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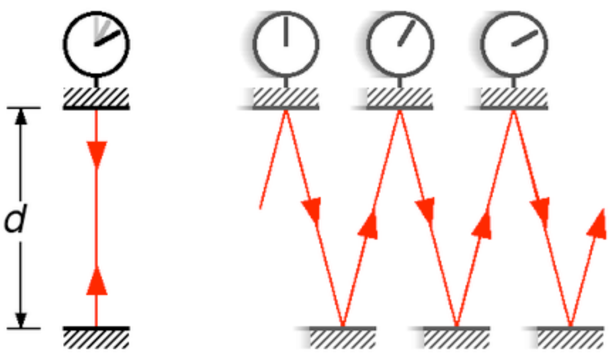
Criticism of the moving light clock

1. the effects of special relativity - time dilation and space contraction - are shown by comparing the propagation of a light pulse emitted by a light source at rest with the propagation of a light pulse emitted by a light source in motion.

Traditionally, these effects are demonstrated by means of the thought experiment with a moving light clock (a tube in which a photon at the tip of a light pulse oscillates back and forth between two mirrors).

The observer S, who carries a light clock, and the observer S' (who carries a clock) move past each other with the uniform relative velocity v. The observer S's light clock is switched on at the moment of their encounter. At the moment of their encounter, the observer S switches on the light clock held perpendicular to the axis of motion. From the point of view of the observer S, the photon propagates from the lower to the upper mirror of the light clock. It covers the distance d with "speed of light" in the time t.

Now the question is asked, how the other observer S' "sees" the two events first of the sending out of the photon from the lower mirror and second of the arrival at the upper mirror (i.e., how he records them according to place and time in his reference frame). From his point of view, the photon covers a zigzag path in the light clock S moving past.



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

From the point of view of the observer S', the path to be covered by the photon, which is inclined to the axis of motion, is in any case longer than the perpendicularly oriented path d from the point of view of the observer S.

In the Newtonian world of thought, the travel time of the photon between the two mirrors resulting from the experimental arrangement would be the same for all observers. Accordingly, the "velocity" of the photon on the longer path from the point of view of the observer S' would have to be greater than the "velocity of light".

According to the experimentally secured basic assumption of the special relativity theory, however, the propagation of the photon occurs with the same "speed of light" both from the view of the observer S and from the view of the observer S'. The relative speed of the light source has no effect on the propagation of a photon at the tip of a light pulse. If two light pulses of light sources moving to each other are emitted at their meeting at the same time in the same direction, the photons at the tip of these light pulses cannot overtake each other nevertheless.

In view of this limitation and constancy of the "speed of light", the photon from the point of view of the observer S' cannot cover the longer way also in the time span t, but only in the correspondingly longer time span t'. One and the same process (the time span between the event of the sending out and the event of the arrival), must therefore last longer from the point of view of the observer S' than from the point of view of the observer S by a factor still to be determined.

2. at superficial evaluation of this consequence contradicting the Newtonian physics one could think, the cause for it would lie in the fact that at the ("resting") observer S' with increasing relative speed the time passes more and more rapidly. In this case, from his point of view, more time could pass during the same process. - This assertion is not plausible, because at an observer cannot be given different times because of different relative movements of other mass points and these pass differently fast.

Also the opposite opinion, at the ("moved") observer S the time t would pass more and more slowly with increasing relative velocity, cannot be true. The thought experiment assumes a process defined from the point of view of the observer S (with an event at its beginning and an event at its end as well as a time span lying between these events). If this given process resp. this time span is changed afterwards in dependence of the relative velocity ("because there the time passes more slowly"), one gets into a logical circle at the evaluation of the thought experiment.

The insufficiency of the explanations can not be changed by the reservation that the time at the ("resting") observer S' would not pass faster per se but only from the point of view of the observer S or that the time at the ("moving") observer S would not pass slower per se but only from the point of view of the observer S'. Observers cannot "observe" the passing of time in another reference frame. The idea that a stationary observer could see the hands of a moving clock and determine that time is passing more slowly for the moving observer is doubly flawed. First, the synchronized clocks of the moving observer, distributed over the space, would all show a different time, if they could be observed at a certain time. Secondly, an undistorted perception is only conceivable in the infinitely short moment of the encounter with such a clock. To observe moving clocks from a distance means only to receive reports of the immediate perceptions on the spot.

Observers can record (measure) events only in their reference system according to place and time and compare these measurements with the messages of other observers about their measurement results in other reference systems. But even if one now understands the observing in this sense, one would have to draw the conclusion with the discussed light pulse, which would be emitted by the observer S perpendicularly to the axis of motion, "that the time passes there more slowly". However, with a light beam which would be emitted by the observer S - in otherwise the same situation - along the axis of motion in the direction of the distant observer S', one would have to draw the conclusion, however, "that the time passes faster there". Also this result shows the senselessness of the idea of a differently passing time. Whether a time passes faster or slower cannot depend on the direction in which a light pulse emitted by the moving light source, which is "observed", was emitted.

The idea that a uniform relative motion of observers would have an effect on the passing of time in the conventional sense (or on the length of scales in the conventional sense) is not purposeful. The fact that a process from the view of two observers moving to each other can last differently, forces rather to question the traditional terms "time", "space", "velocity" and "speed of light".

3 In order to find out in which direction this questioning could go, we will first try to calculate the extent of the extension of the process duration from t to t' on the basis of Newtonian mechanics.

The calculation of the time span t' according to Newtonian mechanics would have to start from the view of the observer S from the right-angled triangle, which is formed from the distance v*t (the way of the observer S' along the common movement axis), the distance c*t (the path of the photon of his light clock perpendicular to the movement axis) and the hypotenuse c*t' (the searched photon path).

However, the correspondingly longer time span t' due to the greater length of the hypotenuse of this triangle would have the consequence that the observer S with his light clock would move away during the process from the point of view of the observer S' not only by the distance v*t, but by the longer distance v*t' (the relative velocity of the observers v must be the same from the point of view of both observers). On the path c*t' corresponding to the hypotenuse of the described triangle, the photon - from the point of view of observer S' - would miss the upper end of the light clock of observer S who is already too far away. The time span t' determined on the basis of this triangle cannot be correct.

In contrast, the correct calculation must consistently and without taking into account traditional prejudices start from the following three premises: the "speed of light" c of the photon, the relative velocity v of the observers and the spatial distance of two events perpendicular to the axis of motion are equal from the point of view of all observers.

From the point of view of the observer S, the photon starts its propagation at the lower end of the light clock S (event E_1) and ends it at the upper end of the light clock (event E_2). From the observer's point of view, this process takes the time span t. To determine the time span t', which this process takes from the point of view of the observer S', based on the above three conditions, it has to be asked from his point of view, which path the photon - starting from the lower end of the moving light clock S (event E_1) - has to take, so that it reaches the upper end of the light clock of the observer S after the elapse of the time span t' (event E_2). The answer results from a right-angled triangle consisting of the distance v*t' (by which the observer S has moved away from the observer S'), of the distance c*t (the length of the light clock perpendicular to the axis of motion, which is the same for both observers) and of the distance c*t' (the searched path of the photon).

From this it follows that the process duration t' is longer than the process duration t by the so-called "Lorentz factor" $1/sqr(1-v^2 /c^2)$. The observers agree about the time of occurrence of the first event E_1 (their encounter), but not about the time of occurrence of the second event E_2observers agree about the time of occurrence of the first event E (their encounter), but not about the time of occurrence of the second event E (their encounter). To the question, how far they are away from each other at the time of the occurrence of the second event, from their respective point of view two different equally valid answers are given (v*t and v*t', respectively). Not only the mentioned time spans, but also the spatial distances between the observers are different than according to Newtonian mechanics.

If the relative velocity of the moving light clock or the moving observer is increased, then from the point of view of the stationary observer this does not only have the consequence that the moving observer travels faster, but also that the process of traveling - as shown - lasts longer from the point of view of the stationary observer and thus the distance traveled by the moving observer becomes longer disproportionately to the velocity increase. But since the travel duration from the point of view of the moving observer remains the same, he is now able to travel disproportionately far in relation to the chosen relative velocity ("coordinate velocity"). The mentioned longer distance, which he has covered from the point of view of the resting observer, does not only move past him with the same higher relative velocity, but in addition shortened. According to the ratio of the distance covered from the point of view of the stationary observer to the travel time spent from the point of view of the moving observer, the moving observer can reach very high intrinsic velocities. To this ratio of distance (from the point of view of the resting observer) to the time (from the point of view of the moving observer) the statement, the "speed of light" can not be exceeded, does not apply ("own speed").

If the constant effect propagation (the "speed of light") is set "1", then in the calculation triangle the relative speed v has a value between 0 and 1 (this so-called "coordinate speed" is a percentage of the "speed of light"). The Lorentz factor simplifies to $t' = t/sqr(1-v^2)$. That the coordinate velocity v (different from the proper velocity) cannot exceed the "velocity of light" c follows from its definition as a percentage of the "velocity of light" and not from any mysterious physical barriers.

But with this no real understanding of the special relativity theory is won. All considerations are misled in the thought experiment with the moving light clock already in the beginning by the statement that a photon has "speed of light" for every observer. With the use of the traditional and apparently unproblematic term of "velocity" for the description of the propagation of light pulses, the interpretation of the processes moves in the orbits of Newtonian mechanics and cannot get beyond its understanding of time and space. This just leads to statements like that, that a uniform relative velocity could change the course of the time and the extent of the space. The change would turn out in such a way that for the propagation of photons always the "speed of light" would come out. The inner contradictions of such interpretations were already pointed out.

The constancy of the "speed of light" raises questions which are much too deep to be answered by a mere bending of the previous concepts. How can it be that a photon cannot overtake another photon, although the two photons were emitted by light sources moving past each other? (Such a common propagation of the two photons at the tip of light pulses occurs e.g. if two observers moving to each other at their meeting each emit a light pulse along their axis of motion in the same direction.) How can it be that a spherical wave of light from a moving light source cannot overtake another spherical wave of light from a stationary light source. How can it be that the fronts of the two spherical waves propagate together in the form of a mantle which cannot be described by Euclidean geometry?

The Newtonian concepts of time, space and velocity are not suitable to answer these questions without contradictions. One must not start from these concepts to explain the phenomenon of the constant "speed of light", but one must start from the phenomenon of the "speed of light" to arrive at useful concepts of time, space and speed. The constant and uncrossable propagation of effects apart from the movement of mass points (thus the "speed of light") is the Archimedean point of these considerations.

The mentioned common propagation of two photons at the tip of two light pulses, which are emitted at the same place at the same time by two light sources moving to each other, has astonishing consequences. First, the length of the propagation of one light pulse from the point of view of one reference frame is different from the length of the propagation of the other light pulse from the point of view of the other reference frame, because although the two photons at the tips of the light pulses propagate together (one photon cannot overtake another), the starting points of these light pulses, the light sources moving towards each other, move away from each other. Secondly, the photons at the tip of these light pulses, which were reflected together at a mirror, nevertheless return to the mutually moving light sources (the observers) in such a way that the reflection from the view of each observer has taken place at half the time of the respective total propagation of its photon (absoluteness of the half-time reflection; the outward way of a photon emitted by the observer concerned is always equal to the return way).

This finding suggests to replace rigid scales and ticking clocks, whose measurement results, considered as absolute, were the basis of the previous concepts of time, space and velocity, by the length of the propagation of a light pulse from the point of view of the observer who has emitted this light pulse. The distance lying between an observer and a given event is measured by the observer halving the time indicated by his light clock that a light pulse reflected at the event takes from emission to return. This "half-time reflection" is absolute. It does not depend on the "state of motion" of an observer when light propagates in a vacuum.

The suitability of the length of the propagation of a light pulse for the measurement of space and time is based on the thesis that a photon at the tip of a light pulse, which is emitted by an observer from a light source resting with him, always covers from this observer that at space, which it needs at time for it. In other words, from the point of view of an observer, time is what passes when a light pulse travels from the event of its emission to the event of its arrival. Space is what is covered when a light pulse propagates from the event of its emission to the event of its arrival. From the point of view of the particular observer, the length of the propagation of a light pulse from its start from a light source at rest with him (event E_1) to its arrival at a target (event E_2) is both the time span and the space that lies between these two events from his point of view. Our previous conceptions of time and space are reconstructions from the data of the propagation of light pulses brought to us via the sense of sight.

From the difference of the propagation lengths of coordinated light pulses follows for observers moving to each other the difference of the spatial and the temporal distances which $_2$lie between the events of the emission $E_1$and the arrival E from the point of view of different observers. The length of the propagation of a light pulse emitted by an observer (at most fictitiously) is its measure for space and time. The absolute substantial time and space of Newtonian theory gives way to a relational conception of time and space that ties to finite and constant action propagation. The Newtonian mechanics sinks to an approximate calculation without inner truth content, which is only useful for low relative velocities.

Against this background it becomes recognizable that the necessary comparison between the propagation of two light pulses mentioned at the beginning takes place only indirectly in the case of the thought experiment with the moving light clock. Independently of the supposed "observation" of the propagation of a light pulse in the moved light clock, the duration of the propagation is measured with a resting clock, which is basically again a light clock, whose light pulse to be added represents the object of comparison. Without being aware of this, the thought experiment cannot be understood.

The idea of "observing" a photon, which is emitted by a moving light source, must be replaced in the thought experiment by the idea that each of the observers moving to each other at their meeting (event E_1) emits a light pulse from a light source resting with him in each case in such a way that the photons at the tip of the two light pulses propagate together until they arrive together at the end of the process, e.g. arrive at the opposite mirror of a light clock (event E_2). So the deep inner connection becomes visible which exists between the uncrossability of the propagation of effects and time and space.

To stay with the example above, the observer S emits his light pulse perpendicular to the axis of motion, while the observer S' emits his light pulse at such an angle to the axis of motion that the said common propagation of the photons occurs. The angle (resp. the ratio t' = t/sqr(1-v ^{2})) results from the already mentioned right-angled triangle with the sides t, v*t' and t', which however - instead of an "observing" of the photon - is now derived from the coordinated emission of two photons from two observers moving to each other.

The popular scientific explanations complicate this - by the break with the Newtonian mechanics completed - explanation by the - the Newtonian thinking resuming - philosophical interpretation, the extension of the process duration t' would come about by the fact that from the point of view of the observer S' the time t would pass more slowly with the "moved" observer S. "The faster the observer S moves, the more slowly the time passes with him. " "At very high velocities 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, "Time Dilation"; 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).

The above question about the trajectory of the photon from the point of view of the observer S' is posed in the habits of Newtonian thinking and thus a gain of knowledge is made difficult: By which factor must the time t pass slower at the observer S from the point of view of the observer S' "moving" with the velocity v, so that the photon can start its propagation with c at the meeting of the two observers at the lower end of the "moving" light clock S and end it at its upper end?

The claimed change of the time lapse at the moving observer S and thus the change of the process duration at this observer S (allegedly only "from the point of view of the observer S'", whatever is to be understood by it), leads to a logical circle at the evaluation of the thought experiment, because at the observer S the length of the light clock and thus the process duration form the unchangeable starting points of the thought experiment. Therefore, if a time process itself would change somewhere (which is actually not the case), this could only be the time process at the observer S', as the different time spans measured by him at different relative velocities would show. The "observation" of a slower passing of time at a moving observer S by an observer S' at rest is a nonsensical idea.

This becomes clear additionally by the fact that the light pulses emitted by the observer S in each case in certain directions would have to propagate within the scope of a slower time lapse (observed by the observer S'), but with other directions within the scope of a faster time lapse (observed by the observer S'). Also the objection raised against it, that always only the mean values of composite light propagations, which return to the observer S as the origin of their propagation, may be examined, is not valid:

"Watch out, fake light clock!

Occasionally one sees animations with light clocks ticking twice as fast as the ones shown here. With them, the counter jumps over on the one hand when the pulse reaches the upper mirror, and on the other hand when it reaches the lower mirror. Such light clocks lead the simple functional principle ad absurdum, because how does the counter know when the pulse arrives at the lower mirror? This information would first have to be laboriously transferred from the lower mirror to the counter. But this transmission cannot be done faster than the speed of light. In particular, the information would not reach the counter before the light pulse itself already arrives again at the upper mirror. " (M. Pössel, "From the Light Clock to Time Dilation", in: Einstein Online Vol. 04 (2010), 1101; https://www.einstein-online.info/spotlight/LichtuhrZeitdilatation/).

Why a measured value (the above described "seeing" of a photon) should be absurd, only because it is communicated later, is not comprehensible.

The contradictory nature of the assertion of a slower passing time is not changed by animations in which a light clock aligned perpendicularly to the direction of motion and flashing more and more slowly with increasing speed gives the impression that the observer at rest can watch how time passes more slowly for the moving observer. All clocks of his system are supposed to be affected by this slowing down (cf. e.g. M. Pössel, "Von der Lichtuhr zur Zeitdilatation" in: Einstein Online Vol. 04 (2010), 1101; https://www.einstein-online.info/spotlight/LichtuhrZeitdilatation/; "Obviously, from my point of view, the moving light clock goes clearly slower than my own light clock of the same construction. (...) Judged from my space station, all the clocks of the space station moving relative to me go slower than my own clocks. Just as the moving clocks run slower, all processes on the other space station also run slower for me - five-minute eggs boil longer and still have the right consistency in the end, and the pianist on board the other station who plays the minute waltz needs considerably more time for it than it corresponds to the usual performance practice. ").

The oblique light paths "seen" by observer S' in this example originate from a photon emitted by observer S normal to the axis of motion and which triggers a blink when it returns to him. Each blink is recorded according to the Lorentz transformation by time and place in the coordinate system of the observer S'. With increasing relative velocity, from the point of view of the observer S', the light paths and thus the time spans between the blink signals lengthen (as above the time span t' compared to the defined time span t). The frequency reduction of the blink characters, which is accompanied by the increase of the relative velocity, is therefore nothing else than the (relativistic) transversal Doppler effect from the point of view of the observer S', which can change or even reverse depending on the angle of the approach. A Doppler effect has nothing to do with another passing of time in the sphere of the uniformly moving object. It occurs reciprocally at the observers without distinguishing one of them (principle of relativity). With none of them the time passes therefore slower. One cannot seriously claim that the time in a distant ambulance with following horn would pass slower because one hears the tones deeper.

In summary, the constancy of the "speed of light" is not due to the fact that a substance "time", which would be measured with any "objective" clock, and a substance "space", which would be measured with an "objective" rigid scale, would always change in the sphere of a moving observer in such a way that for the "speed of light" always the same value comes out. The said constancy is rather a consequence of the circumstance that photons cannot overtake each other and that the length of the propagation of a light pulse represents both the time passed during this process and the space covered thereby. Therefore, for a photon, the ratio of the distance traveled to the time required for it must necessarily be "1" from the point of view of all observers. The constant effect propagation gives birth to space and time in the ratio of 1:1.

The popular scientific representation with its spectacular assumption of a time passing more slowly with the uniformly "moved" observer disregards the scientific principle of economy. Time is not a substance which could pass slower or faster. The results of the thought experiment speak for the correctness of the view of Leibniz, who against Newton advocated the view that time is a relation (cf. *S. Clarke*, Der Briefwechsel mit G.W. Leibniz von 1715/16, Übers. *Ed Dellian*, Hamburg, Meiner (1990)).

Vienna, January 7, 2022

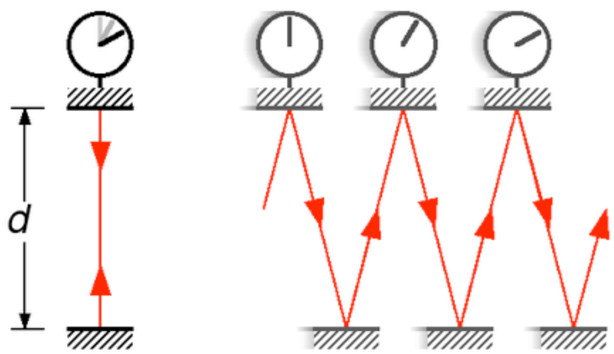
Appendix:

Popular science representations (square brackets [] not in original):

1) German Wikipedia edition:

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

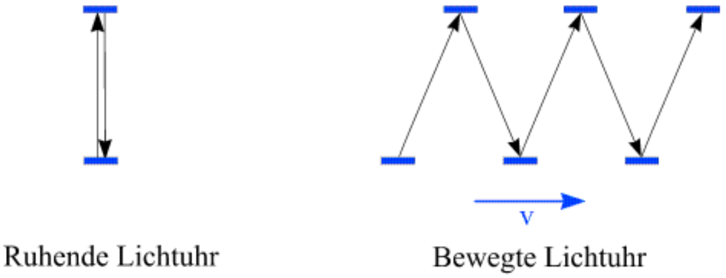
as of 7/17/2019



"If a light clock A is given, from the point of view of an observer [*from the point of view of system A*] moving with it (i.e. resting relative to it), a flash will need the time $T_0 = d/c$ for the simple path between the mirrors. (...) If now a second light clock B [*the light clock resting in the other system B, which is now to be "observed" from the system A*] is moved perpendicularly to the connecting line of the mirrors with the velocity v, then the light must cover a greater distance between the mirrors from the point of view of the A-observer than with clock A. Assuming the constancy of the speed of light, **clock B** therefore **moves slower than clock A for** the A observer. The time T' = d'/c, which the light flash needs for the simple path d' between the mirrors, is given by the Pythagorean theorem $d'^2 = d^2 + (vT')^2$. By inserting the expressions for d and d' and solving for T' one finally obtains $T' = T_0 * 1/\text{sqr}(1-(v/c)^2)$ (...)."

2) Franz Embacher, University of Vienna:

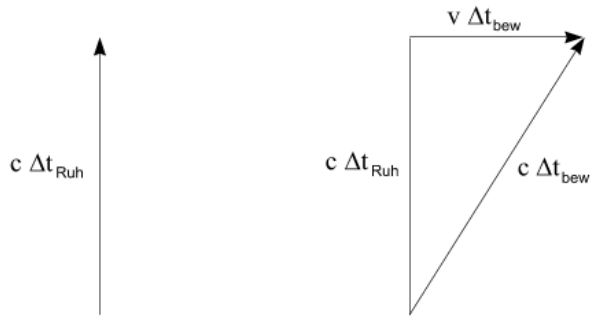
https://homepage.univie.ac.at/franz.embacher/SRT/Zeitdilatation.html as of 7/17/2019



"The left graphic shows the light clock [*S*] from the point of view of an observer who is opposite to it in rest, i.e. from the point of view of its rest system. We now ask how the same process looks like in an inertial system moving against it [*from the point of view of system S'*], where the direction of motion is supposed to be transverse to the direction of travel of the photons. For an observer in this new system [*from the point of view of system S'*], the light clock [*S*] is moving, and we denote the value of its velocity by v. The photons will travel along oblique 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 also just as well imagine that two light clocks of identical design are available and we consider [*from the point of view of the system S']* one at rest (left) [*a light clock S'*] and one moving with velocity v (right) [*a light clock S*].

All photons represented here have the same speed. However, the distance from the lower to the upper mirror is longer [from *the point of view of the system S'*] for the photon of the moving light clock [S] than for the photon of the resting light clock [S'], and therefore a larger time period passes [from the *point of view of the system S'*] until it reaches from the one to the other mirror! (...) The time duration, which a process takes in one inertial system, is not necessarily equal to the time duration, which passes during the same process in another inertial system. The moving light clock [*S*] has [*from the point of view of the system S'*] a longer period than the resting one. This means that the process of photon commuting, when observed from a moving system [S'], is slower [*longer-duration cycles occur less frequently*] than in the resting system of the light clock [*S*] . ... this effect ... is often summarized in a concise way with the words **"moving clocks go slower"** and is called time dilation ('time dilation').

(...)



Ruhende Lichtuhr Bewegte Lichtuhr

The duration of the process in the rest system of the light clock [*from the point of view of the system S*] is $_{Ruh}$denoted by Δt. Therefore, the distance of the two mirrors is c Δt_{Ruh}, since c is the velocity 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 $_{bew}$ denote by Δt. The path covered by the photon (...) has therefore [from the point of view of the *system S'*] the length c Δt_{bew}. As distance of the two mirrors we adopt the value c Δt determined in the rest system$_{Ruh}$. During the process, the upper mirror has advanced by the distance v Δt_{bew} (since *the* light clock in this system moves to the right with the velocity v [*from the point of view of the system S'*]). Altogether these three lengths form a right-angled triangle. (...)

$(c\ \Delta t_{Ruh})^2 + (v\ \Delta t_{bew})^2 = (c\ \Delta t_{bew})^2$

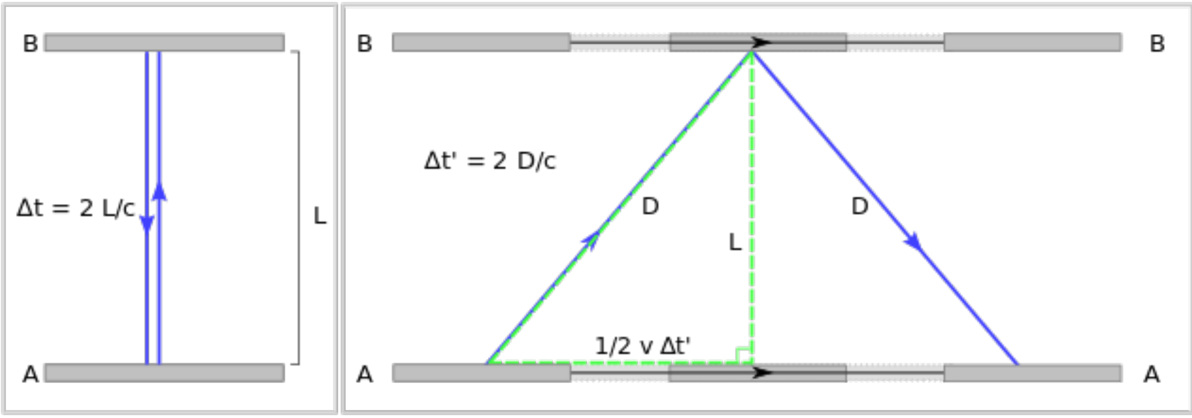
(...)

'A clock moving with velocity v goes [*from the point of view of system S'*] $^{-1/2}$slower by a factor of $(1 - v^2/c^2)$ than in its rest system.' "

<u>3) English Wikipedia edition</u>:

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

as of 7/17/2019



"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 frame [*"resting" system S*] in which the clock rests (diagram on the left), the light pulse [*the photon at the tip of the light pulse*] 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 frame of reference of an observer [*from the point of view of the "stationary" system S to the left*] traveling at velocity v relative to the stationary system of the clock [*S*] (diagram to 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 of this clock [*the process duration t of the clock at rest in the system S]* must become longer from the point of view of the moving observer [*from the point of view of the system S'*] [*t' is longer than t*]. **That is**, **in a frame of reference moving relative to the local clock** [*from the point of view of system S'*], **that clock** [*the clock at rest in system S*] **appears to run slower**. The simple application of the Pythagorean theorem leads to the well-known prediction of special relativity (...). "}