

Light-Speed & Aether

Have you ever shaken a rope to make a wave travel from one end to the other end? Or have you thrown a pebble into a pond to watch a wave spread out from the point of impact? As a child, I was fascinated by the waves coming into the shore of the Pacific Ocean.

In these examples, the waves are all molecules in motion. For a rope or string, the molecules and the string moves sideways, and physicists call this a *transverse* wave. Still, the wave itself seems to progress along the length of the string, though the molecules have little or no motion in this direction; and this type of wave is called a *traveling* wave.

The “velocity of propagation of transverse waves in a stretched string equals the square root of the tension divided by the mass per unit length.” [F. W. Sears, **Mechanics, Heat and Sound**, p. 480, Addison-Wesley (1950)] Thus, for waves in a string, pond, ocean, and air, the wave velocity depends upon the properties of a *medium* that “carries” the wave. In the common cases cited above, the medium consists of ordinary material composed of atoms filled with charged particles. Is it unreasonable to believe, then, that light waves are not also carried by a medium known as the “luminiferous aether”? *Existence of the aether* is a fundamental question for physics, and the following article by Curt Renshaw presents an analysis of the historical experiments that were conducted to detect a medium of some kind (that some have called an aether).

A second, related question concerns the velocity of the wave of electromagnetic radiation:

What is the velocity of light? And, specifically, how is that velocity specified:

- (1) as its velocity in departing from its source,
- (2) as its velocity through the aether, or
- (3) as its velocity in arriving, relative to the observer?

Dr. Renshaw uses a phrase that suggests his answers to these questions—“Aetherless Galilean Space.” His analysis of pertinent experiments shows that the data can be explained **without the assumption of an aether**. And his successful use of the Galilean Transformation, based on the *principle of relativity* [explained in *Foundations of Science*, vol. 3, no. 1, “Time Motion and Relativity”], suggests **that the velocity of light is relative to both source and observer** in keeping with the principle of relativity and Emission Theory.

—Editor

Curt Renshaw, "Fresnel, Fizeau, Hoek, Michelson-Morley, Michelson-Gale and Sagnac in Aetherless Galilean Space," Galilean Electrodynamics, Vol. 7, No. 6 (November/December 1996). Curt Renshaw, 680 Americas Cup Cove, Alpharetta, Georgia 30005-4365 USA. TCICurt@aol.com, <http://renshaw.teleinc.com/>. Used by permission of Galilean Electrodynamics.

(See the entire paper published in Galilean Electrodynamics for the complete, rigorous derivation of equations in this paper. Equations retained in this edited reprint correspond to the original equation numbers.)

Fresnel, Fizeau, Hoek, Michelson-Morley, Michelson-Gale and Sagnac in Aetherless Galilean Space

Abstract. The experiments of Fizeau, *et al.*, in the years 1851-1925 were all designed to test for the motion of the Earth through the presumed aether, or to test for the extent to which the aether was constrained and carried in a moving, material medium. The results of these experiments defined the Fresnel coefficient of aether drag and the Lorentz Transformations, each formulated to explain the nature of the aether as evidenced by the data obtained. Building on these results (and much original thought), Einstein developed the Special Theory of Relativity, keeping many of the results in form, but abandoning the aether. Analyzing the results of these experiments without the assumption of an aether eliminates the Fresnel aether drag coefficient, the Lorentz Transformation, length contraction and time dilation, and, with this, the basis for Special Relativity. The correct form and value for the solutions are then derived utilizing Galilean Transformations.



Dr. Curt Renshaw

Introduction. In this paper, we will survey chronologically the experiments and theories of Fresnel, *et al.*, performed over a hundred year period, beginning in 1818. We will demonstrate the errors in base assumptions and result interpretations in each case, and we will show how these errors compounded with each additional test. At the same time, we will document the results by assuming aetherless, Galilean space, and show that all experiments are compatible with these assumptions—without the need to invoke length contraction, time dilation, or Fresnel's "aether drag coefficient."

Fresnel's Coefficient of Aether Drag. Fresnel was a firm believer in the concept of an aether, as it was "establishment" physics of the day. He proposed that the density of aether in a material body was different than that in the free aether. From an application of elastic waves to optics, Cauchy derived the ratio of the *elastic constant of a substance* to the measure of its *density, or mass per unit volume*, finding this ratio is equal to c^2 where c is the velocity of light in space (or in the aether, as Fresnel assumed).

Building on this, Fresnel imagined a bar of cross sectional area moving through the aether with velocity v . This bar sweeps up aether, where it acquires a new density, yet is only partially carried along by the bar. Thus the velocity of the bar with respect to the constrained aether, v_1 , is different than the velocity of the bar with respect to the outside aether. While the velocity and density of the constrained aether changes, its mass must remain constant.

Light travels faster in a vacuum than in a material, and the refractive index η is defined as c/c_1 , with c_1 representing the velocity of light through the bar at rest. Now, the velocity of light in the moving bar is simply the velocity of light through the aether in the bar minus the velocity of the constrained aether through the bar, or:

$$c_1' = c_1 - v_1 = c - \frac{1}{\eta^2} v \quad (4)$$

Finally, the velocity of light as measured by an observer stationary in the lab frame of the moving bar is given by c_1' plus the velocity of the bar through the lab frame, or:

$$c_1'' = c_1' + v = c_1 + v \left(1 - \frac{1}{\eta^2} \right) \quad (5)$$

This is the well known convection coefficient, or “aether drag” coefficient as derived by Fresnel. Most books on Special Relativity Theory (SRT) praise Fresnel for his insight and ability in obtaining this important formula, even though they contend he got there by using bad assumptions. His theory is considered to be what Petr Beckmann refers to as a mere “equivalence” [4]—a theory which produces the correct answer mathematically, but is based on the wrong underlying assumptions.

SRT derives this same result, based on the Relativistic addition of velocities as obtained by invoking *length contraction* and *time dilation*. This equation has been “verified” experimentally, though, in all cases, the desired result was known in advance. We will now show that these “verifications” also support the Galilean view, well within the limits of experimental error, leading to the firm possibility that both Fresnel’s theory and Einstein’s theory are mere equivalences.

The Experiment of Fizeau. In 1851, Fizeau carried out an experiment which tested for the aether convection coefficient. This was the first such test of Fresnel’s formula—derived without experimental evidence over twenty years earlier. Fresnel, in fact, had died more than twenty years before this experiment took place, a point of interest only because many texts derive Fresnel’s formula based on the results of experiment, rather than the other way around. Experimental results, within the level of error available in the mid-1800’s, are not sufficient to derive Fresnel’s formula. These results can only confirm that, within error limits, the formula provides answers consistent with experiment.

Fizeau’s experiment involved passing light two ways through moving water ($v \sim 7$ m/s) and observing the interference pattern obtained, as illustrated in figure 1. Varying the velocity and direction of the flow allowed for a variety of test points. By observing the change in interference pattern, the effective velocity of light through the moving medium,

as measured in the lab frame, was calculated. Within experimental limits, the results obtained by measuring the fringe shift agreed with the results predicted by Fresnel's formula (5).

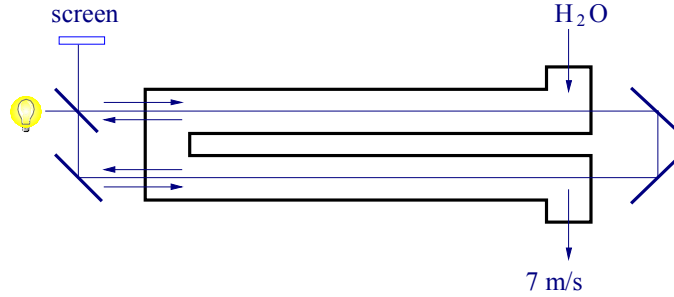


Figure 1. The experiment of Fizeau.

We now examine this experiment in a purely Galilean environment. We will look only at the one-sided effect of light moving in the same direction as the flow of water. The analysis for the reverse case is identical with the sign of v reversed. Since the water is moving with respect to the light source, the frequency of the light will be red-shifted [1]:

$$\begin{aligned} v' &= \frac{c}{c+v} v = \frac{v}{(1+v/c)} = \frac{v}{(1+v/\eta b)} \\ &= \frac{c}{\lambda(1+v/\eta b)} \approx \frac{c}{\lambda(1+v/\eta c)} \end{aligned} \quad (6)$$

Once in the water, the motion of the light is given by:

$$v'' = \frac{b}{\lambda'} = \frac{b}{\lambda(1-v/\eta c)} \approx \frac{b(1-v/\eta c)}{\lambda} = \frac{b'}{\lambda} \quad (8)$$

where b' represents the effective apparent velocity through the moving water with respect to the water. To determine the effective apparent velocity as measured in the lab frame, we simply add the velocity of the water with respect to the lab, v , and, realizing that $b/c = 1/\eta$ obtain:

$$b'+v \approx b \left(1 - \frac{v}{\eta c} \right) + v \approx b - \frac{v}{\eta^2} + v \approx b + v \left(1 - \frac{1}{\eta^2} \right) \quad (9)$$

Equation (9) is, of course, identical to Fresnel's equation (5).

Hoek's Interferometer. In 1868, Hoek performed an experiment similar in nature to that of Fizeau, but one which is much simpler in concept and easier to explain in the absence of an aether. Hoek's experiment lies about midway in simplicity between that of Fizeau and the later Michelson-Morley experiment.

As shown in figure 2, the Hoek interferometer passed a beam of light two ways around a loop where one leg passed through a tube filled with water. By rotating the apparatus through various angles, and observing the manner in which the interference patterns shift,

one can determine the degree to which the aether is constrained by the water due to the motion of the earth in its orbit.

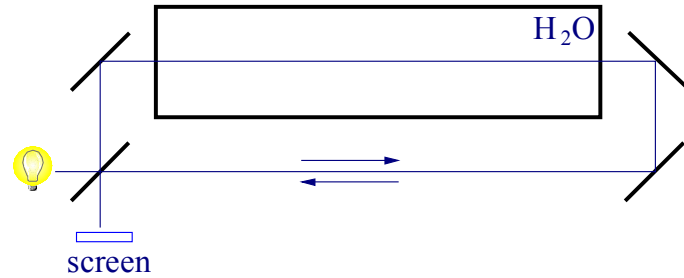


Figure 2. The experiment of Hoek

When Hoek carried out the experiment, the fringe pattern did not change at all for any orientation. This implies that each of the light beams take equal time to complete the circuit, regardless of the orientation of the equipment. Consulting figure 2, then, we obtain the following relation:

$$\frac{d}{c_1 + \phi - v} + \frac{d}{c + v} = \frac{d}{c_1 - \phi + v} + \frac{d}{c - v} \quad (10)$$

where ϕ is the Fresnel convection coefficient. Solving (10) for ϕ yields:

$$\phi = \left(1 - \frac{1}{\eta^2}\right)v \quad (11)$$

where Hoek neglected terms of second order and higher and obtained Fresnel's formula. Hoek's analysis proceeds well if an aether is assumed. However, if we eliminate the aether, as we have done so far, we see that Hoek's experiment demonstrates nothing. The apparatus is small; thus, during the time of the experiment the motion of the equipment due to the earth may be considered as linear and inertial. Further, all components of the apparatus maintain the same speed and direction. Thus, in the frame of the apparatus, we can assume the experiment to be at rest, and no fringe shift is expected. If we rotate the equipment, it is still at rest in its own inertial frame; and thus, there is no change in the interference pattern. Thus, in equation (10), we can simply eliminate ϕ (or set it equal to 0) and obtain an identity, which is the aetherless solution Hoek neglected to consider. Had he considered this solution, the next test in this story might never have been performed.

The Michelson-Morley Experiment. The successful experiment of Michelson and Morley was performed in 1887. Utilizing an interferometer similar in principle to that depicted in figure 3 (but with many more reflections than indicated), they hoped to measure the velocity of the earth through the aether by measuring the degree to which the observed fringe pattern shifted as the apparatus was rotated through ninety degrees. The results expected were of the second order in v/c . Specifically, a fringe shift of $2l\beta^2/\lambda$ was expected, or a value of about 0.37. When the experiment was performed, no fringe

shift was observed. This should have been expected, since Hoek had already demonstrated that there was no aether. In the absence of an aether, this experiment is even simpler than that of Hoek. Not only is there no relative motion between the various components of the apparatus, but there is also no material with a refractive index different from air placed in the path of the beam. If Hoek predicts no fringe shift, then clearly Michelson-Morley predicts no fringe shift. However, since the experiences of Fresnel, Fizeau and Hoek had all been interpreted in terms of an aether, this null result was entirely unexpected. But even at this point, the aether concept was not abandoned. Instead, Fitzgerald in 1892, and later Lorentz, came up with an explanation—*all material bodies contract in the direction of their motion with respect to the aether by the factor $(1 - v^2/c^2)^{1/2}$.*

Length Contraction in Verse
 Submitted by Clayton Harrison

There was a young fencer named Fisk,
 Whose speed was exceedingly brisk.
 So fast was his action
 The Fitzgerald contraction
 Reduced his rapier to a disk.

Rather than admitting the obvious, that there is no aether, Lorentz and Fitzgerald found a correction to the aether theory which allowed it to survive—simply change the length of every object placed in motion, and continue to change that length as the velocity continues to change. Of course, another part of this balancing equation indicates that *time* also changes with velocity, but Lorentz did not need this piece to explain Michelson-Morley, and considered the effect a mathematical oddity only.

Lorentz was trying to save the aether concept. Even though we, the observers, the lab and the entire interferometer set-up are all in the same inertial frame of reference (IFR), the length contraction still occurs. The reason it occurs, according to Lorentz, is that the apparatus is moving with respect to the aether. It is this motion which causes the length contraction.

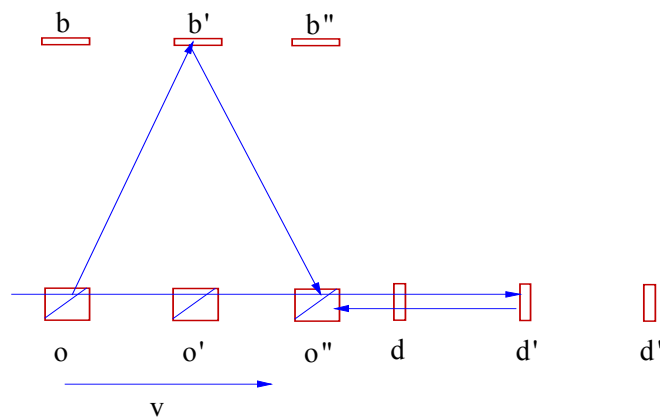


Figure 3. The Michelson-Morley Experiment

At this point, we see that Hoek created an *equivalence*—developing a value for ϕ that supported the observed results, but was better represented by eliminating the term altogether. As experiments improved, and Michelson-Morley obtained second order results, the theory had to change to maintain equivalence and length contraction was added. The aether theory was saved.

In 1905, Einstein realized that, in order to maintain the mathematical validity of this equivalence theory, the time contractions could not be ignored. Playing with the math, he was able to show that by considering the time and length contractions as real, and abandoning the aether concept, all experimental results could be explained. Additionally, some purely imaginary thought experiments could be explained, not that any such results require any explanation at all.

It is important to realize that the length contraction proposed by Einstein is not the one proposed by Lorentz. In the Michelson-Morley experiment, length contraction occurs in Lorentz theory due to motion with respect to the aether. In Einstein's theory, no such length contraction exists, as there is no relative motion between apparatus and observer. Thus, the Michelson-Morley experiment is not a test of Special Relativity.

In Special Relativity, Einstein effectively replaced the aether with any arbitrary observer, such that motion through the inertial frame of the observer obtained all the characteristics of what was formerly motion through the inertial frame of the aether. It was at this point that the mathematical time dilation became real and necessary.

We now have the final equivalence theory, one which has eliminated the aether that was never required in the first place, but kept all the ad-hoc corrections induced to save that theory from the contradictory results of real-world experiments. How much more appropriate it would have been to simply eliminate the aether at the time of Fizeau's experiment, and arrive at the correct Galilean results we have seen so far—results which fully support the observations of each of the three experiments documented. (There is a fourth experiment in this series, a test of aberration carried out by Arago using a telescope filled with water. However, the null result of this experiment is obviously supported by an aetherless theory. The effect has been addressed in [1] and adds no new insight here.)

We are now in a position to analyze experiments which prove problematical for Special Relativity. This non-applicability of SRT would be acceptable, if it were not that the domain of validity of Special Relativity is routinely applied to situations which are more out of range than the cases we are going to address. These include the Hafele-Keating round-the-world clocks experiment and milli-second pulsar timing algorithms [3] to name a few.

The Sagnac Experiment. The experiments of Sagnac in 1913 and Michelson-Gale in 1925, proved an embarrassment for Special Relativity, requiring the full force of General Relativity to explain their results. The complexities of these experiments explains their absence from most standard texts on Einstein's theories. Aether theories may be used to explain these experiments, but these theories, then, often fall short of explaining the

experiment of Fizeau. However, *if one abandons Einstein's Second Postulate, the results can be explained quite simply without the need for General Relativity, and without resorting to concepts of aether or absolute space.* This is true for the experiments of Fizeau, Hoek, Michelson-Gale, and Sagnac.

The idea of abandoning SRT's second postulate begins again with what Petr Beckmann [4] referred to as an *equivalence*—a mathematical description that, while it produces correct answers, is based on faulty assumptions. Einstein noticed that observers all recorded the same observed velocity of light, apparently regardless of their velocity with respect to the source.* He also had Maxwell's equations. His goal was to make these equations invariant under transformation between Inertial Reference Frames (IFRs), while keeping them compatible with the observed speed of light. He had at his disposal two concepts—the concept of *interrelated space and time*, and the concept of *constant light velocity*.

Light-Speed in Verse

Submitted by Clayton Harrison

There was a young fellow named Bright,
Whose speed was much faster than light.
He started one day
In a relative way
And returned the previous night.

Einstein made the assumption that light velocity, even in transit, was absolutely consistent from all IFRs. From this assumption, he derived that *lengths contract* and *time dilates* due to the relative velocities of these IFRs. He could just as easily have assumed that lengths and time remain absolutely consistent between IFRs, and that light emerges from its source in a continuum of velocities, from zero to some undetermined upper limit. The two approaches are mathematically equivalent as far as any experiment dealing with both a light signal and a measure of length or time is concerned. Thus, Doppler equations and an apparent increase in mass with velocity will appear in both approaches. Only when considering an experiment which covers only one issue, such as determining (1) the simultaneity of distant events, or (2) the one-way speed of light for two distinct IFRs, will a difference arise between the two approaches. This concept was proposed in an earlier paper by this author [1], and was picked up again by Cynthia Whitney [2], in which she states: “We here adopt a more physically operational interpretation of the light-speed postulate. We require only that observable intensity pulses appear to propagate with isotropic speed c ...we interpret ‘light velocity’ not to mean abstract phase velocity, but rather to mean only observable velocity.”

* In many experiments, extinction of light by an air molecule and emission with a new velocity is ignored. Fox is one of the few researchers to recognize the significance of an adequate vacuum to eliminate extinction and re-emission during tests of the Second Postulate [J. G. Fox, “Experimental Evidence for the Second Postulate of Special Relativity,” *American Journal of Physics*, **30** (4) 297-300 (April, 1962)]. —*Editor*.

In the Sagnac experiment, we have a source, mirrors and screen all on a rotating platform. (This experiment has been repeated using artificial satellites orbiting the earth to obtain the same results.) The source light is split so that one beam travels clockwise and the other counter-clockwise around the apparatus. When the beams are brought together, an interference pattern forms and the fringe displacement is measured. The General Relativistic solution to this problem is more complex than this paper deserves, and will not be presented. Instead, we derive the Galilean solution. There are actually two good approaches to this problem. One was addressed in [2], the other is presented here.

As with the experiment of Hoek, the motion of the beam-splitting and combining mirror may be considered linear during the term of the experiment. For example, even with a velocity of $r\omega = 30$ m/s, the difference between the linear approximation ($\sin \theta$) and the actual distance traveled ($r\omega\tau$) is on the order of 10^{-12} , as shown:

$$d\theta = \frac{dl}{2\pi r} = \frac{r\omega\tau}{2\pi r} = \frac{r\omega(2\pi r/c)}{2\pi r} = \frac{r\omega}{c} = 3 \cdot 10^{-6}$$

$$\frac{\theta - \sin \theta}{\theta} = \frac{3 \cdot 10^{-6} - \sin(3 \cdot 10^{-6})}{3 \cdot 10^{-6}} \approx 1.5 \cdot 10^{-12} \quad (12)$$

While it is not necessary for the current discussion, it is of value to note that the acceptable region of linearity can be extended indefinitely. We are concerned only with the location and velocity of the mirror as a source compared with the location and velocity of the mirror as an observer at a later instant. The path taken by the mirror to get from its origin to its final destination is not important. We can always model the trip as having been along the most linear route, at a speed equal to the distance between these points divided by the time required to make the trip. We are then left with a small component of velocity at each mirror which is normal to our presumed linear route. However, this normal velocity component would be the same for light traveling each direction of the circuit, and would therefore have no effect on the final solution, whether considered under SRT or any competing theory ([1,2] for example). Now, back to Sagnac.

Having seen in (12) that the effective path length for the entire circuit changes by $r\omega\tau$, we must add this change to the light path moving in the direction of rotation, and subtract it from the light path moving counter to the rotation. Our linear approximation, accurate to within 10^{-12} , demonstrates that this effect is experienced in the frame of the apparatus itself. Since this movement is rotational, unlike the Michelson-Morley or Hoek experiments, as the light moves through its circuit, various parts of the apparatus appear to be in motion with respect to each other. For example, in a four mirror system, while one mirror is moving east, the mirror to one side is moving south, while the mirror to the other side is moving north. The mirror on the opposite side of the wheel is moving west at a velocity of $2v$. When integrated over the entire circuit, the effect is the addition and subtraction just addressed. This results in the following analysis for the Sagnac experiment:

$$\begin{aligned}
l_1 &= 2\pi r + r\omega\tau \\
l_2 &= 2\pi r - r\omega\tau \\
dl &= 2r\omega\tau \\
\tau &= \frac{2\pi r}{c} \\
dl &= 2r\omega\tau \frac{2\pi r}{c} = \frac{4\pi r^2\omega}{c} = \frac{4A\omega}{c}
\end{aligned}
\tag{13}$$

This effective difference in path length results in a fringe shift as seen experimentally and given by:

$$dN = \frac{dl}{\lambda} = \frac{4A\omega}{\lambda c} \tag{14}$$

The preceding theory for the Sagnac equation (14) was developed without invoking an aether, or SRT. Data measured by Sagnac, in accordance with equation (14), are not the null result of the Michelson-Morley experiment, lending support to aether theories. Nevertheless, the results are predictable within a Galilean framework without the necessity of an aether. An identical result, equation (20), will be derived for the Michelson-Gale Experiment.

The Michelson-Gale Experiment. This experiment utilized a large rectangular array of pipes and mirrors, with the legs lying in the direction of the earth's rotation having a length of 2010 feet, and the legs lying along longitudinal lines having a length of 1113 feet. A calibration loop had the same longitudinal length, but only a very short length in the direction of the earth's rotation, so that the effect of the earth's motion in the direction of the light traveling the 2010 foot legs could be compared to the effect in the calibration loop in which light traveled only a negligible distance in this direction. By comparing the fringe displacement of the large loop to that of the calibration loop, the effect of the earth's motion (through the aether) was to be discovered. This setup is depicted in figure 4.

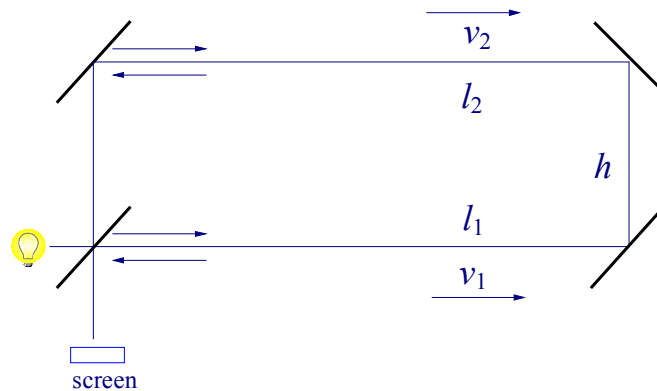


Figure 4. The Michelson-Gale Experiment

Unlike the Michelson-Morley interferometer, this experiment did not produce null results—a displacement was observed, and that displacement was closely related to the rotational velocity of the earth, apparently lending support to aether theories. Here we will show that, *without the initial assumption of an aether, the Michelson-Gale experiment proceeds quite naturally in a Galilean framework.*

Since the equipment is very large, and is located on the earth, the long legs of the equipment are not equal (adjustments of the mirrors compensated for this), nor is their velocity equal. If ϕ_2 is the latitude of the top leg, and ϕ_1 is the latitude of the lower leg, then we have the following, where v_0 is the rotational velocity of the earth at the equator:

$$\begin{aligned} l_1 &= l_0 \cos \phi_1 & l_2 &= l_0 \cos \phi_2 \\ v_1 &= v_0 \cos \phi_1 & v_2 &= v_0 \cos \phi_2 \end{aligned} \quad (15)$$

Now, as light makes its way around the circuit, one beam clockwise and the other counter-clockwise, there is a difference in the time to complete these trips, due to the different velocities and lengths, even in the frame of the apparatus. As with the Sagnac experiment, if one is on the apparatus on a south-leg mirror, the north-leg mirror will appear to have a linear velocity with respect to the south leg mirror. This is again due to the rotational nature of the equipment, this time due to the unequal rotational velocities as seen from different latitudes. Once again, the second-order and higher effects are too far below the limits of experimental error to be determined.

The difference in travel time for each beam was derived and is given by (19):

$$dt = \frac{4A\omega}{c^2} \sin \phi \quad (19)$$

Now, the shift in fringe pattern due to differing arrival times of (19), as compared with the control loop of the experiment, is given by:

$$dN = \frac{dt \cdot c}{\lambda} = \frac{4A\omega}{\lambda c} \sin \phi \quad (20)$$

This is the exact result obtained by Michelson and Gale, and is obtained without invoking an aether, time dilation, length contraction or General Relativity. While the example could have been handled with identical results by simply projecting the area of the apparatus onto a plane normal to the rotation axis, it is better to show the analysis in terms of the apparatus itself. In this way one eliminates claims that the projected area is in no way related to the actual apparatus, or that GRT is required to accurately describe the effects of the projection itself.

Summary. We have seen how the initial assumption of the existence of an aether led to more and more corrections to the theory to explain continually improved experiments. In the end, Einstein did away with the aether—and was left only with the “corrections” to Galilean theory. This paper, especially in connection with [1] and [2], has shown that *none of these corrections are necessary.* Thus, through a strange series of bad assumptions and faulty interpretations, Einstein was led to Special Relativity Theory, a

theory which provides a mathematical equivalence to the areas to which it is applied, but which is based on faulty underlying principles. How much simpler it is to go back to first principles when experiment contradicts theories, rather than to keep building “castles in the air” to rescue a doomed theory. ♦

References

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