**Lorentzian Ether Theory**

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# 1 Background

What is light? There are many ways that we can describe the properties of light: it has colors, it warms things, it passes through glass etc., but this doesn't really help us understand what it is. There is one incredibly simple experiment that does provide some insight into the nature of light; it is called the dual-slit experiment. In this experiment, a beam of light passes through two parallel thin slits in a wall and projects onto a flat screen on the other side. The screen then shows a pattern of brightness and darkness that exactly corresponds to the peaks and troughs of waves. This result suggests that light is actually a wave, which is a conclusion that is supported by many additional experiments and equations.

If we do assume that light is a wave, then this raises an important question: what is doing the waving? In the ocean, water is waving; with sound, air is waving—but light can propagate through empty space! Clearly light is a different kind of wave, unlike ocean waves and sound waves which can only exist in matter. Whatever is doing the waving for light must be something we cannot directly detect, but despite our ignorance of its nature, we give it a name: ether.

For a while, scientists believed that this ether provided a fixed frame for light to travel through at constant velocity. But then a problem arose. The Michelson-Morley experiment found that the round-trip speed of light is measured to be the same in all directions. So since it is very unlikely that the Earth is exactly stationary in the ether, this implies that the velocity of a light source does not affect the measured round-trip speed of light. This was a surprising result because if light is travelling at a constant velocity in the ether, you would expect to see a difference in the measured speed of light in different directions due to your own velocity in the ether. But as we will see in the next section, there is a solution to this problem that can save the ether theory. Despite this victory, ether theory has been subjected to many more attacks, which some believe disprove the existence of the ether. However, as we will see in this paper, it is not too easy to falsify Lorentzian ether theory.

In fact, according to the Wikipedia article entitled "Lorentz ether theory", the properly modified form of ether theory is experimentally indistinguishable from Einstein's relativity. However, this doesn't mean that the question of the existence of the ether is meaningless. There are significant conceptual differences between the two theories and it is important to decide which theory makes more sense based on which makes it easier to understand the universe.

One phenomenon that could be used as an argument in favor of the ether is the Sagnac effect. This effect is observed by using a beam-splitter to send a beam of light in two different directions around a sequence of mirrors arranged in a polygon on the perimeter of a table. The beams then leave the loop and interfere on a screen to determine if one direction took longer than the other direction. When the table is spun in circles, the interference pattern obtained depends on the angular velocity of the spinning motion. This is no experimental error, the Sagnac effect is currently being used in ring-laser gyroscopes on modern jet planes for navigational purposes. So we can say that the universe does have a preferred rotational reference frame for light, just as it does for mechanical motion. This makes it more reasonable to believe that it also has a preferred reference frame for linear propagation of light, even if such a frame is undetectable.

# 2 The Model

We assume that there is a frame of reference (the ether frame) in which light travels at a constant speed in every direction. We also assume that time dilation and length contraction actually physically occur. So in a frame that is moving with respect to the ether, matter is contracted along the direction of motion and all processes go slower.

The assumption of time dilation and length contraction may seem ad hoc, but there is actually some justification for it. Due to the fundamental assumption of the uniform speed of light in the ether, the round-trip speed of light is reduced in moving frames. The speed increases by a constant term in one direction and decreases by the same amount in the other direction, but these two shifts do not cancel. The light spends more time in the slower direction, so the round-trip speed ends up being slower.

Now according to Quantum Field Theory, all particles are waves, just like light. So within our ether model, we may assume that particles are merely ripples in the ether and that particle motion is a result of the propagation of these ripples. If the ether is supporting this wave motion, there must be some way that the oscillations of the waves are transmitted from one part of the ether to neighboring parts. It is natural that this transmission would proceed at a rate that depends on the speed of light since that would explain why the speed of light is the cosmic speed limit for everything. So in a frame that is moving with respect to the ether, the speed of ripples in the ether would be affected by the decrease in the round-trip speed of light within that frame. This explanation omits any consideration of why the round-trip speed is of fundamental importance, but it gives some plausibility to the idea that particle velocities would be slower in a frame moving with respect to the ether.

Also, we know from particle physics that the four fundamental forces are mediated by force-carrier particles (except perhaps gravity since the graviton has not yet been discovered). If each force carrier particle delivers a finite impulse, the strengths of the forces would scale with the speed of light. If we assume that the strength scales with the round-trip speed of light, then all physical processes based on the four forces will slow by the same amount as particle velocities. Therefore, all possible ways of measuring time would slow and you wouldn't be able to tell locally.

Length contraction is also plausible based on the fact that light travels at a different round-trip speed in the direction motion with respect to the ether. All the ripples in the ether would be squished due to this asymmetry. You can picture this by imagining the concentric circles created by a rock dropped in a pond and then imagining that the waves travel faster in one direction than the other, creating oval-shaped patterns instead of the usual circles. Therefore the lengths of all physical objects would be contracted along this direction.

## 3 Light Clocks

A light clock is a device that measures time by bouncing a pulse of light off a mirror at a fixed distance and measuring how long it takes for the beam to make a round trip.

Let's consider a light clock travelling at speed $w$ with respect to the ether. For a light clock oriented so that the light pulse travels parallel to the direction of travel through the ether, the real duration of a full cycle is

$$T_0^{\|} = \frac{L_0}{c-w} + \frac{L_0}{c+w} = L_0\left(\frac{c+w+c-w}{c^2-w^2}\right) = \frac{2L_0}{c}\frac{1}{1-\frac{w^2}{c^2}}$$

In this paper, we use the notation $X_w$ to refer to the value of quantity $X$ as measured from a frame travelling at velocity $w$ with respect to the ether.

For a light clock oriented so that the light pulse travels perpendicular to the direction of travel through the ether, the real duration of a full cycle is

$$T_0^{\perp} = \frac{2\sqrt{x^2+y^2}}{c}$$

where $y$ is the length of the light clock and $x$ is the distance the clock travels in one half cycle of a light tick. But $T_0^{\perp}$ can also be written as $T_0^{\perp} = 2x/w$ so

$$\frac{x^2}{w^2} = \frac{x^2+y^2}{c^2}$$

$$x^2\left(1-\frac{w^2}{c^2}\right) = \frac{w^2}{c^2}y^2$$

$$x = \frac{w}{c} \frac{y}{\sqrt{1 - \frac{w^2}{c^2}}}$$

$$T_0^{\perp} = \frac{2x}{w} = \frac{2y}{c} \frac{1}{\sqrt{1 - \frac{w^2}{c^2}}}$$

Now we assume a time dilation given by

$$T_0 = \frac{T_w}{\sqrt{1 - \frac{w^2}{c^2}}}$$

and length contraction given by

$$L_0 = L_w \sqrt{1 - \frac{w^2}{c^2}}$$

So in the local frame of reference, we have

$$T_w^{\|} = T_0^{\|} \sqrt{1 - \frac{w^2}{c^2}} = \frac{2L_0}{c} \frac{1}{\sqrt{1 - \frac{w^2}{c^2}}} = \frac{2L_w}{c}$$

This is exactly the same form as we would expect if we were at rest with respect to the ether.

Similarly,

$$T_w^{\perp} = T_0^{\perp} \sqrt{1 - \frac{w^2}{c^2}} = \frac{2y}{c}$$

Again, this is exactly what we would measure in the ether frame. Therefore, it is not possible to distinguish between ether theory and relativity theory with simple round-trip light measurements. [1]

# 4 The One-way Speed of Light

According to Lorentzian ether theory, the pulse of light in the parallel light clock is going to take longer going one direction than the other. One could say that half of the light's trip is against the "ether wind" and the other half is with the "ether wind". This appears to provide a simple method for determining the clock's velocity with respect to the ether. If we could just measure the one-way speed of light in each direction and compare, we could get the parallel component of the clock's ether velocity.

There is a complication with this experiment, however. The only way to measure the one-way speed of light is with some kind of clock, and in order to compare the velocities in the two directions, you need two clocks at separate locations that are synchronized. If the clocks weren't synchronized, then we wouldn't know how long ago the other end emitted its pulse.

The most obvious method is to synchronize two clocks in one location, then transport one of the clocks to a remote site (slow-clock transport synchronization). We can move the clock at an infinitesimal velocity to minimize time-dilation effects. But as we'll show below, the transported clock will still pick up a time-shift that exactly cancels the time shift that we would expect from the differing relative velocities of light.

So if we can't transport the clocks, the only other option is to synchronize the clocks after they are in their desired locations (remote synchronization). One way to do this is with a slowly moving rod. We make an extremely long rod and tell a collaborator to go to the other end. After receiving a signal indicating that they have arrived, we pull the rod back and slowly push it forward again. When the rod passes its original location, we each transmit a light signal to the other and start a clock. When we receive the signal from the other end, we stop the clock. After writing down these start and stop times, we reunite and compare our delay times. The problem is that the slower you push it, the longer it will take to make up for the length contraction that occurs. The shift in time produced exactly cancels out the expected discrepancy.

[1] We have not shown that this works for arbitrary angles.

First let's find out what we expect to get. Let "upwind clock" refer to the clock that is farther in the direction of travel with respect to the ether. In order to prevent any detectable discrepancy in the one-way speed of light, we must have an upwind time shift of

$$\Delta S_0 = \frac{L_0^{(w)}}{c-w} - \frac{L_0^{(w)}}{c+w} = L_0^{(w)}\left(\frac{(c+w)-(c-w)}{c^2-w^2}\right)$$

$$= \frac{L_0^{(w)}}{c}\left(\frac{2w/c}{1-\frac{w^2}{c^2}}\right)$$

where the superscripts on the lengths indicate the ether velocity of the object being measured. The quantity $\Delta S_0$ refers to the shift in the timing of events. A positive value means that the upwind clock should show an earlier time. This makes that clock send its pulse later in absolute time according to the predetermined start time, which cancels out the fact that its signal travels faster relative to the lab frame. Notice the sign difference between the change in clock time versus the change in event time: $\Delta T_0 = -\Delta S_0$.

## 4.1 Slow-Rod Synchronization

Let $v$ by the velocity of the rod in the lab frame and let $w$ be the velocity of the lab frame with respect to the ether. We use the notation $L_0^{(w+v)}$ to denote the contracted length of the rod when moving at velocity $v$ in the lab frame, as measured from the ether frame. This contraction is relative to the length used to determine how far away the collaborator would be waiting, which is $L_0^{(w)}$. The rod will take longer to reach the far end and shorter to reach the near end due to length contraction. The time shift can be calculated as the length difference divided by the velocity $v$, then multiplied by two since the shift is applied to both the near end and the far end.

$$\Delta S_0 = \frac{2\Delta L_0}{v} = 2\left(\frac{L_0^{(w)} - L_0^{(w+v)}}{v}\right) = \frac{2L_0^{(0)}}{v}\left(\sqrt{1-\frac{w^2}{c^2}} - \sqrt{1-\frac{(w+v)^2}{c^2}}\right)$$

Now we expand the second square root as a power series in $v$.

$$= \frac{2L_0^{(0)}}{v}\left(\sqrt{1-\frac{w^2}{c^2}} - \left(\sqrt{1-\frac{w^2}{c^2}} + \frac{1}{2}\left(\frac{-2w/c^2}{\sqrt{1-\frac{w^2}{c^2}}}\right)v + O(v^2)\right)\right)$$

In the limit $v \to 0$,

$$\Delta S_0 = \frac{2L_0^{(0)}}{c}\left(\frac{w/c}{\sqrt{1-\frac{w^2}{c^2}}}\right) = \frac{L_0^{(w)}}{c}\left(\frac{2w/c}{1-\frac{w^2}{c^2}}\right)$$

This is the time shift needed to cancel out observable discrepancies in the one-way speed of light.

## 4.2 Slow-clock Transport Synchronization

What if we synchronized two clocks in one location and then transported one clock slowly to a distant location? Even when the clock is moving slowly, we still pick up a time shift during the motion. Say the transported clock moves with velocity $v$ in the lab frame and the lab frame moves with velocity $w$ with respect to the ether. Later we will take the limit as $v \to 0$ to eliminate relativistic corrections. We begin by calculating the time shift $dS$ that occurs when the clock is moved a distance $dx$ at velocity $v$. We calculate in the reference frame that both clocks will be in when the experiment starts, which is moving at a velocity $w$ with respect to the ether.

$$dT_w = dT_{w+v}^{(w+v)} - dT_w^{(w)} = dT_0^{(w+v)}\sqrt{1-\frac{(w+v)^2}{c^2}} - dT_0^{(w)}\sqrt{1-\frac{w^2}{c^2}}$$

Assuming $v$ is the same in both reference frames to first order in $v$,

$$= \frac{dx_0^{(w+v)}}{v}\sqrt{1-\frac{(w+v)^2}{c^2}} - \frac{dx_0^{(w)}}{v}\sqrt{1-\frac{w^2}{c^2}}$$

Now we have,

$$x_0^{(0)} = \frac{x_0^{(w)}}{\sqrt{1-\frac{w^2}{c^2}}} = \frac{x_0^{(w+v)}}{\sqrt{1-\frac{(w+v)^2}{c^2}}}$$

Therefore,

$$dT_w = \frac{dx_0^{(w)}}{v}\left(\frac{\sqrt{1-\frac{(w+v)^2}{c^2}}}{\sqrt{1-\frac{w^2}{c^2}}}\sqrt{1-\frac{(w+v)^2}{c^2}} - \sqrt{1-\frac{w^2}{c^2}}\right)$$

$$= \frac{dx_0^{(w)}}{v}\frac{1}{\sqrt{1-\frac{w^2}{c^2}}}\left(\left(1-\frac{(w+v)^2}{c^2}\right) - \left(1-\frac{w^2}{c^2}\right)\right)$$

$$= \frac{dx_0^{(w)}}{v}\frac{1}{\sqrt{1-\frac{w^2}{c^2}}}\left(1-\frac{w^2}{c^2}-\frac{2wv}{c^2}-\frac{v^2}{c^2}-1+\frac{w^2}{c^2}\right)$$

$$= dx_0^{(w)}\frac{1}{\sqrt{1-\frac{w^2}{c^2}}}\left(-\frac{2w}{c^2}-\frac{v}{c^2}\right)$$

In the limit $v \to 0$,

$$dT_0 = -\frac{dx_0^{(w)}}{c}\frac{2w/c}{\sqrt{1-\frac{w^2}{c^2}}}$$

Converting to ether coordinates,

$$dT_0 = \frac{dS_w}{\sqrt{1-\frac{w^2}{c^2}}} = -\frac{dx_0^{(w)}}{c}\frac{2w/c}{1-\frac{w^2}{c^2}}$$

Now we integrate over the whole distance the clock travels, call it $L_0^{(w)}$,

$$\Delta T_0 = \int_{x=0}^{x=L_0^{(w)}} dT_0 = -\frac{L_0^{(w)}}{c}\frac{2w/c}{1-\frac{w^2}{c^2}}$$

And finally,

$$\Delta S_0 = -\Delta T_0 = \frac{L_0^{(w)}}{c}\frac{2w/c}{1-\frac{w^2}{c^2}}$$

Again, this is the time shift needed to cancel out observable discrepancies in the one-way speed of light.

# 5 Conclusion

Based on the simple experiments described, we have not yet found a way to distinguish between Einstein's relativity and Lorentzian ether theory. There are further experiments claiming to disprove the ether theory, which will be analyzed in future papers. These experiments include:

- One-way with remote synchronization: light pulses emitted from the midpoint in both directions.

- Round-trip with an extra mirror on the return trip, making a triangle.
- Round-trip with refractive medium on one side.
- Frame comparison (remote observation of time dilation and length contraction might show which is moving faster with respect to the ether).
- Light speed through moving water (Fizeau Experiment)
- A charged parallel-plate capacitor moving through the ether should orient itself perpendicular to the motion. (Trouton-Noble)
- One-way speed of light measured by Doppler shift. (Römer)
- Mossbauer Effect measured with Doppler Effect (Champeney)

## 6 References


- Wikipedia - Lorentz Ether Theory (http://en.wikipedia.org/wiki/Lorentz_ether_theory)
- Ether and the Theory of Relativity by Albert Einstein (http://www.tu-harburg.de/rzt/rzt/it/Ether.html)
- The Sagnac Effect (http://en.wikipedia.org/wiki/Sagnac_effect)
- Classical Electrodynamics by J.D. Jackson (Jackson is careful to never explicitly say that ether theory was disproved.)