Relativistic time dilation: theoretically a reality associated only With the light clocks

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Abstract

In this article, a new version of Einstein's thought experiment reveals something which was never pondered about. Light clock used in thought experiment by Einstein which runs on light pulse is not an ideal clock to measure time in moving situations. A light motion analysis presented in article brings out a special peculiarity of light. "The speed of light is a constant, independent of the motion of the light source and all observers. Whereas the direction of light is dependent upon the motion of source and the observers" is the peculiar trait of light which gives time dilation effect in light clock used in thought experiment. Other clocks which don't run in light pule don't show this effect. There is no such peculiarity in machinery of the other clock that might cause the time dilation effect in thought experiments. Practical experiments are in good agreement with relativistic time dilation effect. The light clock thought experiment which gave time dilation concept itself is revealing something different in the new version of thought experiment followed by the light motion analysis.

1. Introduction

Newtonian mechanics was incapable of explaining the peculiar aspects of light and its motion. Albert Einstein framed STR to account for peculiar behavior of light. Einstein used one of the laws of Maxwell's electromagnetism which is

$$C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

as a base for devising special theory of relativity. This law of electromagnetism was given representation as a postulate by Einstein in STR, which states that-

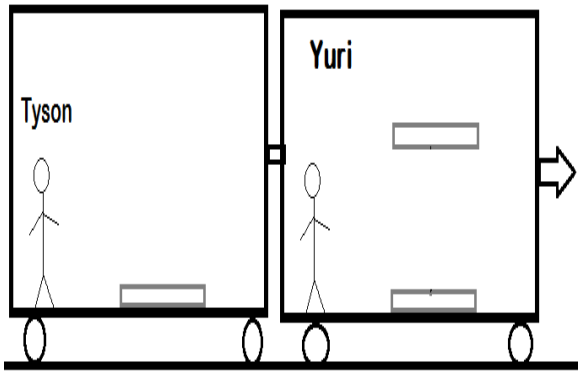
"The speed of light is a constant, independent of the motion of the light source and all observers"

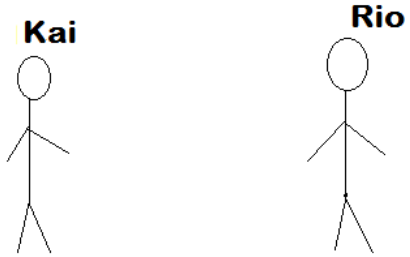
Though this postulate seems silent it gave out breaking results with Einstein's thought experiment .In thought experiment Einstein considered a light clock in a moving train .A person in the train measures time Δt_0 for one tick. A stationary observer measures time Δt for one tick. The relation between Δt_0 and Δt came out as –

$$\Delta t = \frac{\Delta t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

This is the famous time dilation equation. This time dilation equation and its further application brought together gave many results. If Einstein's thought experiment is seen in a different point of view it reveals something else. It reveals something which was never pondered about.

2. New version of Einstein's thought experiment



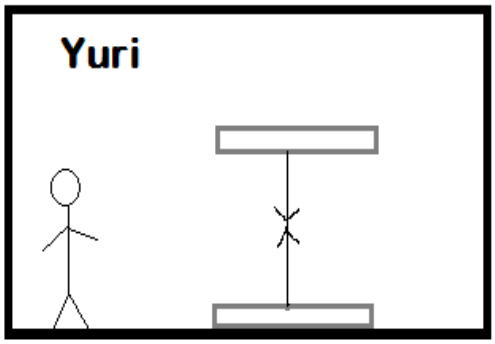


Consider a thought experiment. A train is moving in a track with velocity *v*.

It has two wagons and an engine. Yuri is standing in a wagon with light clock. (Light clock consists of two mirrors separated by a distance *l* between which a light pulse moves. Time for light to move from bottom mirror to top mirror and then back is one tick).Rio is a stationary observer who is watching this wagon. Tyson is standing on another wagon with ball clock. (Ball clock consists of machinery which ejects a ball upward with a velocity say α. Time taken by ball to go up and return to the machinery is one tick).Kai is a stationary observer who is watching this wagon.

Yuri-Rio Observation

1. From point of view of Yuri



Total distance travelled by light pulse= *l*+*l*

Speed of light pulse=*c*

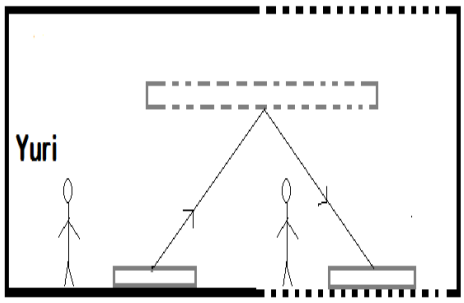
Time for one tick,

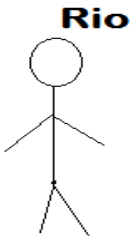
$$\Delta t_0 = \frac{total\ distance\ covered}{speed}$$

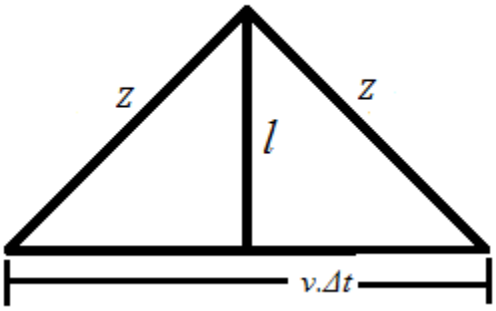
$$\Delta t_0 = \frac{l+l}{c}$$

$$= \frac{2l}{c} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

2. From point of view of Rio







Δt→time for one tick i.e., time taken to go from bottom mirror to top mirror and then back

$$Z^2 = l^2 + \left(\frac{v.\Delta t}{2}\right)^2 \quad \ldots\ldots\ldots\ldots (2)$$

Light pulse travels 2Z at speed *c* in time Δt, it implies that

$$2Z = c.\Delta t$$
$$Z = c.\Delta t/2$$

Substituting this value in (2)

$$\left(\frac{C.\Delta t}{2}\right)^2 = l^2 + \left(\frac{v.\Delta t}{2}\right)^2$$

$$\frac{c^2.\Delta t^2}{4} = l^2 + \left(\frac{v^2.\Delta t^2}{4}\right)$$

$$\Delta t^2 = \frac{4l^2}{c^2} + \frac{v^2\Delta t^2}{c^2}$$

$$\Delta t^2 \; - \frac{v^2.\Delta t^2}{c^2} = \frac{4c^2}{c^2}$$

$$\Delta t^2 \left(1 - \frac{v^2}{c^2}\right) = \frac{4l^2}{c^2}$$

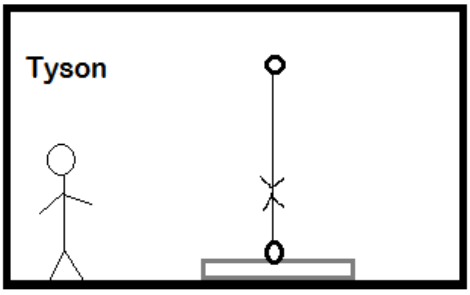
Substituting equation (1) in above

$$\Delta t^2 \left(1 - \frac{v^2}{c^2}\right) = (\Delta t_0)^2$$

$$\boxed{\Delta t = \frac{\Delta t_0}{\sqrt{1-\frac{v^2}{c^2}}}}$$

Tyson –Kai observation

1. From point of view of Tyson



Initial velocity with which ball is projected by machinery=α

For half motion,
Initial velocity =α
Acceleration=-g
Final velocity=0

Using $v = u + at$

$$0 = \alpha + (-g)(t_{1/2})$$

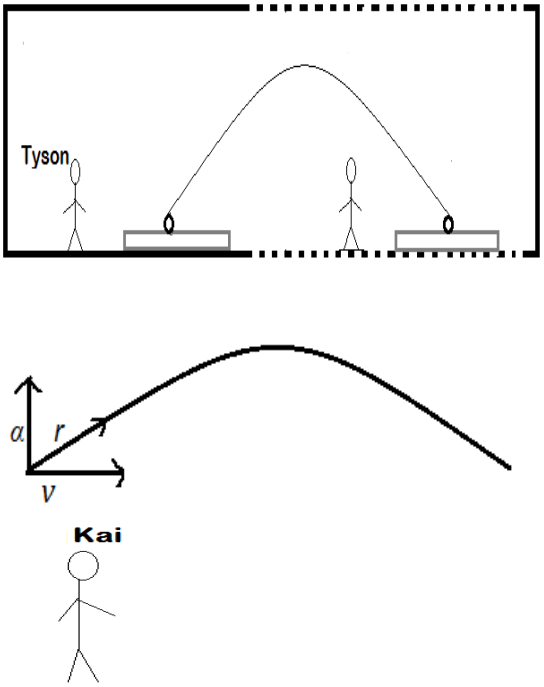
$$-\alpha = (-g)(t_{1/2})$$

$$t_{1/2} = \frac{\alpha}{g}$$

Therefore, the time for one tick i.e. time to go up and then come back is

$$T_0 = \frac{2\alpha}{g} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

2. From point of view of Kai



For Kai the ball moves in combined effect the of train's horizontal velocity and vertical velocity of ejection given by the machinery. $r = \sqrt{\alpha^2 + v^2}$ is the resultant velocity of ball in resultant direction. It is well known fact that whatever be the horizontal velocity of train it will only affect the horizontal displacement of ball whereas vertical velocity and thus the vertical height will remain unaffected. (Vertical velocity is the velocity, with which machinery projects the ball)

For half motion,
Initial vertical velocity of ball=α
(Because the horizontal velocity of train will affect only horizontal component not the vertical velocity of ball)

Acceleration=-g

Final vertical velocity of ball=0

Using $v = u + at$

$$0 = \alpha + (-g)(t_{1/2})$$

$$-\alpha = (-g)(t_{1/2})$$

$$t_{1/2} = \frac{\alpha}{g}$$

Therefore time for one tick i.e., time taken to attain height and come back is $T = \frac{2\alpha}{g}$ ..... (4)

From (3) and (4) it is clear that,

$$T = \frac{2\alpha}{g} = T_0$$

$$T = T_0$$

Rio's time measurement and Yuri's time measurement for light clock are not the same. Yuri measured a smaller time of tick than Rio. It can be concluded that moving clock ticks slower. This is what Einstein proposed in his thought experiment using light clock.

Kai's time measurement and Tyson's time measurement for ball clock are the same. It can be concluded that moving clocks doesn't run slower.

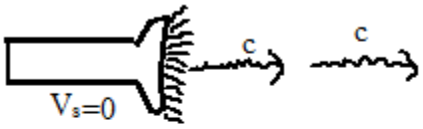
Which perception is right? Which perception is a reality? Was Einstein's thought experiment a failure?

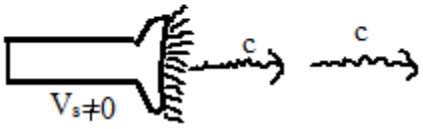
Einstein's thought experiment is not a failure. Moving light clocks indeed get slower. Einstein was right. But the conclusion that since the light clocks get slower hence other clocks, physical clocks, biological clocks will also tick slower was a misconception. Actually time doesn't run slower with increasing speed, it is the light clock that ticks slower. Light is much more peculiar than what it is thought about. Light clock which runs on light pulse is not an ideal clock for measuring time in moving situations. The coming Light Motion Analysis will reveal the fact.

3 Light Motion Analysis

Postulate of STR states that-
"The speed of light is a constant, independent of the motion of the light source and all observers"

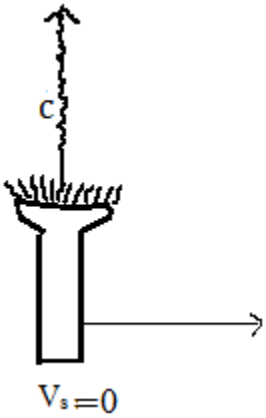
Whether the direction of motion of light depends upon the motion of source? Whether the direction of motion of light is affected by the motion of source? There is no description about the direction of light in the postulate. It can be claimed that direction of motion of light has no role to play. But that is not the case. When direction of motion of source and direction of ejection of light are same then obviously light will move in the same direction of ejection with speed c. The following illustration depicts that→



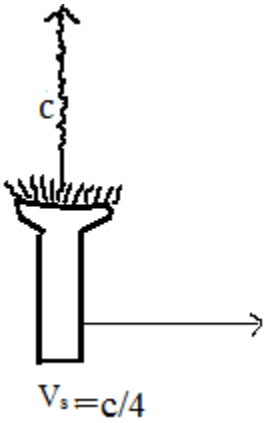


When the direction of motion of source is perpendicular to direction of ejection of light and if the direction of motion of light is not affected by source then whatever be the velocity of motion of source, light will always move in its direction of ejection. The following illustration depicts this→

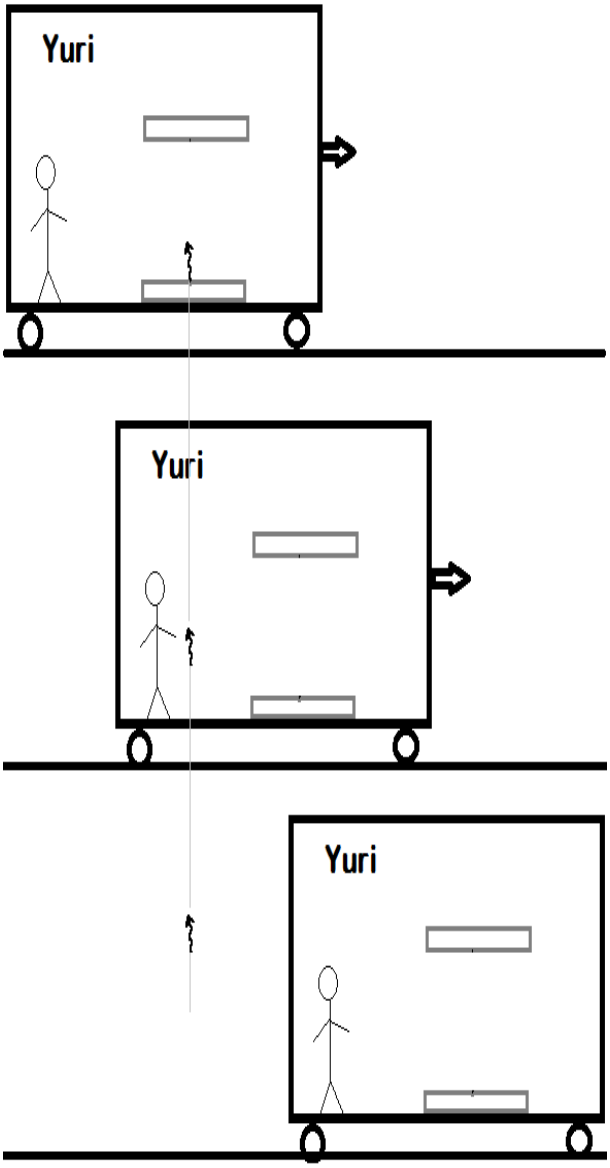
(a) Velocity of source in horizontal direction is zero

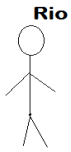


(b)Velocity of motion of source in horizontal direction is c/4



If the above consideration and illustration is right then its analogous condition where the light clock moves in horizontal direction with light pulse ejected in vertical direction will give the following scene to Rio (the stationary observer watching the wagon).Light irrespective of the motion of source will trace the ejected direction. The following illustration depicts such scenario→

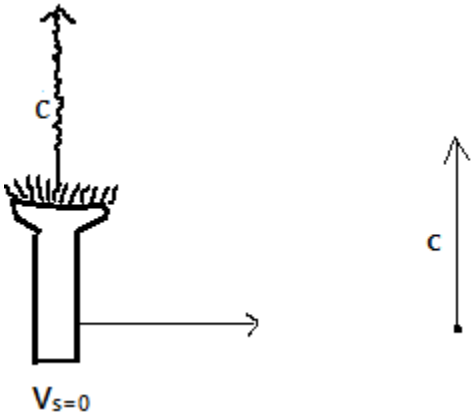




But this scenario is not the truth. Rio observed something else. Rio didn't observe the light travelling in a vertical straight line path; instead he observed the light pulse travelling in an inclined straight line path. Hence it can be concluded that direction of motion of light is affected by the direction of motion of source.

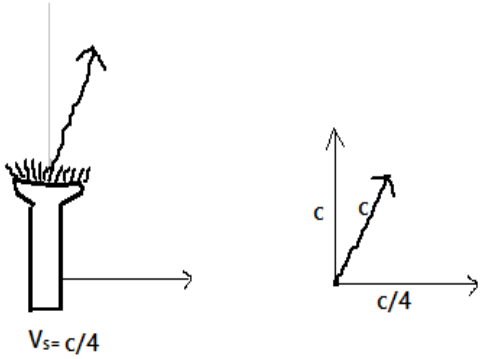
When the direction of motion of source is perpendicular to the direction of ejection of light, then light traces a direction which is resultant of the lights velocity(*c*) and velocity of source (V_s) but speed of light still remains *c* in this resultant direction. It's only the direction of light which gets affected by the motion of source but not the speed. The following illustration depicts this→

(a)Velocity of motion of source in horizontal direction is zero



Velocity of source is zero. Therefore the resultant direction of light pulse lies in direction of ejection of itself. Light pulse moves along the resultant direction with its usual speed.

(b) Velocity of motion of source is C/4 in horizontal direction



Source has velocity c/4 in horizontal direction; light has velocity of ejection c in vertical direction. The light pulse will trace a direction which is combined effect of c and c/4.It will move in resultant direction with its usual velocity c.

Direction of motion of light

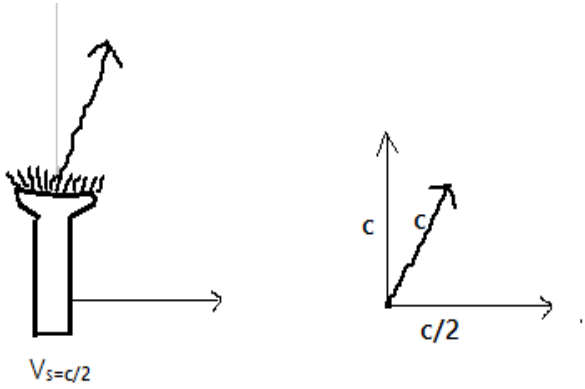
$$\theta = tan^{-1}\left(\frac{c}{c/4}\right)$$

$$\theta = tan^{-1}(4)$$

$$\theta = 75.9°$$

Velocity of motion of light=*c*

(c)Velocity of source is c/2 in horizontal direction



Light moves in the resultant direction with its usual speed. Direction of motion of light

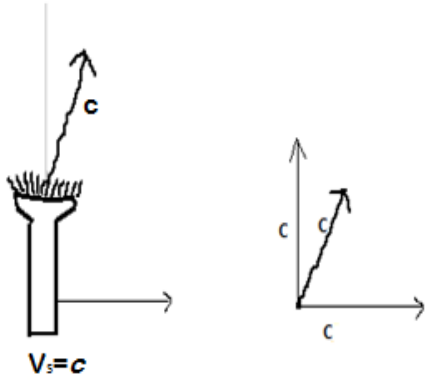
$$\theta = tan^{-1}\left(\frac{c}{c/2}\right)$$

$$\theta = tan^{-1}(2\,)$$

$$\theta = 63.4°$$

Velocity of motion of light = *c*

(d)Velocity of motion of source is c in horizontal direction



Light travels in the resultant direction with its usual speed.

Direction of motion of light

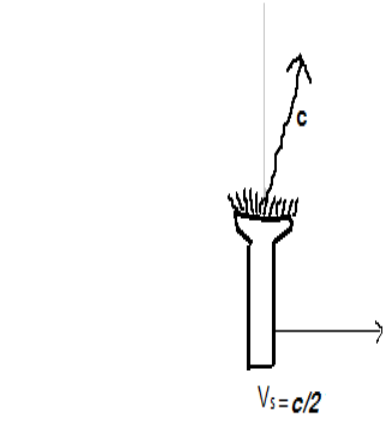
$$\theta = tan^{-1}\left(\frac{c}{c}\right) = 45°$$

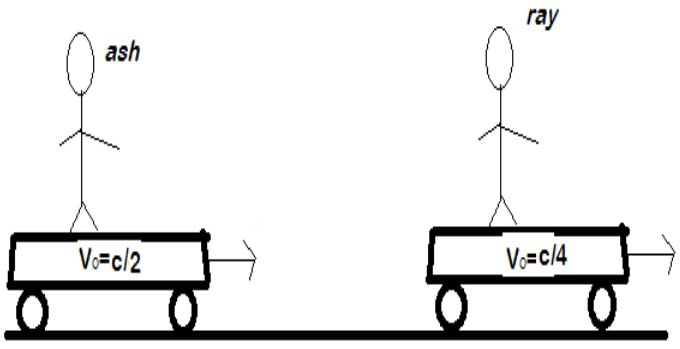
Velocity of motion of light =c
The direction of light is affected by the motion of light source. Hence direction of light is dependent upon the motion of light source.

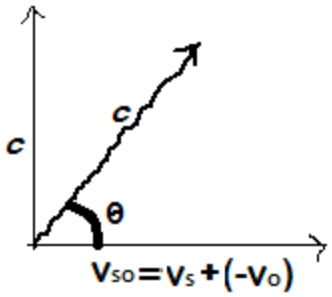
Whether the direction of light is dependent upon the motion of observers?

Yes, direction of light is dependent upon the motion of observers. Every observer will have different perception of lights direction depending upon their velocity with respect to the source. The following illustration depicts this→

Source is moving with velocity *c*/2 in horizontal direction and the observer Ray is moving at velocity *c/4* and observer Ash is moving at velocity c/2







(a)For Ray

Velocity of source with respect to Ray $= V_s - V_o = \frac{c}{2} - \frac{c}{4} = \frac{c}{4}$

Direction of motion of light,

$$\theta = tan^{-1}\left(\frac{c}{V_{so}}\right)$$

$$\theta = tan^{-1}\left(\frac{c}{c/4}\right)$$

$$\theta = 75.96°$$

Velocity of motion of light=c

In Ray's frame light traces direction $\theta = 75.96°$ with its usual speed c

(b) For Ash

Velocity of source with respect to Ash

$$= V_s - V_o = \frac{c}{2} - \frac{c}{2} = 0$$

Direction of motion of light,

$$\theta = tan^{-1}\left(\frac{c}{V_{so}}\right)$$

$$\theta = tan^{-1}\left(\frac{c}{0}\right)$$

$$\theta = 90°$$

,

Velocity of motion of light=c

In Ash's frame of reference light traces direction $\theta = 90°$ with its usual speed

The result of Light Motion Analysis is→

"The speed of light is a constant, independent of the motion of the light source and all observers. Whereas the direction of light is dependent upon the motion of source and the observers."

In other words,

"Every observer will have same speed of light irrespective of their velocity with respect to the light source. Whereas each one of them will have different perceptions of direction of light depending upon their velocity with respect to the light source."

4. Interpretation of thought experiment with the Light Motion Analysis Result

Light clock possess velocity in horizontal direction along with the train whereas light is ejected in vertical direction. The velocity of motion of source (light clock) along with train brings a change in the direction of light pulse. This change in direction of light pulse is observed by Rio (in his frame of reference light clock is in relative motion).The change in direction of light pulse cannot be observed by Yuri because in Yuri's frame of reference light clock is at relative rest. In Rio's frame of reference light travels an inclined straight line path with speed c. In Yuri's frame of reference light travels a vertical straight line path with speed c. Hence Rio observes longer time for light pulse to go from bottom mirror to top mirror and come back. Whereas Yuri
observes smaller time for light pulse to go from bottom mirror to top mirror and come back. Overall, it appears that time runs slower to Yuri. Light moves in resultant direction with its usual speed.
Observers in every frame of reference will see different trajectory (direction)
but same speed for light. Hence observers in every reference frame will have different time of tick than others.

Ball clock moves in horizontal direction along with train whereas the ball is of ejected in vertical direction. Velocity of motion of ball clock along with train changes the direction of motion of ball and also the resultant velocity of ejection of ball. This change is observed by Kai (in his reference frame ball clock is in relative motion).The change in direction of motion of ball and the change in velocity of ejection is not observed by Tyson because in his reference frame ball clock is at relative rest. Kai observes a projectile path of ball with velocity of ejection $\sqrt{\alpha^2 + v^2}$ .Tyson observes a vertical path of ball with velocity of ejection α.Kai observes a larger trajectory and larger velocity whereas Tyson observes a smaller trajectory and smaller velocity. Overall, time of tick for Kai and Tyson comes out as same. Ball moves in resultant direction with its resultant velocity. Observers in every frame of reference will see different trajectory and different velocity of ejection. Hence observers in every reference frame will have the same time of tick.

Hence it is clear that time dilation is just a peculiarity associated with light clocks which runs on light. "Motion of source or observer affects the direction of light but not the speed" is the peculiar trait of light which gives time dilation affect. In thought experiment, light clock which runs on light pulse is not an ideal clock to measure time in moving situations; relative motion does not affect any other clock (ball clock, physical clock) because they don't run on light pulse.

5. Conclusion

Light clock used in the thought experiment is not an ideal clock to measure time in moving situtations."The speed of light is a constant, independent of the motion of the light source and all observers. Whereas the direction of light is dependent upon the motion of source and the observers" is the peculiar trait of light which causes the moving light clocks to get slowed down. Other clocks which don't run in light pule don't show this effect. There is no such peculiarity in machinery of the other clock that might cause the time dilation effect in theoretical thought experiments, we simply cannot consider without any reason that other clocks will appear to run slow just like the light clock. Experiments like comparison of muon lifetimes at different speeds,

measurement of the doppler shift from a source moving at right angles to the line of sight, flying atomic clocks in east and west direction etc. are in agreement with relativistic time dilation. The light clock thought experiment which gave time dilation concept itself is revealing something different in the new version of thought experiment followed by the light motion analysis.Theoretically it comes out that relativistic time dilation is mere a reality associated only with the light clocks though practical experiments reveal something else. Maybe the actual picture of relative reality is different from what it was thought.

References

[1] Nicholas J. Giordano, *College Physics: reasoning and relationships*, Brooks/Cole,Cengage Learning(USA)(2010),Page 919-920

[2] Halliday, Resnick and Walker, *Fundamentals of physics*,6th Edition,Wiley Publications, Page 920-945