Is Time Dilation a scientific theory?

Ziaedin Shafiei
ziaedin@hotmail.com

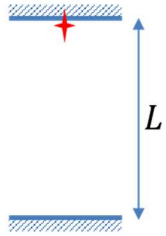
23 October 2017

Abstract
The idea of time dilation was initially proposed by Einstein in 1905[1] as one component/consequence of the theory of special relativity (SR). Based on a thought, not real, experiment it maintains that a light clock which is moving away from an observer with a constant speed, goes slower in comparison with a stationary clock. This slower *tick* is imagined in a clock which is positioned so that the direction of light movement within the clock at rest is perpendicular to the direction of the relative movement of the clock, φ=90°.

It is shown in [2] that the idea of length contraction and time dilation is not supported by Michelson and Morley (M&M) [3] experiment. It is argued further here that the thought experiment did not try, for no obvious reason, to test the clock function in any other angles, *i.e.* φ<90°. It is shown that if the clock so positioned that φ<90° not only the clock on average goes even more slower but also the ticks become irregular. One tick is slower and the following one is faster than the tick of the stationary clock. This irregularity is worse when φ=0°. The first problem can be corrected by another component of SR, namely, length contraction. However, irregular ticks are left untouched by the theory.

Also, in SR the tick of the clock is studied when it only moves away from the observer. Moreover, no associated time delay is considered in the tick. It is shown that a related time delay or time advance must be considered in the ticks when the clock moves away from or returns to the observer, respectively. Time dilation, thus, was proposed based on incomplete analysis of one thought experiment and not all-inclusive analysis of real experiments necessary for developing a scientific theory.

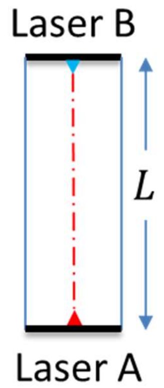
1. - Introduction
Einstein's light clock is not an entirely thought creation device. A famous version of it was built by Michelson and Morley in 1887 which can be considered as two light clocks perpendicular to each other. In principle, LIGO is also a stationary version of M&M clocks. Einstein imagined the clock as simply a pulse of light being bounced between two parallel mirrors L meters apart in vacuum. It is assumed that different observers can easily detect/follow the plain working of the clock. Thus, this appliance has been the clock of choice in special relativity (SR). The way the light moves within a moving clock in vacuum is, however, Einstein's own postulation. It is shown[2] that M&M experiment does not validate time dilation and length contraction.



Thus, then, the constancy of the speed of light was not experimentally proven if the erroneous idea of length contraction was not proposed by FitzGerald and Lorentz to explain away the null result from M&M experiment. For proposing SR Einstein accepted length contraction and added time dilation without proper experimental validation.

The question is: accepting the constancy of the speed of light in vacuum, can we accurately and consistently measure time with this apparatus and propose the idea of time dilation as asserted by SR?

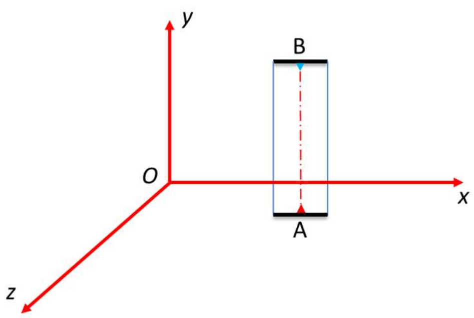
For accurate, high resolution, time measurement the distance between the two mirrors, L, should be as short as possible. Now let us check its consistency?



To study this clock in detail it is better to consider a more elaborated and practical version which is also easier for analysis of its working and can be augmented with counters for better observation. Two lasers **A** and **B** are fixed in the centre of two parallel circular plates in a cylindrical structure with the height of L. Two photocells are also fixed on the insides of the circular plates. We can assume that when the upper plate receives a red pulse in vacuum from laser **A**, laser **B** immediately emits a blue pulse and vice versa, ad infinitum.

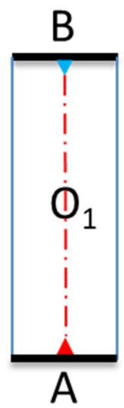
2. Basic Time Measurement

Suppose the clock is at rest, $\boldsymbol{v} = \mathbf{0}$ in all three perpendicular Cartesian directions ($\boldsymbol{x}$, $\boldsymbol{y}$ and $\boldsymbol{z}$). In other words, we assume the clock is put in an inertial reference frame (IRF) and observed from the same frame. The time for the pulse of light to travel between the two plates is $\boldsymbol{L}/\boldsymbol{c}$ ($\boldsymbol{c}$ being the speed of light in vacuum).



2.1. The Effect of Observer Position

Case 1



Suppose the observer is positioned at point O_1 inside the clock which is the middle point on the line between **A** and **B**. Any light pulse from **A** or **B** reaches the observer with a time delay of $L/2c$. The duration between any two consecutive light pulses spotted by the observer is,

$$\mathrm{T_{AB}} = \mathrm{T_{BA}} = L/c$$

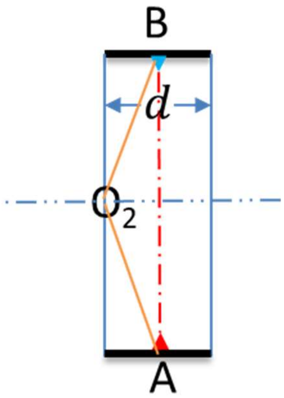
Where $\mathrm{T_{AB}}$ is the time duration measured between observing a flash from A followed by a flash from B. We can call this a tick.

$\mathrm{T_{BA}}$ is the time duration measured between observing a flash from B followed by a flash from A. We can call this a tock.

Case 2

Suppose the observer moves to point O_2 on the middle of a side line. The observer is now outside of the light beam and practically cannot see anything to measure. But if he could see the flashes, they could be observed with a delay of,

$$\frac{L}{2c}(1 + d^2/L^2)^{1/2}$$



which is the duration for light travel along the length of AO_2 or BO_2 lines. However, the duration between the two consecutive light pulses detected by the observer in this new position is,

$$\mathrm{T_{AB}} = \mathrm{T_{BA}} = L/c$$

which is the same as observed in **case 1.**

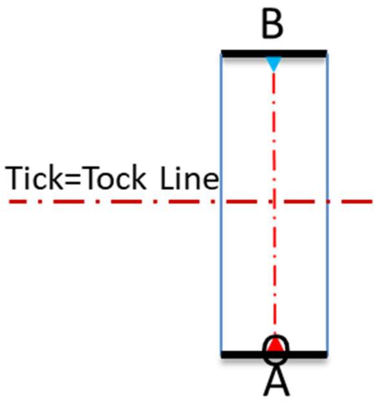
Case 3

Suppose the observer moves to point A. The time intervals between two flashes detected by the observer in this new position is

$$\mathrm{T_{AB}} = 2L/c$$

$$\mathrm{T_{BA}} = 0$$

In general, the time intervals between two flashes seen by the observer in any point inside or outside the clock varies between 0 and $2L/c$. In other words, the duration of a tick is not the same as the duration of a tock in Einstein's clock unless the observer is positioned on a perpendicular line to the laser beams bisecting it at the middle of AB line. Let us call this line the Tick=Tock Line (TETL).



The addition of the two measurements, tick plus tock, however, is constant from any observing point and equals to

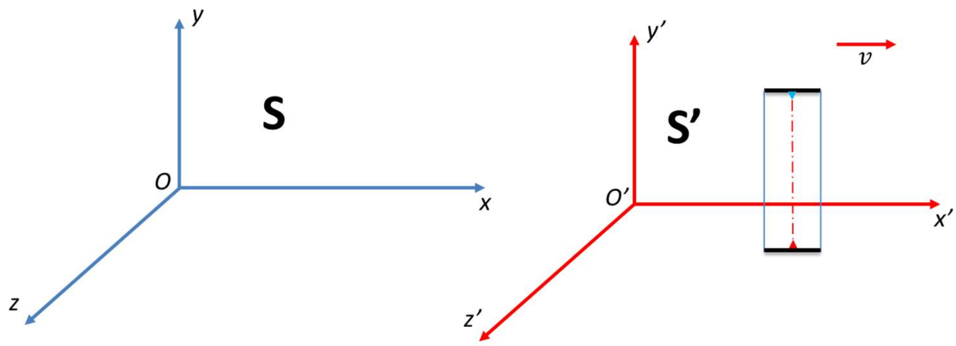
$$T_0 = \mathrm{T_{AB}} + \mathrm{T_{BA}} = 2L/c \qquad \text{(Eq 1)}$$

It can be concluded that an observer positioned anywhere, within the frame of the clock, can only accurately and consistently measure time by observing the duration of two consecutive flashes from the same source (A or B) as a unit of time. Alternatively, the observer should stay on the TETL. The difference between a tick and a tock and the introduction of the TETL for a consistent time measurement thus highlights a limitation of the clock which will be discussed later.

The measurement comes with a delay between a flash and its observation which depends on the distance between the observer and the source of the flash at A or B.

2.2. The Effect of the Clock Movement

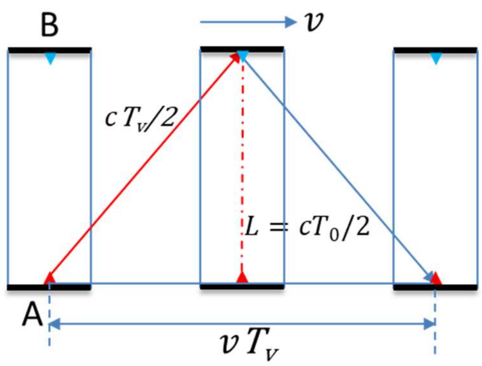
Now we consider two coordinate systems S and S’. They are inertial reference frames (their movements are non-accelerating). Suppose S and S’ move relative to each other with a constant velocity of v. Suppose an observer in S is monitoring the clock in S’.



Case 4 (SR standard position of the clock)

The observer in S sees the light clock moves to the right with constant speed v. It is suggested by SR that for the observer in S the light has to travel longer for the round trip from A to B and back to A as shown

The time for the round trip can be calculated as:



$(cT_v/2)^2 = (vT_v/2)^2 + L^2$

$(cT_v/2)^2 = (vT_v/2)^2 + (cT_0/2)^2$ (from Eq 1)

$c^2T_v^2 = v^2T_v^2 + c^2T_0^2$

$c^2T_v^2 - v^2T_v^2 = c^2T_0^2$

$T_v^2(1 - v^2/c^2) = T_0^2$

$T_v = T_0/(1 - v^2/c^2)^{1/2}$

$T_v = T_0\ \gamma$ (Eq 2)

Where γ is Lorentz factor.

Lorentz factor

$\gamma = 1/(1 - {}^{v^2}/_{c^2})^{1/2}$

$v = 0 \Rightarrow \gamma = 1$

$v = c \Rightarrow \gamma = \infty$

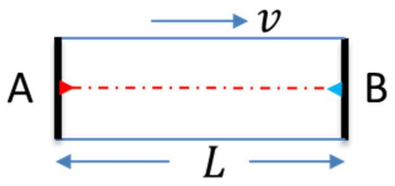
$1 \leq \gamma \leq \infty$

According to SR, Eq 2 indicates that a moving clock runs slower. This is known as time dilation. As the speed of the clock gets closer to the speed of light, the clock appears to run slower and slower until it freezes at $v = c$.

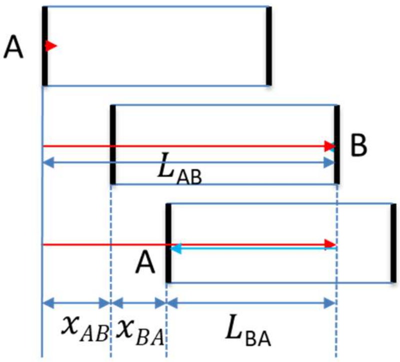
Eq 2 is the standard time measurement between two IRFs. Mathematics of SR also relies on γ for length contraction and relativistic mass variation.

Case 5 (turning Einstein's light clock)

Suppose the light clock is turned 90° so that the direction of beam from A to B is in line with v.



For the observer in S' the unit of time is still the same, T_0. For the observer in S the light has to go longer from A to B and shorter from B to A as shown. From A to B we can write the following equation.



$L_{AB} - x_{AB} = L$

$T_{AB}c - T_{AB}v = cT_0/2$

Therefore, the time interval for light to go from A to B, tick, is

$$T_{AB} = \frac{cT_0}{2(c-v)} \qquad \text{(Eq 3)}$$

From B to A we can write the following equation.

$L_{BA} + x_{BA} = L$

$T_{BA}c + T_{BA}v = cT_0/2$

and thus, the time interval for light to go from B to A, tock, is

$$T_{BA} = \frac{cT_0}{2(c+v)} \qquad \text{(Eq 4)}$$

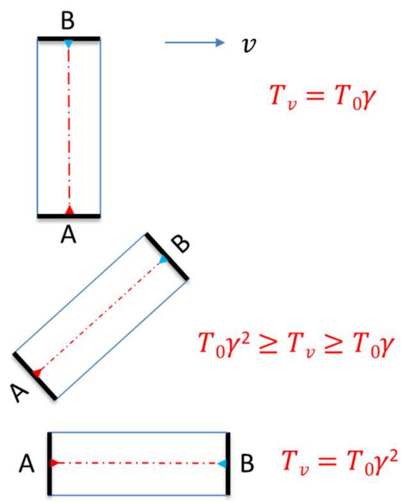
The total time interval for the round trip of light then is

$$T_v = T_{AB} + T_{BA} = T_0/(1 - v^2/c^2)$$

$$T_v = T_0\gamma^2 \qquad \text{(Eq 5)}$$

2.3. The Effect of the Clock Orientation

It is now clear that the average factor of time dilation depends on the orientation of the clock. In other words, the direction of the clock affects the time measurement by the observer in S. The average difference is anything between $T_0\gamma$ and $T_0\gamma^2$ depending on the orientation of the clock.



This issue can be solved by length contraction. It is apparent that if the length of the clock is contracted by a factor of $1/\gamma$ in the direction of its movement Eqs 2 and 5 become equal. Thus, the clock timing should be corrected accordingly, whatever its orientation.

One should note that SR accepts length contraction as a real scientific fact and not a mere trick or deceptive impression. It is definitely not like the illusion of seeing a jumbo jet getting smaller as it flies away from an observer or believing that time freezes if a sand clock rests on its side.

It should be added that length contraction was put forward to justify the existence of aether after M&M null result. George FitzGerald and Hendrik Lorentz wrongly proposed that objects shrink in the direction of their motion relative to aether. In fact, this idea was based on a simple oversight and should not have been proposed in the first place if they had examined the movement of the half-silvered mirror in M&M experiment. This incorrect idea was accepted into special relativity but was defined as shrinking of any physical object when it is moving with a constant speed in relation to an observer. This idea has inherent contradiction as a 1m ruler in one IRF must be, not appears to be, 0.5m according to an observer in a 2nd IRF and 0.5cm, or any other length between 0 to 1m, from an observer in a 3rd IRF depending on their relative speeds! But let us not be distracted by SR paradoxes and get back to the clock.

2.4. Widening Gap Between Ticks and Tocks

It is also evident from Eq 3 and 4 that a tick is not anymore equal to a tock if the clock is not positioned perpendicular to direction of its movement. Depending on the orientation of the light clock and quantity of v, the durations of a tick and a tock of the clock in S' can be enormously different if observed from S. For example, in Case 5 the following inequality holds

$$T_0\,/4\ \leq tock \leq T_0/2\ \leq tick \leq\ \infty$$

Can this issue somehow be fixed as well? Obviously, length contraction cannot fix this issue and no any other solution has ever been proposed or been discussed. In fact, time dilation in SR is only examined when the clock is perpendicular to the direction of its relative motion.

The key question is: does time go slower in one tick and then goes faster in the following one? It does if we accept SR argument for time dilation. It should be added that fast and slow sequences of time is also true according to SR in Case 3. To avoid this uncomfortable issue, SR relies on only one specific orientation of the light clock for time measurement where the durations of ticks and tocks are equal if read from S knowing that the relative speed with S' can be non-zero in any of the three known dimensions of space. The addition of a tick and a tock practically solves the orientation problem of the clock but it cannot explain the widening difference between a tick and a tock.

3. Effect of Delay and Advance

There are two more points which are also not considered in SR and are briefly studied here.

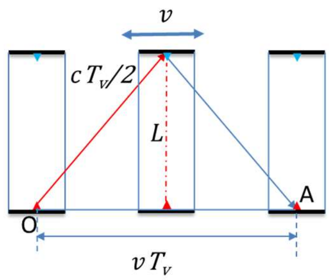
1. All discussions of time in SR is concentrated on the frames S and S' when they are moving away from each other. What happens if the frames are approaching each other?
2. There has been no discussion on the effect of time delay or time advance on the unit of time when a clock is moving away from observer in comparison when it is returning to the

observer. In other words, what is the effect of the direction of the clock movement on time dilation?

3.1. Approaching Frames with Standard SR Clock Position

Suppose the clock is approaching the observer in S. For the observer the unit of time for a returning clock is the same as for the moving away one. But there is a time advance and a time delay in each case, respectively.

Time Delay Between Two Pulses When the Clock is Moving Away



When the clock is moving away from the observer in S, it moves with the speed of v for T_v between two pulses from, say, laser A. Suppose the first pulse is flashed with zero distance from the observer. The second pulse would be $x = T_v v$ away and the time for the second pulse to go from A to the observer is $T_{Delay} = T_v \frac{v}{c}$. Thus, the total time between two pulses from laser A when the clock moves away is:

$$T_{TotalAway} = T_v + T_{Delay} = T_0\, \gamma\, (1+ \frac{v}{c})$$

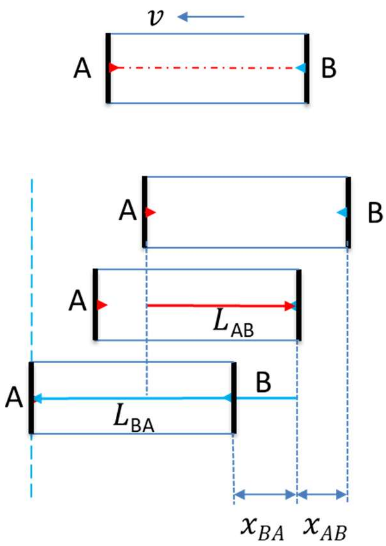
Time Advance Between Two Pulses When the Clock is Returning Back

Likewise, the total time measured between two pulses from laser A by the observer in S when the clock approaches the observer is:

$$T_{TotalReturn} = T_v + T_{Advance} = T_0\, \gamma\, (1- \frac{v}{c})$$

3.2. Perpendicular to Standard Clock Position

If the approaching clock is rotated 90⁰ from the standard position the light has to go shorter from A to B and longer from B to A if monitored by the observer in S.



The time for light to go from A to B or tick is:

$$T_{AB} = \frac{cT_0}{2(c+v)}$$

and the time for light to go from B to A or tock is:

$$T_{BA} = \frac{cT_0}{2(c-v)}$$

returning time is thus

$$T_v = T_{AB} + T_{BA} = T_0/(1 - \frac{v2}{c2}) = T_0\gamma^2$$

Which is the same as the clock moving away with one difference that in this case a tick is shorter than a tock.

Time Delay Between Two Pulses When the Clock is Moving Away

For the observer the clock is moving away with the speed of v for T_v between two pulses from laser A. Suppose the first pulse is flashed with zero distance from the observer. The second pulse is thus $x = T_v v$ away and the time for the second pulse to go from A to the observer is

$$T_{Delay} = T_v \frac{v}{c}$$

The total duration measured by the observer in S is thus:

$$T_{TotalAway} = T_v + T_{Delay} = T_0\, \gamma^2\, (1+ \frac{v}{c})$$

Time Advance Between Two Pulses When the Clock is Returning Back

Similarly, the time advance for the second pulse is

$$T_{Advance} = -T_v \frac{v}{c}$$

And the total time measured by the observer in S when the clock is approaching is

$$T_{TotalReturn} = T_v + T_{Advance} = T_0\, \gamma^2\, (1 - \frac{v}{c})$$

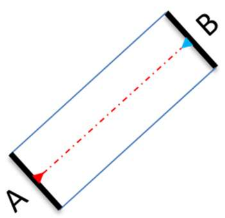
4. Total Time Dilation Factor

Time dilation factor therefore depends on

1. Relative speed between two frames S and S'
2. Orientation of the clock
3. Direction of the movement of the clock

All are significantly affect unit of time, but the last two are neglected in the calculation of time dilation in SR. With the assumption of the constancy of *c* the complete formulas for the averaged unit of time observed in S can be summarised as:

$$T_{Away} = T_0\, \gamma(1+\frac{v}{c})$$
$$T_{Return} = T_0\, \gamma(1-\frac{v}{c})$$



$$T_0\, \gamma^2(1+\frac{v}{c}) \geq T_{Away} \geq T_0\, \gamma(1+\frac{v}{c})$$
$$T_0\, \gamma^2(1-\frac{v}{c}) \geq T_{Return} \geq T_0\, \gamma(1-\frac{v}{c})$$

$$T_{Away} = T_0\, \gamma^2(1+\frac{v}{c})$$
$$T_{Return} = T_0\, \gamma^2(1-\frac{v}{c})$$

SR now needs to reinterpret this phenomenon.

Appendix A shows that a boat clock exhibits the same characteristics of a light clock. Thus, the concept of light clock is not unique or new. It is true that we can ignore time delay and advance in a boat clock case but we cannot do the same for a light clock.

5. Conclusions

Time dilation has been based on examining the working of Einstein's light clock in just one specific position/orientation of the clock, namely the clock must be perpendicular to the direction of its relative speed with the observer. It is shown that the theory does not make sense if the orientation of the clock is changed. In fact, not only the overall/average time dilation factor changes but also ticks are not consistent any more. One slow tick is followed by a fast one. The gap between the two successive time intervals becomes significant as the relative speed between the clock and its observer get closer to *c*. Does time slow down for a while and go super-fast a while later ad infinitum?

SR has a solution for the first problem by accepting length contraction but there is no remedy for irregular ticks.

It is further argued that one more factor is not considered in SR study of time dilation. The theory does not consider any time delay or advance due to the direction of the movement of the clock relative to the observer. It is shown that the direction of the movement also affects time dilation factor.

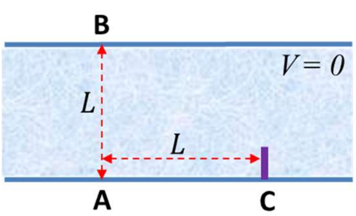
As the theory is based on one condition of light clock in a thought experiment and not all-inclusive real experiments necessary for developing a scientific theory it cannot be regarded as a scientific theory, especially that no real experiment corroborated its initial announcement.

6. References

1. A. Einstein, On the Electrodynamics of Moving Bodies, June 30, 1905.
2. Z. Shafiei, Michelson and Morley Experiment Does Not Validate Length Contraction, **viXra:1709.0261**, 2017.
3. A.A. Michelson, E. Morley, On the Relative Motion of the Earth and the Luminiferous Ether, American Journal of Science, 1887, 34, pp 333–345.

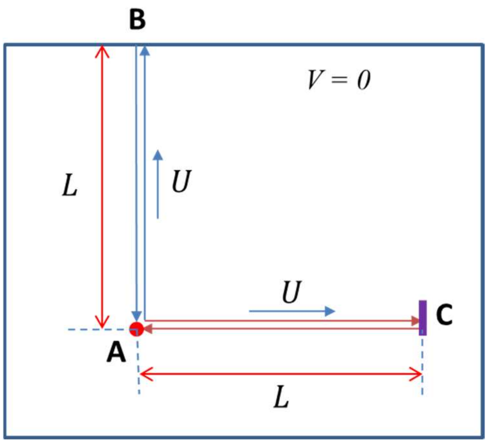
Appendix A: Boat Clock

Consider a canal in which the speed of water flowing through it can be controlled. Initially water is standing still, $V = 0$. Two toy boats repeatedly travel from point A with the constant speed of U for the following two straight round trips.



1. The 1st boat aims to reach point B across the river and return

2. The 2nd boat aims to reach point C in downstream and return



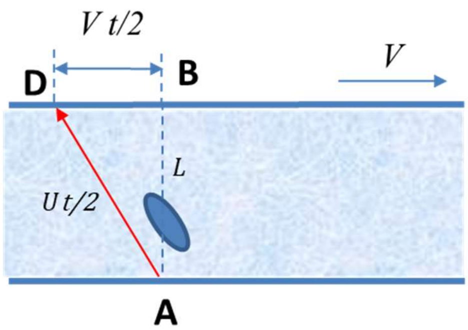
Both trips are observed from the river bank. This setting was considered by M&M to explain the operational principle of the equipment they designed for testing the theory of aether (as a universal fixed reference frame).

Duration of each trip is:

$t_0 = t_{0\,\boldsymbol{ABA}} = t_{0\,\mathbf{ACA}} = 2L/U$

Both boats return to point A at the same time. Generally, the duration of any equal distance round trip is the same in any direction when $V = 0$ and U being constant. This duration can be assumed as the unit of time.

Unit of time in ABA route when water flows



With water flowing at constant speed of V the first boat must proceed at the direction of line **AD** (at an angle of φ to the left of vertical line **AB**) to be able to reach point **B** in a straight line. The same angle applies to the return trip.

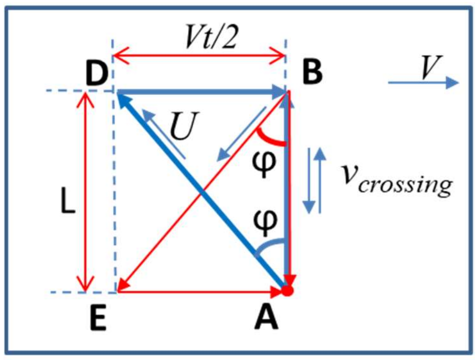
The following equation can be used for the calculation of a new unit of time for a boat clock:

$U^2t^2 - V^2t^2 = 4L^2$

$t^2(U^2 - V^2) = 4L^2$

The increased unit of time thus is

$t_{\mathbf{ABA}} = t_{\mathbf{AB}} = t_{\mathbf{BA}} = \frac{2L}{U}/\sqrt{1\text{-}\, V^2/\, U^2}$



And its relation to the proper time, t_0, is

$t_{\mathbf{ABA}} = t_0/\sqrt{1\text{-}\, V^2/\, U^2}$

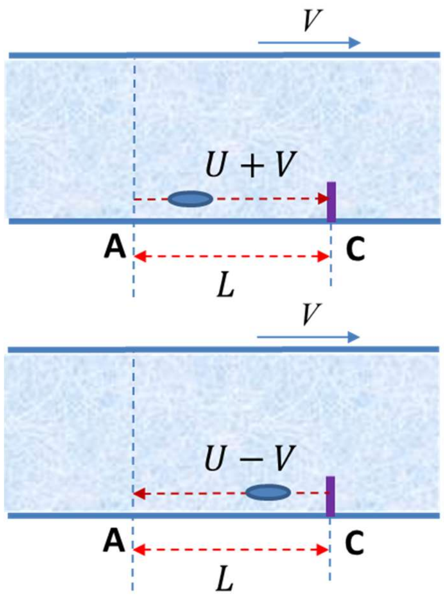
The above formula is a familiar expression in special relativity, used in time dilation and length contraction

$T = T_0/\sqrt{1\text{-}\, v^2/\, c^2}$

Unit of time in ACA route when water flows

The duration of **A** to **C** trip is $t_{\mathbf{AC}} = \frac{L}{U+V}$

and the duration of **C** to **A** trip is $t_{\mathbf{CA}} = \frac{L}{U-V}$



Duration of a return trip is

$t_{\mathbf{ACA}} = t_{\mathbf{AC}} + t_{\mathbf{CA}} = \frac{L}{U+V} + \frac{L}{U-V} = \frac{2L}{U^2-V^2} = \frac{2L}{U}/(1- V^2/ U^2)$

And its relation to the proper time, t_0, is

$t_{\mathbf{ACA}} = t_0/(1- V^2/ U^2)$

Which is similar to the formula for time dilation due to the light clock moving with speed v along the direction and then opposite of light.

$T_v = T_0/(1 - {v^2}/{c^2})$

Relation between the two units of time

The relation between the two different time durations is

$t_{\mathbf{ACA}} / t_{\mathbf{ABA}} = 1/\sqrt{1- V^2/ U^2}$

Which is similar to the relation between units of time of light clocks in the two perpendicular directions.

It can be concluded that the working principle of the light clock used in relativity is the same as the boat clock where a toy boat goes back and forth with the *constant* speed U from bank to bank or between two points along the canal (a downstream-upstream route).

Similar to the light clock one can, at least in theory, use the repeating travel of the toy boat as a clock. When water in the canal is not flowing ($V = 0$) then one can use the duration of each journey as the unit of time, t_0 (proper time). With water flowing with a constant speed then the duration of the trips changes and this fact is nothing to do with length contraction or time dilation. Simply the clock is sensitive to the flow of water in the canal and it is not a good choice for time keeping.

The comparison is not in any way the proof of constancy of the speed of light just to show the concept of light clock is not unique.