}, t)$$

Where $s(\vec{r}, t)$ is the source function which is property of the medium at different points and $u(\vec{r}, t)$ denotes the amplitude function for the light wave [3]. The only weakness in the theory (apart from light quantization which was unknown yet) was that it gave different results when seen from the point of view of moving observers. To save the situation one has to allow the possibility of length contraction for moving frames along the axis of motion.

Consider two perpendicular beams which bounce back to interfere at the original point. An observer moving along one of the arms with a speed $v$ must agree that both beams travelled the same path length so, let $l$ and $l'$ be the original and observed length of the arms,

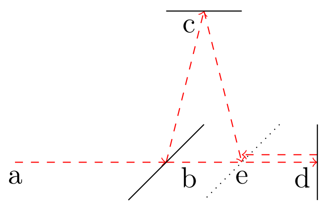



Figure 1: Two paths highlighted $a, b, c, e$ and $a, d, e$ when the apparatus moves.

Assuming there is no ether,

$$\text{length of path 1} = \text{length of path 2}$$

$$\frac{2l}{\sqrt{1-v^2/c^2}} = \frac{l'}{c+v} + \frac{l'}{c-v}$$

$$l' = l\sqrt{1-v^2/c^2}$$

Thus, moving rods must contract by a factor $\gamma = \sqrt{1-v^2/c^2}$, if there is no preferred frame of reference. On the other hand, if the observers disagreed about the interference then the speed of light is not absolute and thus, ether is confirmed for it is a preferred frame.

# 4 Setup

To detect ether with Michelson-Morley experiment, we split a beam into two perpendicular components via a beam splitter, and then interfere them by converging them to the original point with the help of two mirrors. The interference pattern thus formed is then observed on a screen.

Figure 2: Experimental Setup for Michelson-Morley Interferometry

In our setup, we adjusted the perpendicular arms to 51cm and 57cm at 81° angle, while the screen was placed 6 meters apart from the beam-splitter.

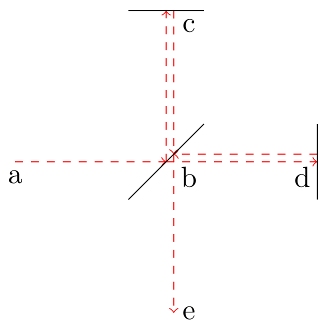



Figure 3: An illustration of Michelson-Morley interferometry via ray diagram. The two paths that start from source $a$ to interfere at screen $e$ are represented as $a, b, c, e$ and $a, d, b, e$.

## 5 Experiment Procedure

The procedure for the experiment is as follows:

1. Place a beam splitter in-front of a monochromatic and coherent laser source to split its beam into two perpendicular components.

2. The component of the beam that transmits the beam splitter is then reflected 180 degrees via a mirror. Thus, the transmitted beam comes back to the beam splitter where it is partially reflected on a screen. Thus, the net effect is a bright spot on the screen that had undergone a partial transmission first and then a partial reflection on the beam splitter.

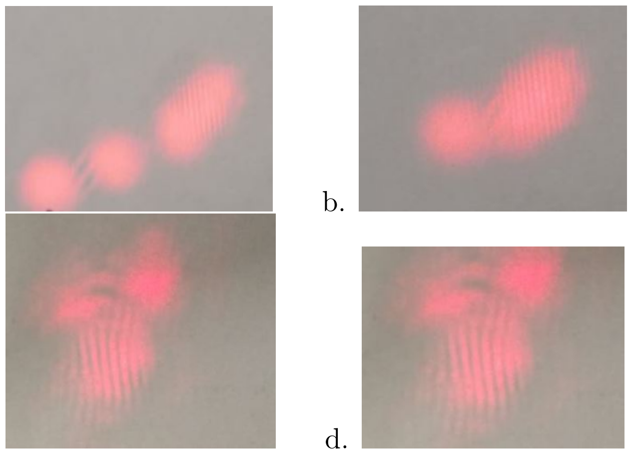
3. The other component of the beam that was partially reflected from the splitter is also

bounced back using a mirror where this time it partially transmits through the splitter to interfere with the former spot on the screen. The interference gives us a pattern in the form of fringes which could be curly or slanted depending on the smoothness and obliqueness of the mirrors and splitter.

4. The interference pattern thus formed is observed via a camera fixed with the apparatus on different times of a day, or a year, to check for a change in the position of fringes. Alternately, the entire apparatus can be placed on a floor floating on a water surface where it is rotated gently to check for a change in the interference pattern.

## 6 Results

Our observations for the experiment is summarized as follows:



a. b. c. d.

Figure 4: Interference pattern captured on the screen. (a) 27-4-2022 at 1:00pm. (b). 27-4-2022 at 3:00pm. (c) 28-4-2022 at 1:00pm. (d) 28-4-2022 at 3:00pm.

As the Earth rotates at 450m/s at the latitude of our apparatus, the change in the velocity of the apparatus between 1:00pm to 3:00pm is given by cosine law of vector addition,

$$\triangle v = v\sqrt{2(1-\cos(\theta))} \approx 232.94\text{m/s}$$

Thus, the data say about the observations when the change in the velocity of apparatus is incurred by 232.94m/s approximately to detect ether.

# 7 Conclusion

In conclusion, the first iteration did not support our theory most probably due to apparatus used was extremely sensitive to outside influences such as air. The second iteration yielded relatively better data in favour of the theory. The biggest source of error was identified to be the lack of rigidness of the apparatus and air pressure. The iron stands and clamps that we used were too sensitive especially for large distances, as we observed the pattern was vibrating.

# 8 Discussion and Future Work

The setup used was prone to very slight air pressure and as a result, the interference patterns were disturbed on first day. So, for future improvements we propose a more rigid apparatus. We also propose more polished surfaces for the reflections and the beams be confined inside a vacuum so that air pressure is eliminated entirely. For recording data of the pattern, we were taking picture manually using a camera while a better way would have been to fix a camera with the apparatus to easily compare the difference. Also, if the observations were taken in the lapse of 12 hours, the corresponding change in the velocity of the apparatus would have been 900m/s approximately which gives more confidence about ether's absence.

## References


[1] A. A. Michelson and E. Morley, “On the relative motion of the earth and the luminiferous ether,” 1887.

[2] C. Huygens, “Treatise on light,” 1678.

[3] H. von Helmholtz, “Treatise on physiological optics,” 1910.