A Reconsideration of

The Michelson-Morley Experiment

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Part 1

Introduction

A reconsideration of the Michelson-Morley experiment shows that the mathematical and conceptual theories that underpin the experiment are flawed. The conceptual and mathematical flaws are serious enough to nullify both the results of the experiment and its conclusions. Any reconsideration of the experiment must take into account that there were at least two definitions of the term *ether* when Albert Michelson and Edward Morley first did their experiment. Many scientists considered ether a hypothetical, invisible substance that pervaded all of space and served as a medium for the transmission of light waves. That definition of ether is used the reconsideration of the experiment in parts 2 and 3 of this paper. Other scientists considered ether a continuous expanse of empty space, extending in all directions, and part 4 of this paper examines the experiment employing that definition. The conclusion, part 5, of the paper summarizes the experiment's shortcomings when either definition is used.

Part 2

The Michelson-Morley Experiment Probes the Luminiferous Ether—the Medium for the Propagation of Light Waves

First performed in 1887, The Michelson-Morley experiment used a complex apparatus to probe the nature of the luminiferous ether. The luminiferous ether is often called the æther or simply the ether. “Ether wind” is a misleading term because the prevailing opinion among scientists in the late 19th century was that the luminiferous ether was stationary under most conditions. These scientists thought the ether wind effect was caused by the motion of the earth through the stationary ether. It is similar to the experience produced by riding a bicycle on a windless day. As the bicycle rider pedals along, he feels as though a wind is blowing on his face. As the speed of the bicyclist increases, the wind increases in its apparent speed.

Another aspect of the Michelson-Morley experiment was that from its results the absolute velocity of the earth could be determined. To accomplish this task, two precise time measurements needed to be made. They are the measurement of the duration of a light beam’s round-trip journey along one arm of the apparatus and the duration of the light beam’s round-trip journey along the other arm of the apparatus. These measurements had to be made when one arm of the apparatus was aligned with the motion of the earth and the other arm was perpendicular to the apparent ether wind.

The centerpiece of the Michelson-Morley experiment is a device called an interferometer; it is a device that divides a light ray into two beams and then brings them together again to cause interference. The recombination of these two beams of light produces interference fringes (bands of more intense color). When these fringes are counted, they give information about the light.

The main part of the apparatus consists of two identical arms fitted together to form a right angle. When one arm is aligned with the motion of the earth, the other arm will be perpendicular to it. Each arm is of equal length. At the arms' vertex a single ray of light is split into two beams by a half-silvered mirror. One beam travels along one arm, and the other beam travels along the other arm. A fully-silvered mirror is at the far end of each arm. Each half of the split light ray strikes its respective mirror and returns along its respective arm, and the two beams rejoin producing interference fringes.

If the earth was moving through ether that was stationary, it was mathematically determined that one light beam would take longer than the other to complete its round-trip journey. This conclusion was decisively drawn, although the arms were of equal length. The round-trip journey, of the light beam traveling in the arm aligned with the motion of the earth, would take longer to complete than the round-trip journey of the light beam traveling in the arm that was perpendicular to the motion of the earth. If the ether surrounding the earth was partially dragged along by the motion of the earth, the overall outcome would still be the same. The only change would be in the size of the difference between the round-trip duration for one arm as compared to the other arm. Albert Michelson and Edward Morley believed each of these possible outcomes could be detected and distinguished by the interferometer. Each outcome would produce a distinct set of slight changes in the interference fringes of the recombining light beams.

The entire apparatus was mounted on a granite slab. Floating in a basin filled with mercury, the granite slab could be rotated. It was hypothesized that the rotation of the apparatus would produce slight changes in the interference fringes. They would occur as the arm of the interferometer perpendicular to the motion of the earth was rotated until it exchanged position with the arm of the interferometer aligned with the motion of the earth.

Early in chapter 2 of L. R. Lieber's book, *The Einstein Theory of Relativity,* the formula t_1 is introduced. It is the formula for the time it takes the light beam to make a round-trip journey in the arm of the apparatus aligned with the motion of the earth. L. R. Lieber writes, "Therefore the time required to travel from A to B would be a/(c - v), where ***a*** represents the distance AB, and the time required for the trip from B to A would be a/(c + v). Consequently, the time for the round trip would be $t_1 = a/(c - v) + a/(c + v)$ or $t_1 = 2ac/(c^2 - v^2)$."[1]

The formula for the time, t_2, it takes the light beam to make a round-trip journey in the arm of the apparatus that is perpendicular to the motion of the earth, is introduced by the author two pages later. L. R. Lieber writes, "So the time for the round trip from A to C and back to A, would be $t_2 = 2a/(c^2 - v^2)^{½}$."[2]

a = the length of the light path, which is the same in both arms of the apparatus.

c = the speed of light.

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[1]Lillian R. Lieber, *The Einstein Theory of Relativity: A Trip to the Fourth Dimension* (New York: Rinehart & Company, Inc., 1936, 1945), p. 9

[2]Ibid., p. 11

v = the velocity of the apparent ether wind.

When the formulas, t_1 and t_2, are mathematically analyzed, it is revealed that t_1 is greater than t_2. Therefore, it takes more time for the light beam in the arm of the apparatus aligned with the motion of the earth to make its round-trip journey than it does for the light beam in the arm of the apparatus that is perpendicular to the motion of the earth. To make this analysis two crucial requirements must be met. The first requirement is that ***a*** represents the same length in both equations. The second requirement, is that both equations contain the term $(c^2 - v^2)$.

These requirements cause difficulties when analyzing the behavior of the light beam in the arm of the apparatus perpendicular to the motion of the earth. In this arm, the apparent ether wind should sweep the light beam downwind. That would make its light path longer than light path ***a***. This is analogous to a swimmer who tries to swim across a river. To make his journey as short as possible, the swimmer will try to follow a line that runs perpendicularly to the shoreline and intersects his starting point. Nevertheless, inevitably, the current will sweep the swimmer downstream, which increases the distance of his journey. He actually ends up swimming along the hypotenuse of a right triangle, instead of one of its legs.

This difficulty is overcome in the formula t_2 by using the term $(c^2 - v^2)^{1/2}$. This insures that the light path in formula t_2 equals the light path in the formula t_1. However, it introduces its own difficulties.

Before we continue any further, an excerpt from pages 11 and 12 of L. Lieber's book will show the confidence she had in the swimmer analogy. She states, "But what has all this [the swimmer analogy] to do with the Michelson-Morley experiment? In that experiment, a ray of light was sent from *A* to *B:* At *B* there was a mirror which reflected the light back to *A*, so that the ray of light makes the round trip from *A* to *B* and back, just as the swimmer did in the problem described above. Now, since the entire apparatus shares the motion of the earth, which is moving through space, supposedly through stationary ether, thus creating an ether wind in the opposite direction, this experiment seems entirely analogous to the problem of the swimmer."[3]

A further examination of the analogy between the light beam and a swimmer will reveal the difficulties with this explanation. The light path ***a*** is

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[3]Ibid.,pp.11-12.

represented by a perpendicular line running across the river. The line begins at the swimmer's starting point. If the swimmer knows three facts, he can calculate the precise angle by which he must deviate from the perpendicular in an upstream direction to counteract the effects of the current. These three facts are the following: the velocity of the current, the speed at which he swims and the trigonometric equations known as the *Law of Sines*. The swimmer must also know that the current flows perpendicularly to a line measuring the width of the river. The swimmer swims upstream at an angle expressly chosen so that, when the current sweeps him downstream, his path forms a line that is perpendicular to the flow of the river and intersects his starting point.

The following is an example of the calculation a swimmer can make, and it should be noted that the velocity of the current is crucial to the calculation. Let us say there is a river that flows east to west. A swimmer on the river's south bank wants to swim to the north bank along a perpendicular line. The river is 20 miles wide, and we will imagine that the width of the river is side ***a*** of a right triangle whose base is on the opposite side of the river. The current flows at a constant rate of 3 mph, and the swimmer swims at a constant speed of 5 mph. The lengths of both side ***b***, the base, and side ***c***, the hypotenuse, of the triangle are unknown. It is known that the ratio b/c = 3 mph/5 mph. The ratio b/c equals this ratio: the speed of the current/the speed of the swimmer. This is true because of the principle of similar triangles. Solving the ratio for ***b*** gives: b = c(3/5) = (.6)c.

The *Law of Sines* is the following: a/Sine A = b/Sine B = c/Sine C. The angles ***A***, ***B***, and ***C*** represent the angles directly opposite the respective sides ***a***, ***b***, and ***c***. We know angle ***C*** is 90^{o} because the current flows perpendicularly to a line measuring the width of the river. The sine of 90^{o} equals one. If we substitute (.6)c for ***b*** and 20 miles for ***a*** and one for sine ***C,*** we have: 20miles/sine A = (.6)c/sine B = c/1. Solving the equation for sine ***B*** we have sine ***B*** = .6. Therefore, angle ***B*** equals approximately 36.87^{o}. The swimmer must swim at an upstream angle of approximately 36.87^{o} from the perpendicular in order for the current to carry him back to the perpendicular.

A swimmer can swim at an angle that precisely deviates from the perpendicular. Swimming at this angle allows the current to carry him back to the perpendicular. A light beam can also precisely deviate from the perpendicular light path ***a***. This deviation will allow the apparent ether wind to carry the light beam back to the perpendicular light path ***a***. The term (c^2

$- v^2)^{1/2}$ is the proper term to use when the light beam is being carried back to the perpendicular by the apparent ether wind. Once the light beam is carried back, it is mathematically changed from the hypotenuse of a right triangle into the leg of a right triangle. The Pythagorean theorem determines that the length of the leg ***a*** of a right triangle is: $a = (c^2 - b^2)^{1/2}$.

The difficulty arises in determining the precise angle the light beam should deviate from the perpendicular. This angle must allow the apparent ether wind to carry it back to the perpendicular. To calculate that angle, the velocity of the apparent ether wind must *already* be known, but the velocity of the apparent ether wind is unknown. Unless the precise angle of deviation is *already* known, the formula t_2 cannot be employed. However, we do not know the angle that the light beam (in the arm of the interferometer perpendicular to the motion of the earth) must deviate from the perpendicular in order for the apparent ether wind to blow it back to the perpendicular. Therefore, the equation $t_2 = 2a/(c^2 - v^2)^{1/2}$ is invalid.

Instead, a formula similar to the equation $t_{2'} = 2b/(c^2 + v^2)^{1/2}$ must be used to describe the path of the light beam when it travels perpendicularly to the apparent ether wind. Its use does not require a known angle of deviation.

b = the distance the light beam travels when swept downwind by the apparent ether wind–it is a longer distance than that of light path ***a***.

c = the speed of light.

v = the velocity of the apparent ether wind.

An argument can be made that to employ the formula $t_2 = 2a/(c^2 - v^2)^{½}$ it is not required that the precise angle of deviation must be known. The argument is that since the interferometer rotates, it will pass through the precise angle of deviation necessary for formula t_2 to be correctly employed. It is true that the interferometer will pass through the precise angle of deviation. It is analogous to a swimmer who swims across a river many times and with each trial he choses a different angle as measured from the perpendicular. By trial and error he will discover the precise angle that allows the current to carry him back to the perpendicular.

However, when arm ***A*** of the rotating interferometer comes to the precise angle of deviation that allows the apparent ether wind to blow the beam of light (traveling along its arm) so that it is perpendicular to the apparent ether wind, the other arm, arm ***B***, of the interferometer will not be perpendicular to that beam of light. The apparent ether wind does blow the beam of light in arm ***A*** so that it advances to its "correct position."[4] The apparent ether wind does not blow the beam of light in arm ***B*** so that it advances to its "correct position."[5] Therefore, the beam of light in arm ***B*** lags behind from its "correct position."

Arm ***B*** of the interferometer is not perpendicular to the beam of light in arm ***A*** because the beam of light in arm ***A*** has been blown downwind by the apparent ether wind. It has been blown until it is perpendicular to the apparent ether wind while the beam of light in arm ***B*** of the interferometer has lagged behind, and so it will not be aligned with the motion of the apparent ether wind. Therefore, the formula for the beam of light in arm ***B***, $t_1 = 2ac/(c^2 - v^2)$ cannot be correctly employed. Arm ***B*** of the interferometer is not perpendicular to the beam of light blown downwind by the apparent ether wind. Arm ***B*** of the interferometer is still perpendicular to arm ***A*** because the arms themselves are not affected by the apparent ether wind, only the light beams traveling along the arms are affected by the apparent

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[4] The "correct position" for the light beam in arm ***A*** is perpendicular to the apparent ether wind.

[5] The "correct position" for the light beam in arm ***B*** is aligned with the apparent ether wind.

ether wind.

The light beam traveling along arm ***A*** of the interferometer has been blown downwind by the apparent ether wind. Therefore, the light beam is no longer parallel to arm ***A***. Since it is no longer parallel to arm ***A**,* it cannot be perpendicular to arm ***B*** because the arms are at right angles to one another. Since the light beam traveling along arm ***A*** is not perpendicular to arm ***B***, it is not perpendicular to the light beam traveling along arm ***B***.

The effect that the apparent ether wind has on the light beam traveling along arm ***B*** is very slight, but it actually increases the amount by which the beam of light in arm ***B*** lags behind from its "correct position."

Though the rotating interferometer passes through the precise angle of deviation required for formula t_2 to be correctly employed, it does so in a way that makes it incorrect to employ formula t_1.

There is another problem with the argument. The mirror at the far end of arm ***A*** of the interferometer would need to be tilted at a precise angle to meet two requirements: (1) that the incoming light beam's path is shortened so that it changes from the hypothenuse of a right triangle into the leg of a right triangle and (2) so that once the light beam has struck the mirror, the returning light beam will be traveling at the proper angle for it to be blown back to the perpendicular by the apparent ether wind. These two requirements may be incompatible with each other. The precise angle the mirror must be tilted to fulfill either requirement is unknown. Therefore, for all the reasons listed above, t_2 is the incorrect equation to employ, and a formula similar to $t_{2'}$ is the correct equation to employ.

The equation $t_{2'} = 2b/(c^2 + v^2)^{½}$, as with the other equations already mentioned, is an expression of the general equation time = distance/speed. The distance is 2***b*** because the light beam makes a round-trip journey, and it is assumed that each leg of the journey has a length which equals ***b***. (We will soon see this assumption is incorrect.) The speed of the light beam is $(c^2 + v^2)^{½}$. The speed is determined by the addition of vectors.

A vector is a mathematical expression denoting a combination of both magnitude and direction. In these equations the vectors used express the speed and the direction of one of the three following quantities: a light beam, the apparent ether wind, or a light beam under the influence of the apparent ether wind. Assuming the earth does not drag or even partially drag the ether along with it, then the vector for the velocity of the apparent ether wind will have the same speed as the vector for the absolute velocity of the earth. However, the direction for the vector of the absolute velocity of the earth is the reverse of the direction of the apparent ether wind's vector. When the vectors, which represent the apparent ether wind and the velocity of a beam of light, are added they form a third vector. It results from the combination of the speeds and directions of these two vectors.

The following is an example of vector addition. Let us say there is a river that flows east to west at a rate of 3 mph. A swimmer is positioned on the river's south bank who is ready to swim to the north bank, at a speed of 4 mph. The river's current can be represented by an arrow 3 units long, pointing toward the west, and beginning at the swimmer's starting point. The swimmer can be represented by an arrow 4 units long, pointing toward the north. This arrow also begins at the swimmer's starting point. These two vectors form two sides of a parallelogram. The other two sides of the parallelogram can be constructed because they mirror the two sides already formed by these two vectors. Once we construct the parallelogram, we can draw the third vector. It represents the addition of the current's vector and the swimmer's vector. We begin the third vector at the swimmer's starting point. We end the third vector at the diagonally opposite corner of the parallelogram. The length of the third vector represents the speed of the swimmer under the influence of the river's current. The position of the third vector represents the direction of the swimmer under the influence of the river's current.

In this example, the third vector is the hypotenuse of a right triangle. One leg of the triangle is three units, and the other leg is four units. Using the Pythagorean theorem we find the length of the hypotenuse/vector is $(3^2 + 4^2)^{½}$ or 5 units. The length of the vector equals the speed of the swimmer under the influence of the river's current. It is 5 mph.

The same reasoning is used to learn the speed of the light beam under the influence of the apparent ether wind. The speed of the light beam is $(c^2 + v^2)^{½}$ when the light beam begins its journey perpendicular to the apparent ether wind. Likewise, the speed of the light beam under the influence of the apparent ether wind is $(c^2 - v^2)^{½}$ when the light beam begins its journey at one specific upwind angle from a line drawn perpendicularly to the apparent ether wind.

For the reasons given before, we are compelled to use the term $(c^2 + v^2)^{½}$. When that term is used, deciding mathematically which of the two possible round-trip journeys will have the greatest duration is impossible.

We cannot mathematically determine which will take longer: the journey of the light beam in the arm of the interferometer perpendicular to the motion of the apparent ether wind or the journey of the light beam in the arm of the interferometer aligned with the motion of the apparent ether wind.

It cannot be mathematically determined whether $t_1 = 2ac/(c^2 - v^2)^{½}$ is greater than, less than, or equal to $t_{2'} = 2b/(c^2 + v^2)^{½}$. Since this is the case, the experimental result that the light beams in each arm of the interferometer take the same amount of time to complete their round-trip journeys is not in conflict with this new mathematical analysis. The original mathematical analysis of equations t_1 and t_2 conflicted with the empirical results of the Michelson-Morley experiment. Part of the original mathematical analysis was based on the legitimate assumption that the apparent ether wind had to have a velocity greater than zero. The most palatable way to resolve the conflict using the original equations was to assume that the velocity of the apparent ether wind was zero.

If the velocity of the apparent ether wind is zero, it must mean that the earth totally drags along the surrounding ether with it as it moves. What is true of the earth would be true for all matter. In this scenario, the ether surrounding the earth is the same as the air inside your car with the windows shut. It does not matter how fast your car is traveling; the air inside your car has a velocity of zero when measured from within your car. An anemometer inside your car will measure the air speed as zero. A weather vane inside your car will not detect a wind blowing from any direction.

The conclusion that the earth totally dragged along the surrounding ether was in direct conflict with the results of many other experiments. They all showed that the earth only partially dragged along the surrounding ether. However, the conclusion of the Michelson-Morley experiment that the earth must completely drag the ether along with it was drawn from an invalid mathematical analysis.

Part 3

A Further Consideration of Certain Aspects of the Michelson-Morley Experiment

Since we have proven that the mathematical underpinnings of the Michelson-Morley experiment are faulty, we can now turn our attention to two items. First, we must modify our notion of the interferometer's ability to measure the absolute velocity of the earth. Second, we must modify the term ***b*** in the equation $t_{2'}$.

Turning our attention to the first item, we recall that the following statement was made on page 17: *Assuming the earth does not completely drag or even partially drag the ether along with it, then the vector for the velocity of the apparent ether wind will have the same speed as the vector for the absolute velocity of the earth. However, the direction for the vector of the absolute velocity of the earth is the reverse of the direction of the apparent ether wind's vector*. This notion needs to be modified. A discussion of the properties of weather vanes and anemometers will explain certain aspects of the interferometer. A weather vane shows the direction of the wind, and an anemometer measures the speed of the wind. What happens if a powerful fan is positioned directly above or below a weather vane? When the fan is turned on, will the weather vane show the direction of this powerful, yet localized wind? No, a weather vane can only rotate around its vertical axis. It can only show the direction of winds that blow horizontally relative to the weather vane's vertical axis. The wind must blow horizontally relative to the weather vane's vertical axis or, at least, have a horizontal component. Only under these circumstances can the weather vane show either the wind's direction or the direction of its horizontal component. Like a weather vane the anemometer can only rotate around its vertical axis. It cannot measure the speed of a wind blowing from directly above it or from directly below it.

The interferometer, as well, can only rotate around its vertical axis. By comparing the effect of the apparent ether wind on a light beam's transit time in the arm of the interferometer aligned with the apparent ether wind to that of a light beam in the arm perpendicular to the apparent ether wind, the interferometer was supposed to produce a measurement of the apparent ether wind's velocity. If the apparent ether wind were to blow from directly above or directly below the interferometer, the speed and the direction of the apparent ether wind would not be registered by the interferometer. The interferometer only measures the apparent ether wind's velocity if it is moving horizontally relative to the interferometer's vertical axis. Otherwise, the interferometer only measures the component of the apparent ether wind's velocity that is moving horizontally relative to the interferometer's vertical axis. It is entirely possible that the interferometer only detects a component of the earth's absolute velocity when it measures the velocity of the apparent ether wind.

Now, we can turn our attention to the second item, which is the term ***b*** in the equation $t_{2'}$. The formula $t_{2'} = 2b/(c^2 + v^2)^{1/2}$ can be modified too more accurately represent the path of the light beam in the arm of the interferometer perpendicular to the apparent ether wind. The light beam begins its journey traveling perpendicularly to the apparent ether wind, and it is blown downwind by the apparent ether wind. When the light beam strikes the mirror at the end of the interferometer's arm, it is no longer perpendicular to the mirror. As with any light beam that strikes a mirror, when this light beam strikes the mirror, its angle of incidence will be equal to its angle of reflection. When the light beam begins its return journey, it is not traveling perpendicularly to the apparent ether wind; it is already traveling at a downwind angle before it is affected by the apparent ether wind. Under the influence of the apparent ether wind the light beam will be blown even farther downwind. The light beam's return journey does not measure length ***b*** because it travels a distance whose measurement is longer than length ***b***. We can call this measurement length ***f***. The time it takes the light beam to travel length ***f*** is given by the formula:

$$t_f = f/(c^2 + v^2 - 2cv \cos F)^{1/2}$$

c = the velocity of light.

v = the velocity of the apparent ether wind.

cos F = the cosine of the angle directly opposite vector ***f***. Vector ***f*** is the longest leg of an oblique triangle. The second longest leg is ***d***, and it is equal in length to ***b***. Leg ***d*** represents the path the returning light beam would have taken if it were not affected by the apparent ether wind during its return journey. Leg ***d*** represents the reflection of light path ***b*** according to the rule that the angle of incidence equals the angle of reflection. The shortest leg of this oblique triangle is ***e***. It represents a measurement of the total distance that the light path ***f*** is blown in a downwind direction by the apparent ether wind. (The length of leg ***e*** does not include the distance that light path ***f*** is directed downwind by the optical principle that the angle of incidence is equal to the angle of reflection.)

In the equation for t_f, listed above, the Law of Cosines is used to add the vectors ***c*** and ***v***. The Pythagorean theorem is not used because the vectors no longer form a right angle. The light beam is no longer perpendicular to the apparent ether wind when it begins its return journey.

A further difficulty is encountered. The light beam's return journey down the arm of the interferometer will not bring it back to the exact point from which it began to travel up the arm of the interferometer. It will return to a point downwind from its starting point. How does the light beam return from this downwind position? The light beam must travel back from its downwind position to recombine and interfere with the light beam returning from the other arm of the interferometer.

Even if a river had only a modest current, a swimmer would face the same type of situation swimming across the river and back. Once the swimmer returned to the side from which he started, he would need to swim upstream to reach his starting point. Swimming upstream would be slow going for the swimmer because he would have to contend with the full force of the current. The swimmer can consciously decide to swim upstream; however, that is not possible for a beam of light.

Once the light beam has somehow traveled the upwind distance necessary to reach its starting point, it must make a 90° turn so that it can recombine and interfere with the returning beam of light from the other arm.

A more accurate measure (but still incomplete) of the total time for the round-trip journey of a beam of light traveling perpendicular to the apparent ether wind is given by the formula:

$$t_{2''} = t_b + t_f$$

or

$$t_{2''} = b/(c^2 + v^2)^{1/2} + f/(c^2 + v^2 - 2cv \cdot \cos F)^{1/2}$$

c = the velocity of light.

v = the velocity of the apparent ether wind.

cos F = the cosine of the angle directly opposite length ***f***.

b and f = light paths of various lengths—***f*** is longer than ***b*** and ***b*** is longer than ***a***.

The results of the Michelson-Morley experiment require that $t_1 = t_{2''}$. Solving this equation for ***v*** is difficult. Compared with the original equation for t_2 the new equation, $t_{2''}$, is cumbersome and the equation still does not fully account for the light beam's return to its original position.

Most physicists in the 19th century believed that the ether was stationary or only partially dragged by the motion of the earth and that the motion of the earth through the ether produces an apparent ether wind. They should have concluded that under these conditions the Michelson-Morley experiment cannot produce results of any validity. The formula for the time it takes a beam of light to make a round-trip journey in an arm of the interferometer that is perpendicular to the apparent ether wind is incorrect. The modified version of the formula for the time it takes a beam of light to make a round-trip journey under the same conditions is cumbersome and incomplete. Solving the equation for the variable ***v*** is difficult. Since the conclusions of the Michelson-Morley experiment are invalid, they offer no empirical evidence that the luminiferous ether is totally dragged along by the earth. No empirical evidence exists to contradict the evidence, garnered from many ingenious experiments, that the luminiferous ether is only partially dragged along by the earth. No longer is there any contradictory empirical evidence about the nature of the luminiferous ether. No need exits to introduce the Lorentz and Fitzgerald contraction of matter to explain away a contradiction that no longer exists.

The Lorentz and Fitzgerald contraction of matter explained the empirical result that t_1 equals t_2. It did so without making it necessary that the earth totally drags along the surrounding ether as it moves. If matter contracts along the axis aligned with the direction of motion, it would explain why t_1 equals t_2. Though according to the mathematical analysis they should not be equal. The mathematical analysis definitively claimed this: the time, t_1, of a round-trip journey of a beam of light traveling first against the apparent ether wind and then returning with the apparent ether wind *would be longer* than the time, t_2, of a round-trip journey of a beam of light traveling perpendicularly to the apparent ether wind.

The contradiction between the mathematical analysis and the empirical evidence could be explained by assuming a contraction of matter along the t_1 axis. That is along the axis aligned with the direction of the apparent ether wind. The supposition of Lorentz and Fitzgerald is that the length of the arm of the interferometer aligned with the motion of the earth contracts just enough to make the round-trip times equal in each arm of the interferometer.

Once the original mathematical analysis is shown to be invalid, no need exits to introduce the Lorentz and Fitzgerald contraction of matter along the t_1 axis to reconcile the empirical results with the mathematical analysis.

Part 4

The Reconceptualizeded Michelson-Morley Experiment Probes the Ether—A Frame of Reference at Absolute Rest

Another interpretation of the ether is possible. In this interpretation there is no apparent ether wind produced by the motion of the earth through the stationary ether. Since no apparent ether wind exits, no mechanism is present to blow a beam of light that is perpendicular to the motion of the earth (or what would be the apparent ether wind if it existed) downwind. In this scenario the ether is empty space and not a medium that is necessary for the propagation of light beams. In this empty space an observer at absolute rest can be present. The notion that the ether was empty space coexisted with the notion of the ether as a medium for the propagation of light. The notion of the ether as empty space was known to A. Michelson and he was not averse to it.

Lee Smolin in his book *The Trouble with Physics,* published in 2006, comments on the attempts to find the absolute velocity of the earth. On page 37, he states, “Several attempts had been made to detect Earth’s motion through the aether before 1905, when Einstein proposed special relativity, and they had failed. Proponents of the aether theory had just adjusted their predictions so as to make it harder and harder to detect

Earth's motion."[6] It seems odd that the "proponents of the aether theory" did not expose the flaws with the Michelson-Morley experiment. Perhaps, though some kind of realization that the apparent ether wind version of the Michelson-Morley experiment was invalid did exist.

L. R. Lieber in her book *The Einstein Theory of Relativity*, published in 1945, does not suggest that the apparent ether wind interpretation of the experiment is invalid. At least explicitly she makes no such suggestion, but her complete dependence on the analogy between the behavior of the light beams and the behavior of a swimmer is problematic especially since her explanation is strained at points. However, by the time Stanley Goldberg's book, *Understanding Relativity: Origin and Impact of a Scientific Revolution*, was published in 1984 the apparent ether wind interpretation of the experiment had been abandoned. It was replaced with a version that employed empty space and an observer at absolute rest. L. Smolin claims that the proponents of the ether theory adjusted their predictions to make the earth's motion harder and harder to detect. However, the proponents of special relativity were not averse to changing the interpretation of the Michelson-Morley experiment in an attempt to keep it from being

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[6]Lee Smolin, *The Trouble with Physics: The Rise of String Theory, the Fall of a Science, and What Comes Next* (Boston/New York: Houghton Mifflin, 2006), p.37.

invalidated.

Appendix 5 of S. Goldberg's book is entitled, "Ether Drift Experiments: The Search for the Absolute Frame of Reference," and it contains a six-page description of the Michelson-Morley experiment. Several features in his description of the experiment deserve an examination.

An observer at absolute rest observes the split light ray following two paths. These two paths can be analyzed mathematically to generate the formulas t_1 and t_2. S. Goldberg's formulas for t_1 and t_2 are mathematically equivalent to the original formulas for t_1 and t_2 but other differences are present. For example, S. Goldberg's formulas are no longer derived through a process that includes the addition of two vectors that represent a light beam and the apparent ether wind respectively. A vector representing the apparent ether wind is not even present in S. Goldberg's scenario. Though, a vector representing the absolute velocity of the earth is present.

In L. Lieber's description of the experiment, the apparent ether wind could affect both the speed and direction of a light beam. In S. Goldberg's description only the direction of a light beam can be affected, and this influence is apparently caused by the absolute motion of the earth.

Another distinction between S. Goldberg's formulas and L. Lieber's formulas is that the observer who observes the interference fringes is in a state of absolute rest. No mention is made of the fact that an observer at absolute rest would observe the experimental apparatus passing by at a speed of at least 18 miles/second. Also, the method by which an observer may attain the condition of absolute rest is not mentioned since it does not exist. Though it is most likely that it is not a requirement that the observer be at absolute rest to observe the interference fringes, rather the observer at absolute rest is used to make S. Goldberg's explanation clearer.

According to S. Goldberg, an observer at absolute rest observes that the light beam, traveling perpendicularly to the motion of the earth, behaves as though the directional component of the earth's velocity, **v**, has been imparted to it. The speed of the light beam is unchanged, and only the direction of the light beam is changed by an interaction with the earth's velocity. This change in direction allows the light beam to keep up with the lateral motion of the fully-silvered mirror at the end of the interferometer's arm. The light beam has a forward (upstream) direction imparted to it by the velocity of the earth or perhaps, by another unknown force. This forward motion from the earth combines with the light beam's motion, which is perpendicular to the motion of the earth, with the result being the light beam travels diagonally forward, but with no increase in speed. This violates a fundamental property of light observed by the Dutch astronomer W. De Sitter. The velocity of light is not affected by the velocity of the light source. Einstein writes in his book, *Relativity: The Special and the General Theory*, “By means of similar considerations based on the observations of double stars, the Dutch astronomer De Sitter was also able to show that the velocity of propagation of light cannot depend on the velocity of motion of the body emitting the light.”[7] The velocity of the light beam includes both its speed and direction. It is not enough that the speed of the light beam does not depend on the velocity of the body emitting the light. The direction of the light beam cannot depend on the velocity of the body emitting the light, as well.

In S. Goldberg’s conception, the beam of light perpendicular to the motion of the earth behaves like the well-known example of a ball tossed between two passengers on a moving train as observed by an observer at rest with respect to the earth. The train travels at a constant velocity. The passengers are in an enclosed car so the train’s motion through the air

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[7]Albert Einstein, *Relativity: The Special and the General Theory* (New York: Three Rivers Press, 1961), p. 21

cannot affect the tossed ball. Both stand on a straight line perpendicular to the motion of the train. This means that they are tossing the ball across the width of the train car. From the frame of reference of the two passengers the ball travels back and forth between them in a straight line at a nearly constant speed. From the frame of reference of the observer at rest with respect to the earth the ball travels diagonally forward at a nearly constant speed forming a pattern that resembles a saw's teeth. This is possible because the velocity of the train is imparted to the ball and the passengers who toss the ball. This behavior is impossible for a beam of light because the velocity of the light-emitting source cannot be imparted to a beam of light. S. Goldberg tacitly acknowledges this when he states that the speed of the beam of light remains unchanged. He offers no explanation for the light beam's change in direction.

Actually, the light beam would appear to move at a diagonal angle in a direction opposite to the motion of the earth to an observer at absolute rest. This is similar to the way a light beam behaves because of the influence of stellar aberration. The astronomer who observes stellar aberration is not at absolute rest but merely at rest with respect to the motion of the earth. Unlike S. Goldberg's explanation, if we use stellar aberration as the model to decide what the observer at absolute rest observes, then his observations and those of an observer in motion are the same with respect to the light beam.

A thought experiment should make the situation easier to visualize. Let us assume two bicyclists are riding a tandem bicycle. They are traveling with a constant velocity. The bicycle represents the motion of the earth. A rider in the rear position has a large sack of balloons filled with helium. He releases them one after the other at a uniform rate. When he releases them, they travel straight up at a uniform rate; the moving bicycle does not impart any of its motion to the balloons in this thought experiment. The balloons represent a beam of light traveling perpendicularly to the motion of the earth, and the sack of balloons represents the source of the light beam that is traveling with the earth. At some point the bicyclists stop their bicycle and look around in every direction. Thus, they become observers at "absolute rest." When they look backwards, they observe that the balloons have receded from them along a rising diagonal line. With this example in mind, conceiving of how an observer at absolute rest would observe the light beam moving diagonally forward, instead of receding diagonally, is difficult. Calling the receding, diagonal light beam a “composite light beam” would be more accurate since it is not really a light beam.

If the light beam traveling perpendicularly to the earth’s motion did not have the forward directional change imparted to it by the velocity of the earth, as S. Goldberg suggests, the light beam would strike the mirror, at the end of the interferometer’s arm, downstream from dead center–its correct position. If the mirror was traveling with a very rapid velocity, the light beam would completely miss it. Let us say the light beam strikes the mirror, at the end of the interferometer’s arm, downstream from its correct position by the length ***x.*** While the light beam was returning from the mirror to its point of origin, its point of origin would travel forward by the additional length ***y***. Therefore, the light beam would miss its point of origin—its correct position by a total length of ***x*** + ***y*** in the downstream direction. Thus, the split light beam does not recombine. We have previously encountered this type of problem with the apparent ether wind interpretation.

Even with S. Goldberg’s assumption that a forward directional change can somehow be imparted to the light beam traveling perpendicularly to the motion of the earth, the light beams still do not recombine. A careful study of Figure 11 proves this point. As can be seen from Figure 11, the dotted diagonal line, which represents the light beam traveling perpendicularly to the motion of the earth, follows a distinctly diagonal path. However, it must be traveling perpendicularly to recombine with the other light beam–the light beam aligned with the motion of the earth. Note that the path of the light beam represented by the dotted diagonal line ends before it reaches the observer represented by the eye. If we were to continue the dotted diagonal line, we would observe that it passes to the right (upstream) of the observer represented by the eye. This would represent a clear indication that the split light beams do not recombine; therefore, it is left out of Figure 11.

S. Goldberg's interpretation of the experiment can be seen as an effort to overcome the shortcomings of L. Lieber's conception of the experiment enumerated in parts 2 and 3 of this paper.

The long excerpt that follows is from S. Goldberg's description of the Michelson-Morley experiment, which includes his accompanying schematic diagram. The description of the paths that must be followed for the recombination of the light beams is important especially since the schematic diagram illustrates that these requirements are not met.

The Michelson-Morley experiment depends on observing the behavior of fringes when light beams are combined and allowed to interfere. While all such instruments are known as "interferometers," that term more and more is reserved for the particular interferometers of the Michelson-Morley experiment.

The apparatus is depicted, schematically, in Figure 11. Light is incident from the direction *q* onto the half-silvered mirror at 0. Part of the light is reflected from 0 to the fully-silvered mirror at A and is reflected back to 0, while part of the light incident on 0 is transmitted through 0 to another fully-silvered mirror at C whence it, too, is reflected back to O. Part of the light arriving back from A is transmitted through 0 to the observer while part of the light arriving from C is reflected by 0 to the observer. It is thus possible for the observer (represented by the eye in Figure 11) to observe the fringe pattern resulting from the interference of the two beams of light.

Figure 11 depicts the interferometer in three different positions as it moves through space. The dotted lines represent the paths of the two beams of light as seen by an observer at rest with respect to absolute space. We have arranged the apparatus so that the arm OC of the instrument is parallel to the *x* axis, the presumed direction of the earth's motion through space.[8]

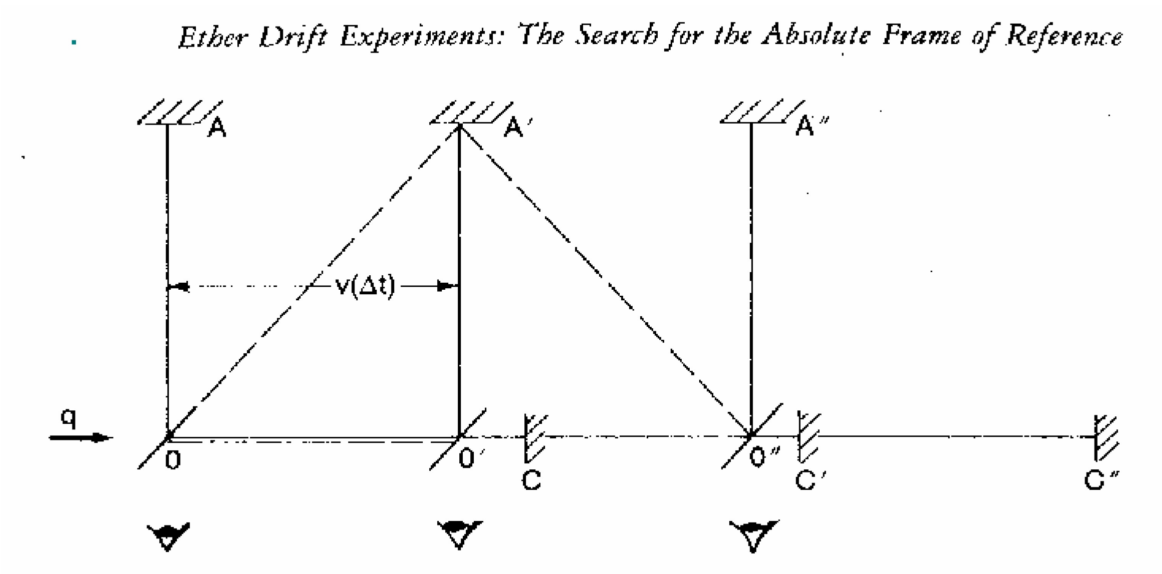

Figure 11

Part 5

Conclusion

Neither the apparent ether wind interpretation of the Michelson-Morley experiment nor the observer at absolute rest interpretation proves that the absolute velocity of the earth is impossible to detect. The flaws in the design of the Michelson-Morley experiment undercut the significance of the results, and the flaws in the mathematical interpretations undercut the

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[8]Stanley Goldberg, *Understanding Relativity: Origin and Impact of a Scientific Revolution* (Boston: Birkhauser, 1984) pp.448-449. Figure 11 p.449.

significance of any conclusions drawn from any possible results. The fact that the experiment detects no change in the interference fringes can only be considered significant if we know the exact nature of the light path in each arm of the interferometer.

In the apparent ether wind interpretation of the experiment the formulas that describe the light paths are incorrect. The apparent ether wind interpretation assumes that the apparent ether wind blows the light beam in one arm of the interferometer in a downwind direction so that it is precisely perpendicular to the motion of the earth. The next assumption, made by the apparent ether wind interpretation, is that the beam of light in the other arm of the interferometer is now aligned with the motion of the earth. This assumption is incorrect. Instead, the proper assumption is that the light beam has not yet reached the position that would align it with the motion of the earth. The light beam lags behind the position that it must assume in order for the formula that describes its behavior to be valid.

Attempts to overcome this dilemma are unsuccessful. For instance, if we assume that a beam of light in one arm of the interferometer is aligned with the motion of the earth, the beam in the other arm will be blown downwind from the perpendicular by the apparent ether wind. A formula designed to describe the light path of such a light beam will be cumbersome and incomplete. Most important, it will not yield any decisive result when it is compared with the formula for a beam of light aligned with the motion of the earth.

In the observer at absolute rest interpretation of the experiment, the light beam perpendicular to the motion of the earth is compelled to behave in a way that violates the empirically observed behavior of light. The velocity of a light source is not imparted to a light beam emanating from it. Velocity includes both speed and direction.

If S. Goldberg's scenario for the behavior of a light beam was correct, a thin beam of light could strike a distant target provided the light source and the distant target were in alignment and moving with the same velocity. Let us say a light source and a distant target are both moving with the same speed of 20 miles per second. They are separated by 186,000 miles as measured along a line that has the target and light source as its respective endpoints and is perpendicular to the axes of motion of both the light source and target. If the light source were to emit a microsecond burst of a thin beam of light along the perpendicular line that leads to the target, the light beam would strike the target. It would somehow hit the target though the target had moved 20 miles downstream from the endpoint of the perpendicular line along which the thin beam of light has traveled.

Both the apparent ether wind interpretation and the observer at absolute rest interpretation of the Michelson-Morley experiment are invalid. For an interpretation of the experiment to be valid the paths of the two beams of light must be accurately described in a way that does not violate the laws of physics. Also, the manner in which the two beams of light recombine to form interference fringes must be described in a detailed manner.