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Generalizing the physical time impact on the astronauts living on the International Space Station to the theory of relativity

Author(s): Danial Karami

Independent author - Contact: Danial.karami2004@gmail.com

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Summary: In this research article, we are going to study the concept of the theory of relativity and after extracting the essential information, we will try to find a relation between the theory of relativity and the results we are obtaining through contemporary physics experiments. It has been investigated that traveling in time is not a dream anymore and time can pass at a different rate for some people.

Keywords: Special relativity, General relativity, Time travel, Astronauts, ISS

INTRODUCTION

Traveling in time has always been a famous topic in the world and many physicists have worked on this subject, but the most important hypothesis about time travel gets back to the 20th century, when Albert Einstein introduced the theory of relativity. This theory includes two main parts; the special relativity, which applies to all physical phenomena when there is no gravity, and the general relativity, which explains the law of gravity and its relation with other forces in nature. Anyhow, by accepting the theory of relativity, we achieve several results, and "time dilation" is the one that this article is going to be based on.

Actually, time dilation expresses that time is relative and it slows down when the speed rises. More precisely, we can claim moving clocks run slower than stationary clocks. Let's check out the following section more to have a better understanding of this concept.

TIME DILATION

Time dilation was predicted by several authors in the beginning of the 20th century. Lorentz factor is the fundamental of time dilation equation and several scientists like joseph Larmor or Emil Cohn advanced on this theory, but it was Albert Einstein who mentioned some unprecedented details!

To begin with, take a look at the following equation where the speed is viewed as

$$speed = \frac{distance}{time}$$

Further, consider the following figure where object (A) is stationary and the other one (B) is a moving object

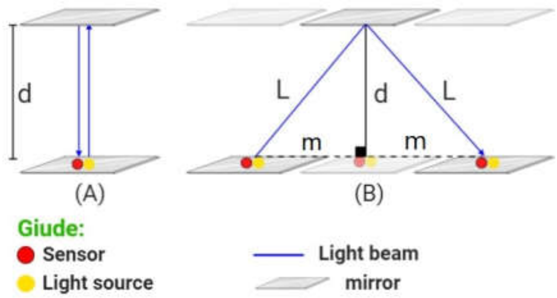

Figure 1. A simple experiment to demonstrate the theory of time dilution

For the condition (A), let's imagine that a light beam exits from the light source and after colliding with the top mirror, it returns and reaches the sensor. If this process happens during ΔT, we can claim that $\Delta T = \frac{2d}{c}$

On the other hand, for the condition (B), as the light beam was continuing its journey to the mirror and getting back to the sensor during $\boldsymbol{\Delta T}$, the whole object has moved so a new path exists here between the mirror and the light source and also between the mirror and the sensor. Here it can be concluded that the light beam is not following the same path in condition (A) and (B) relative to an observer, albeit the light beam always goes straight up and down relative to object. Anyhow, for the condition (B), we have: $\Delta T' = \frac{2L}{c}$

Let's compare the components of the fractions that we formed for conditions (A) and (B).

We know that the speed of light is always a constant number in one environment. Additionally, according to the Trigonometric rules, $L^2 = d^2 + m^2$ and consequently it is evident $2L > 2d$. Subsequently, it must take the light longer to pass $2L$ compared to $2d$, but the considered time $\boldsymbol{t}$ was a constant amount in both experiments! It was at this moment that time dilation was born! Time is personal to us but the amount by which time slows down for a moving object is miniscule and this is why we cannot feel this in everyday life.

Anyhow, let us discuss and evaluate our findings in physics language. We will move forward based on Lorentz term or Lorentz factor, a quantity which describes while an object is moving, how much the measurements of time, length, and other physical properties changes;

$$m = \frac{v\Delta T'}{2} \quad and \quad L = \sqrt{d^2 + m^2}$$

$$\xRightarrow{m = \frac{v\Delta T'}{2}} L = \sqrt{d^2 + \left(\frac{v\Delta T'}{2}\right)^2}$$

By multiplying the above equation by 2 and getting the result divided by c, we can produce $\frac{2l}{c}$ which is equal $\Delta T'$, in notation

$$\Delta T' = \frac{2l}{c} = \frac{2\sqrt{d^2 + \left(\frac{v\Delta T'}{2}\right)^2}}{c}$$

Now square the equation as follows

$$(\Delta T')^2 = \frac{4\left(d^2 + \frac{v^2 \Delta T'^2}{4}\right)}{c^2} = \frac{4d^2}{c^2} + \frac{v^2}{c^2}(\Delta T')^2$$

According to the fraction we wrote for condition (A) in figure 1, $\Delta T = \frac{2d}{c} \rightarrow (\Delta T)^2 = \frac{4d^2}{c^2}$. So, let's use this term to improve our equation:

$$(\Delta T')^2 \left(1 - \frac{v^2}{c^2}\right) = (\Delta T)^2 \Rightarrow (\Delta T')^2 = \frac{(\Delta T)^2}{\left(1 - \frac{v^2}{c^2}\right)}$$

Finally, by removing the power of variables in the above formula, we get

$$\Delta T' = \frac{\Delta T}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Here $\Delta T'$ is the observer time, ΔT is the proper time, v is the velocity (m/s), and c is the speed of light which is approximately ($3.0\ x\ 10^8\ m/s$).

Anyhow, let's proceed further and prove how we can travel in time using the nowadays technology!

Discussion

According to the Lorentz term, in order to feel the impact of time dilation on physical time better, we need to consider a real-life example in which there is an object traveling at a fast speed. As of today, the International Space Station is one of the fastest objects that is able to carry humans, and the question that arises here is that can we claim that time passes at a different rate for anyone who stays there? It is undeniable that the speed of ISS is tiny compared to the light speed, but astronauts can stay there for months, and a lot of information is accessible about it which paves the path for this research! The core of this space station was launched on November 20, 1998, and as time passed by, subsequent parts were added. It takes

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International Space Station 92.68 minutes to rotate around the Earth once and it completes 15.54 orbits per day. As an illustration

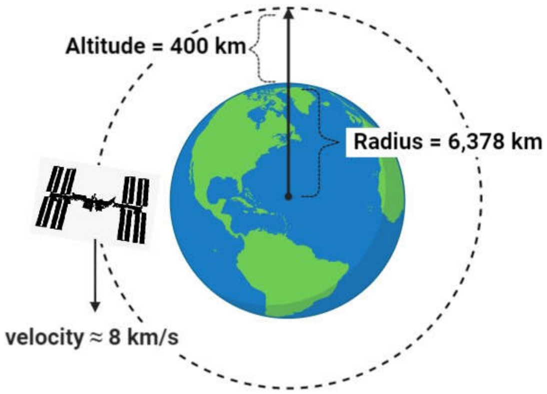

Figure 2. Some general facts about the International Space Station at Earth orbit

Now that we are more familiar with the ISS, we are going to do some calculations to point out that time passes at a different rate for astronauts compared to people who live on Earth.

METHODS

We continue the study by considering a 24 hours period (one day). First of all, let's calculate the distance that an astronaut covers during a day as he or she lives in the International Space Station:

$$s = \frac{d}{t} \rightarrow distance = speed \times time$$

$$d = 27600 \frac{km}{h} \times 24\, h \rightarrow d = \; 662400\, km$$

Hold this result here and then calculate the distance that a normal person on Earth covers in one day. To simplify, we will move ahead by using the circumference of Earth at the equator in our calculations which is 40,075 kilometers. Obviously, the Earth rotates around its axis once a day and the one that lives on Earth's equator, covers 40,075 km. It is here that the big difference happens here; it takes light longer to cover 662,400 km compared to 40,075 km, but the considered time was the same amount for both of them which is a paradox similar to what we studied in time dilation! However, note that still the effect of time dilation is not massive since the light speed is greater $(1{,}079{,}252{,}848.79\; km/h)$. Nevertheless, if we design our experiment for an astronaut who stays at ISS for one year, the result of time dilation will be more impressive.

All in all, time travel is not a dream anymore and the more you stay in space, the more you travel in time. However, technology advancement still needs to provide better conditions for the components of the Lorentz factor so that the effect of time dilation can appear better.

ACKNOWLEDGEMENT

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