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Criticism of the moving light clock

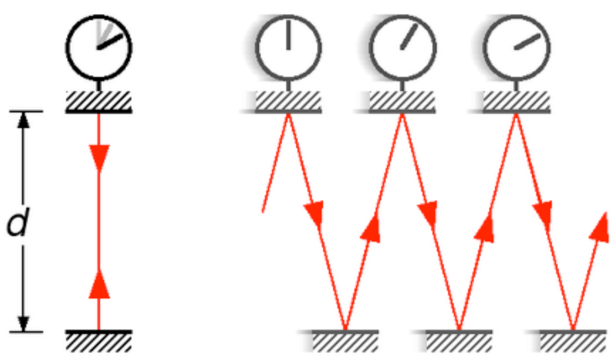
(On the didactics of special relativity)

1 The popular scientific explanation of the special theory of relativity is based on a "light clock". In it, a photon at the tip of a light beam oscillates up and down between two mirrors. It is a measure of space (the distance between the mirrors) and time (the time it takes the photon to reach the other mirror).

Two observers S and S', each equipped with a light clock, move past each other at the uniform relative speed v. At the moment of their encounter the observer S switches on his light clock and emits the photon to their other end. Now the question is asked how the observers S and S' "see" this photon. What is meant by this is the question how they record the events of the presence of the photon at a certain time at a certain place in their coordinate systems S or S' (a photon cannot be "seen" from the side).

The decisive point of view in this question is that an observer basically relies on the display of a light clock at rest when making a distortion - regardless of which aids he uses (primordial meter, atomic clock etc).

From the viewpoint of the observer S, where the light clock S is at rest, the photon oscillates up and down the short path d. From the point of view of the relatively moving observer S', the photon describes a longer zigzag path in the light clock S moving past him:



Source: https://de.wikipedia.org/wiki/Zeitdilatation#Lichtuhr).

The propagation of the photon S between the mirrors of the Lightwatch S (a clock of this Lightwatch) defines a process between two events (emission and arrival). The distance d divided by the "speed of light" gives the time t that light needs from the point of view of the system S to travel the distance d.

According to the basic assumption of the special theory of relativity, the constancy of the "speed of light" (hereinafter: c), the propagation of the photon S occurs from the point of view of the observer S as well as from the point of view of the observer S' with c. The relative velocity v of the observer does not add up to c. From the point of view of the observer S', however, the inclined path to be covered is longer. The photon can no longer travel this path in the time span t, but only in the correspondingly longer time span t'. One and the same process takes longer from the point of view of one observer S' than from the point of view of the other. This is the consequence claimed by the special theory of relativity. It revolutionizes the meaning of the terms space, time and speed. However, this only becomes comprehensible in its full extent when one tries to calculate the extension of the process duration.

2. for a calculation, one will probably first rely on the familiar Newtonian mechanics.

From the point of view of the observer S, the velocity vector of the relative motion of the other observer S' along the motion axis with the magnitude v and the velocity vector of the photon S perpendicular to it with the magnitude c are given. According to Newtonian mechanics, the difference between these two vectors results in the photon path - now from the point of view of the system S' - as a velocity vector inclined to the axis of motion with an amount greater than c. We correct this amount to c. The longer oblique path divided by c would give the longer time t'.

On closer inspection, however, this thought alone does not lead to the goal. If from the point of view of the system S' the longer time t' passes, the Lightwatch also moves away by the longer distance v*t'. Therefore, a photon propagating in the direction of the aforementioned Newtonian difference vector with c would miss the upper end of the light clock. This would be a contradiction, because if an event (the arrival of the photon at the top of the Lightwatch) takes place from the point of view of the system S, then it must also take place from the point of view of the system S'.

Thus, from the point of view of the system S', not only time but also the direction of the photon orbit - in other words, space - must be transformed differently from Newtonian mechanics.

The actual inclination and the actual length of the photon's path from the observer's point of view S' results from three conditions:

(a) Any energetic effect propagation is done from the point of view of all observers with c Each photon propagates from the view of all observers with c. Since the photons propagate in the same way in all light clocks, time passes in the same way for all (unaccelerated) observers.

b) The distance between the upper and the lower mirror of the Lightwatch S, which is perpendicular to the axis of movement, is of equal length when viewed alternately (at right angles to the axis of movement, the spatial distances are equal from the point of view of both observers).

(c) The relative speed of the two observers is equal when viewed mutually (symmetry).

From the point of view of the system S the following process is defined: a propagation of its photon S with c over the length d of the light clock, perpendicular to the axis of motion. The process time t is given by d divided by c. Furthermore, the relative velocity v of the other observer S' is given.

From the point of view of the system S' the photon S propagates with c (condition a), the light clock standing perpendicular to the axis of motion (moved from his point of view) has the length d (condition b) and the other observer S has the relative velocity v (condition c). The photon S must reach the upper end of the light clock, which moves along with the observer S' (a defined event must take place from the viewpoint of all observers). The distance between the two observers on the one hand and the distance between the observer S' and the upper end of the light clock on the other hand develop in the course of the motion sequences during the time span t' in such a way that the photon S also rises vertically above the other observer S from the viewpoint of the observer S'. From the right-angled triangle with the sides v*t' and c*t' and the hypotenuse c*t', it can be seen that the process duration t' is 1/sqr(1-v2/c2) longer than the process duration t by the so-called "Lorentz factor" (see appendix for details).

The process defined above, now recorded from the point of view of System S', takes longer. The distance between the two observers reached during the process duration t from the viewpoint of the observer S is the product of the relative velocity v and the process duration t. The distance between the two observers reached during the process duration t' from the point of view of the observer S' is the product of the relative velocity v and the process duration t' and thus longer. Thus, observers have different views not only on the duration of the process ("time dilation"), but also on how far apart they are when an event occurs ("space contraction").

If the metaphor of "time passing differently" were legitimate, one would have to claim that in the case of an observer at rest - from the point of view of his system S' - time passes all the faster the greater the relative speed of the observer at which the defined process takes place. In contrast, popular scientific explanations claim that time passes more slowly with a moving observer. The apparent contradiction results from the fact that the metaphor is not justified (see below).

3. the right-angled calculation triangle for the derivation of the transformation formula can also be captured intuitively. The mutual "observing" of the emitted photon in the Light Clock S can be thought as if the observers would each emit one photon in suitable directions at their encounter in such a way that the two photons, which are subject to the absoluteness of the propagation of the effect, propagate together with c forever.

The easiest way to achieve this is to emit the two photons along the common axis of motion of the observers. The photons, which cannot overtake each other, they spread out together along the axis of motion.

If, from the point of view of the system S, the photon S is emitted perpendicular to the axis of motion at the time of the encounter, the observer S' must emit his photon S' in an oblique direction matching the relative velocity v so that the photons S and S' propagate together in the course of the time t'. The axis of motion, the light clock set up perpendicular to it and the path of the photon S' form the sides of the right-angled calculation triangle.

4. the absoluteness of the propagation of effects (the "speed of light" c) is above all physical terms. Space, time and speed are only derived from it. In this respect it is the "pivot of the world". If c = "1", the velocity v has a value between 0 and 1 (it is a percentage of the

"velocity of light"). The above transformation formula is simplified by dropping c to t' = t/sqr(1-v2).

5 Unfortunately, popular scientific explanations of the extension of the process duration t' from the point of view of the observer S' suggest that time would pass more slowly by the Lorentz factor for the (unaccelerated) observer S. "The faster the observer S moves, the slower time passes for him. " "At very high speeds v, time almost stops" (cf. M. Carrier, Raum-Zeit, Berlin/New York: Walter de Gruyter (2009), 35). "Moving clocks go slower" (University of Vienna, F. Embacher, "Zeitdilatation"; http://homepage.univie.ac.at/franz.embacher/SRT/Zeitdilatation.html). "Jill is aging more slowly because she's moving!" (University of Virginia, M. Fowler, Galileo and Einstein, Special Relativity: What Time is it?; http://galileo.phys.virginia.edu/classes/109.mf1i.fall03/lectures09.pdf).

This view is in contradiction to the above basic assumption (condition a) that time passes in the same way for each (unaccelerated) observer. That the passing of time cannot be touched by a uniform motion is already evident from the fact that, at the same relative speed, depending on the orientation of the light clock of the observer S', there are an infinite number of possible relations between the time spans of the duration of a certain process t and t', especially also those where the time span t' becomes shorter than the time span t. The heterogeneity of these time effects excludes the possibility of interpreting them as a uniform slowing down of the passage of time in the "moving" reference system.

Even popular scientific animations, in which a flashing light clock perpendicular to the direction of movement gives the impression that the resting observer can watch time pass more slowly when the observer is in motion, do not alter the contradiction in the claim that time passes more slowly. All clocks of his system are supposed to be affected by this slowdown (see e.g. M. Pössel, "Von der Lichtuhr zur Zeitdilatation" in: Einstein Online Vol. 04 (2010), 1101; _COPY2@set_language=de.html; "From my point of view, the moving Lightwatch is obviously much slower than my own, identical Lightwatch. (...) Judging from my space station, all clocks of the space station moving relative to me run slower than my own clocks. Just as the moving clocks go slower, so all the processes on the other space station go slower for me - five-minute eggs cook longer and still have the right consistency in the end, and the pianist on board the other station who plays the Minute Waltz takes much more time for it than is usual in performance practice. ").

The oblique light paths that the observer S' "sees" in this example come from a photon emitted by the observer S normal to the axis of motion and which triggers a flashing signal when it returns to him. Each flashing signal is plotted according to the Lorentz transformation according to time and place in the coordinate system of the observer S'. With increasing relative velocity, the light paths and thus the time intervals between the flashes (as above, the time interval t' is longer than the defined time interval t) from the point of view of the observer S'.

However, the reduction in frequency of the flashing signals associated with the increase in relative velocity is nothing other than the (relativistic) transverse Doppler effect from the point of view of the observer S'. A Doppler effect has nothing to do with another passing of time in the sphere of the uniformly moving object. It occurs reciprocally among the observers without distinguishing one of them (principle of relativity). In none of them does time pass more slowly as a result. One cannot seriously claim that time would pass more slowly in a moving ambulance with a follower horn, because one hears the tones lower.

The Lorentz transformation leaves the flow of time untouched. After all, time is not a substance that could pass more slowly or more quickly. The results of the thought experiment speak for the correctness of Leibniz's view that time is a relation (see *S. Clarke*, Der Briefwechsel mit G.W. Leibniz von 1715/16, Übers. *Ed Dellian*, Hamburg, mine (1990)).

10.1.2020

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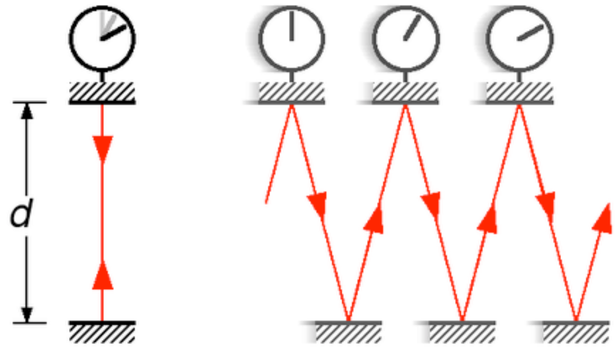
Annex:

German Wikipedia edition:

https://de.wikipedia.org/wiki/Zeitdilatation#Lichtuhr

per 17.7.2019

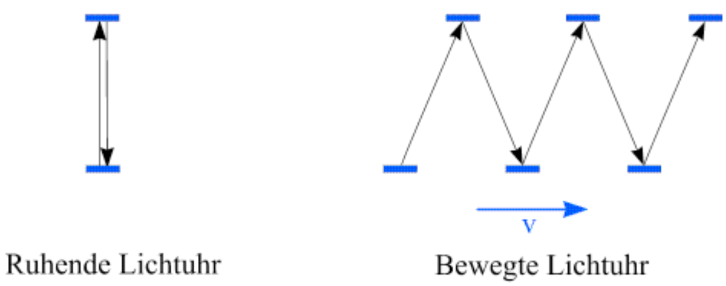


"If a light clock A [resting in system A] is given, from the point of view of an observer moving with it (i.e. resting relative to it) [from the point of view of system A] a flash will need the time $T0 = d/c$ for the simple path between the mirrors. (...) If a second light clock B [the light clock resting in the other system B, which is now observed from system A] is moved perpendicular to the connecting line of the mirrors at the speed v, the light must travel a greater distance between the mirrors from the point of view of the A observer than in clock A. Assuming the constancy of the speed of light, **clock B is** therefore **slower than clock A** for the A observer. The time $T' = d'/c$, which the flash of light needs for the simple path d' between the mirrors, is calculated using Pythagoras' theorem $d'^2 = d2 + (vT')^2$. By inserting the expressions for d and d' and resolving to T' one finally obtains $T' = T0 * 1/sqr(1-(v/c)^{2)}$ (...).".

Franz Embacher, Vienna University:

https://homepage.univie.ac.at/franz.embacher/SRT/Zeitdilatation.html

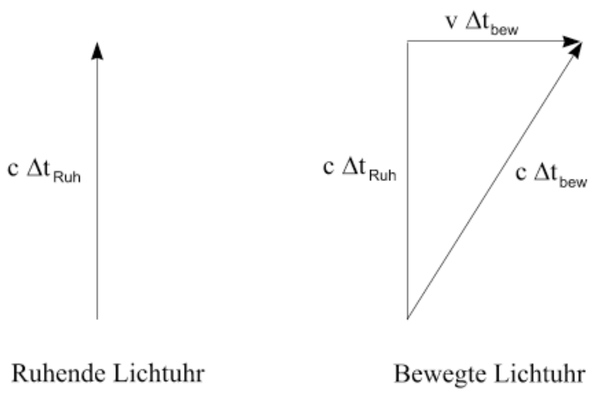
per 17.7.2019



"The graphic on the left shows the Lightwatch from the standpoint of an observer at rest opposite it, i.e. from the standpoint of its resting system. We now ask how the same process looks like in an inertial system [from the point of view of the system S'], where the direction of motion is supposed to be transverse to the direction of the photons. For an observer in this new system [from the point of view of system S'], the Lightwatch is moving, and we denote the value of its speed with v. The photons will move along slanting paths in the moving system [from the point of view of system S'] - this is shown in the right part of the figure above. We can just as well imagine that two light clocks of identical design are available and we [from the point of view of the system S'] consider one at rest (left) and one moving at speed v (right).

All photons shown here have the same velocity. However, the distance from the lower to the upper mirror is longer for the photon of the moving Lightwatch [from the point of view of the system S'] than for the photon of the resting Lightwatch, and therefore a longer period of time elapses [from the point of view of the system S'] until it reaches the other mirror! (...) The length of time that a process in one inertial system lasts is not necessarily equal to the length of time that passes during the same process in another inertial system. The moving Lightwatch has [from the point of view of the system S'] a longer period duration than the stationary one. This means that the process of photon oscillation when observed from a moving system is slower [longer pulses are less frequent] than in the resting system of the Lightwatch. ... this effect ... is often succinctly summed up with the words **"moving clocks go slower"** and is called time dilation ('time stretching').

(...)



The duration of the process in the quiescent system of the Lightwatch [from the point of view of System S] is designated Δt_{Ruh}. The distance between the two mirrors is therefore c Δt_{Ruh}, since c is the speed of the photon. (...).

Seen from the moving system [from the point of view of the system S'], a time interval passes during the same process, which we do not know at first and which we call $_{\Delta tbew.}$ The path covered by the photon (...) has therefore [from the point of view of the system S'] the length c Δtbew. As distance between the two mirrors we take the value c $_{\Delta tRuh}$ determined in the resting system. During the process the upper mirror has moved forward by the distance v $_{\Delta tbew}$ (because the light clock in this system [from the point of view of the system S'] moves to the right at the speed v). In total, these three lengths form a right-angled triangle. (...)

$$(c_{\Delta tRuh})^2 + (v_{\Delta tbew})^2 = (c_{\Delta tbew})^2$$

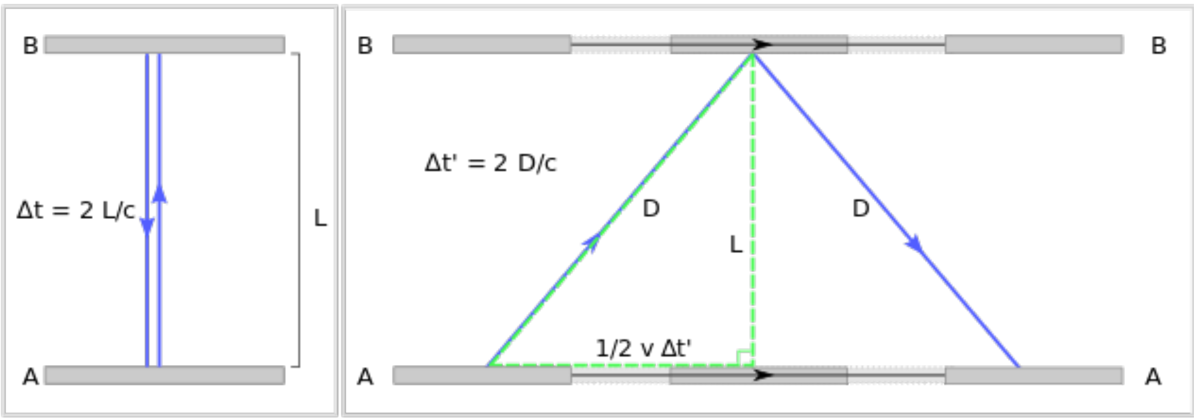
(...)

A clock moving at speed v moves [from the point of view of the system S'] slower by a factor of $(1 - v2/c2^{)-1/2}$ than in its resting system. "

English Wikipedia edition:

https://en.wikipedia.org/wiki/Time_dilation

per 17.7.2019



"In the frame in which the clock is at rest (diagram on the left), the light pulse traces out a path of length 2L and the period of the clock is 2L divided by the speed of light: ...

From the frame of reference of a moving observer traveling at the speed v relative to the resting frame of the clock (diagram at right), the light pulse is seen as tracing out a longer, angled path. Keeping the speed of light constant for all inertial observers, requires a lengthening of the period of this clock from the moving observer's perspective. That is to say, in a frame moving relative to the local clock, this clock will appear to be running more slowly. Straightforward application of the Pythagorean theorem leads to the well-known prediction of special relativity: (...)."

(In the reference system [system S] in which the clock rests (diagram on the left), the light pulse [the photon at the tip of the light beam] follows a path of length 2L. The period of the clock is 2L divided by the speed of light. . . From the point of view of the reference system of an observer moving [from the point of view of the system S to the left] [from the point of view of the system S'], travelling at the speed v relative to the stationary frame of the clock (diagram on the right), the light pulse is seen as following a longer, angled path. **In order to keep the speed of light constant for all inertial observers**, the clock pulse of this clock [the clock resting in the system S] must become longer from the viewpoint of the moving observer [from the viewpoint of the system S']. **That is**, **in a reference system that moves relative to the local clock** [from the point of view of the system S'], **this clock** [the clock at rest in the system S] **seems to run slower**. The simple application of Pythagoras' theorem leads to the well-known prediction of special relativity (...).

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