The Michelson-Morley Experiment: An Experimental Overview

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Introduction

The notable history of the Michelson-Morley experiment of 1887 illustrates the notion that, in science, a null result can nevertheless be a significant one. Until the late 19th century, many physicists wholeheartedly believed in the existence of an invisible, massless medium through which light waves propagated. This mysterious medium was referred to as the *luminiferous aether* (or "ether"). The first scientists to carry out successful experiments regarding the so-called ether were Albert A. Michelson and Edward W. Morley, using an instrument called an *interferometer* to measure the properties of light [1]. The significance of their results not only shocked many scientists around the world, but it earned Michelson the Nobel Prize in Physics in 1907, the first of such an award to be given to an American [2]. The purpose of this essay is to summarize the mechanics and significance of the Michelson-Morley experiment of 1887.

Background

Physicists of the 18th and 19th centuries were aware that a medium was needed in the propagation of *mechanical waves* (such as seismic or sound waves), and they assumed that a medium of an analogous sort was required for the propagation of light waves [1]. In pursuit of evidence of the ether, it was believed that an experiment could be designed to measure Earth's velocity through the ether. The idea was that the relative velocity between the ether and the Earth's frame of reference could be calculated.

One proposed idea was to experimentally measure the upstream-downstream time for the propagation of a light wave (i.e., the velocity of a light wave moving parallel to Earth's rotation), and to compare the result to the cross-stream time for the propagation of a light wave (i.e., the velocity of a light wave moving perpendicular to Earth's rotation) [1]. Figure 1 illustrates this proposed motion of the ether.

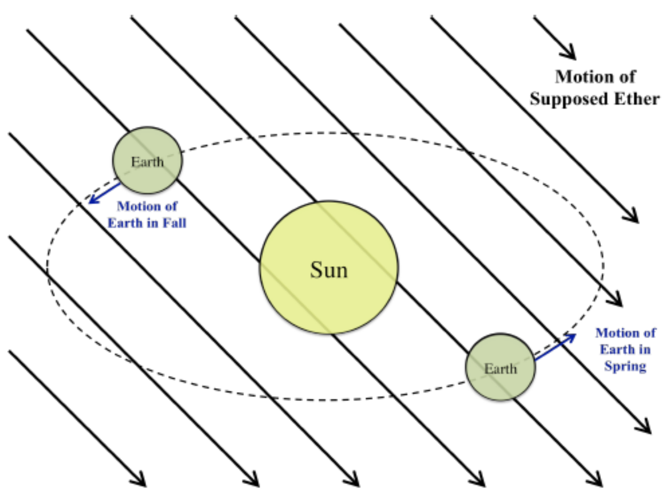

Figure 1: Illustration of the motion of the ether with respect to Earth's motion.

Experimental Setup

The experimental setup of the instrument Michelson conceived, called an interferometer, begins with a light source that travels to a beam-splitting mirror which splits the light into two beams, one parallel to the original direction and one perpendicular to the original direction. Upon being reflected by secondary mirrors, the two split beams travel back to the mirror and recombine, causing observable "fringe" patterns depending on the distance that each individual light beam travels. Bright bands correspond to two wavelength maxima adding together (constructive interference), whereas dark bands correspond to a cancellation effect (destructive interference). Figures 2 and 3 illustrate the basic design of the original Michelson-Morley experiment.

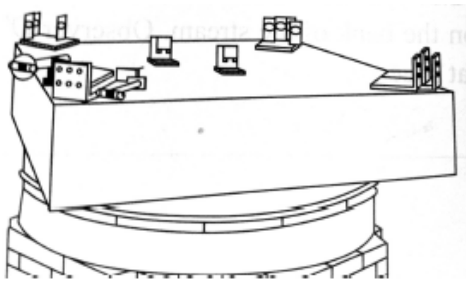

Figure 2: Sketch of the experiment.

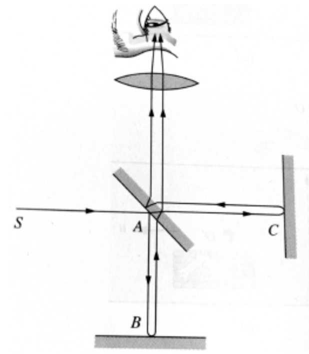

Figure 3: Schematic diagram of the interferometer.

In Figure 3 (a birds-eye view), light is emitted from a source at point S. At point A, the light is split into two separate beams. One light beam travels to a mirror at point B while the other travels to a mirror at point C. Upon reflection of each light beam back to point A, the light beams recombine to form a single light beam, which enters the observer's view. By keeping the distances AC and AB equal, it was believed that there would be a measurable time difference between the parallel and perpendicular paths of the light waves due to the presence of the ether. Ingeniously, Michelson and Morley decided to rotate the apparatus exactly 90 degrees such that the parallel path before rotation became the perpendicular path after rotation.

They performed the experiment and recorded their results, then repeated the experiment six months later. Michelson and Morley failed to observe the Earth's motion through the postulated ether, a conclusion made from the inexistence of an observable change in the fringe pattern.

Discussion and Conclusion

Michelson and Morley failed to detect any observable motion of the Earth relative to the ether. The upstream-downstream and cross-stream velocities did not add in the way that intuition would suggest, and the result ultimately led to the *disposal of the ether hypothesis*. Despite the null result obtained, the tool the experimentalists designed has become a useful instrument to measure microscopic distances with incredible precision. The negative result also led to other areas of important scientific research, such as the special theory of relativity [1].

The purpose of this essay was to summarize the Michelson-Morley experiment of 1887. American physicists Albert A. Michelson and Edward W. Morley obtained a null result in the measurement of the ether, implying that the ether was totally nonexistent. It was shown that a null result does not equal failure in science; rather, it may in fact lead to revolutionary thinking. The talents and contributions of Michelson and Morley were many. For example, Michelson's work led to some of the most accurate measurements of the speed of light at the time, and in 1920, he used an advanced version of the interferometer to determine the diameter of the well-known star Betelgeuse, with a diameter 1000 times that of the Sun. Michelson's measurement was considered to be the first accurate measurement of the size of a star [2].

References

1. K. Krane, *Modern Physics 3rd Edition*, John Wiley & Sons, Inc., February 2012.
2. "Albert A. Michelson – Biographical", Nobelprize.org, Nobel Media AB 2014, accessed 2017. (http://www.nobelprize.org/nobel_prizes/physics/laureates/1907/michelson-bio.html)