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Special Relativity Facing Some Paradoxes

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Abstract:

Time dilation is one of the consequences of Special Relativity (SR) or the Special Theory of Relativity (STR). For one given object (or person), time flows slower the faster the object travels. The object is traveling inside a system, whether the universe, the given galaxy, the solar system or even a smaller system. We will have two worlds: the world of the fast moving object and another world, namely the rest of the system, which is observed by the moving object as stationary. We may consider them as two worlds, since each has its own time running differently. Since one world is included in the other, both worlds interact with each other in many aspects, including energy, flow of material, pressure, and temperature to name few. Since energy (just like temperature and the flow of material) depends on time, the situation gives birth to a number of paradoxes. During the interaction between both worlds, which time should we refer to and, therefore, which energy, flow of material and temperature should we consider? Should we consider the time of World 1 (the fast moving object) or that of World 2 (the relatively stationary environment or system)? The present article illustrates these paradoxes through thought experiments and scenarios. In the end, we should either 1) find an explanation to these paradoxes within the framework of SR, 2) modify some aspects

of SR or add more postulates to cover these paradoxes, or 3) abandon SR if neither 1) nor 2) is possible.

1. Introduction

The Special and General Relativity theories have been the subject of several works published in Physics Essays [1-3] and elsewhere [4-12]. For example, P. Sploter saw a weakness in Einstein's Theory of Relativity in the sense that it cannot explain the eccentricities. She observed that the maximum inclination of the orbit of each planet in the solar system to the equatorial plane of the Sun shows no correlation between the inclination and the eccentricity of the orbit [1,2]. Earlier, J.F. Chazy stated that the problem of explaining Mercury's orbit is not answered by Albert Einstein's General Relativity Theory [4]. L. Essen points out that the Lorentz length contraction factor is an arbitrary assumption [5]. D. Bohm discusses the causality problem of tachyons and concludes that either it must be assumed that no physical action faster than light is possible, or else, Einstein's understanding of relativity does not stand [6]. In his book, "Relativity, Time and Reality: A critical investigation of the Einstein Theory of Relativity from a logical point of view" [7], H. Nordenson, member of the Swedish Academy of Science, more famously known for awarding the Nobel Prize in physics, identifies several weaknesses of Einstein's Theory of Relativity, and establishes a critical conclusion stating that the Theory of Relativity is not physics but philosophy, and poor philosophy for that matter. P. Sploter sees the Theory of Relativity merely as a mathematical model that should not be used to create a new physical science based on hypothetical equations. C. Roychoudhouri discussed the concept of a 4D universe. He builds his reasoning starting with the fact that the running time is not a physical parameter that we can directly measure and asks the pertinent question, whether we should consider the concept of 4D space-time as the final reality of our cosmic system [8].

Of course, besides this criticism, there are incomparably more works supporting Einstein's Theory of Relativity. While my work does not belong to this category, it goes beyond the scope of the aforementioned criticism. It considers another aspect that, to the best of my knowledge, has never been considered in literature, namely the interaction between two systems traveling at different speeds. Relying on a thought experiment, this paper discusses time dilation and reveals ultimately that the Special Relativity Theory may face a paradox, which I refer to as the “Interaction paradox”. I believe that the present work is of nature to interest the readers of Physics Essays by enriching their discussion on the limitations of the Special and General Relativity theories.

2. Special Relativity and Time Dilation

In 1905, Einstein advanced two postulates [13], which later served as the pillars of Special Relativity [14]. First, the laws of physics do not change for objects that are stationed or moving in non-accelerating frames of reference. Second, the speed of light in a vacuum is the same for all observers, regardless of the motion of the light source. SR implies a wide range of consequences, including length contraction, relativistic mass, mass–energy equivalence, and time dilation. In this article, we will limit attention to time dilation.

SR replaces both the Galilean transformations [15] of Newtonian mechanics [16] with the Lorentz transformations and states that time and space cannot be defined separately from each other. All four dimensions, space (3D), and time (1D) are interwoven into a single continuum known as spacetime [17]. In particular, events that occur at the same time for me (such as illuminating two lamps in front of me) may be observed at different times for you (if you come from the right or the left hand side).

That said, according to SR the laws of physics are still valid, including energy conservation and the principle of causality. For example, if one event creates (or causes) another one, any observer sees the creator (or the cause) before the creation (or the effect), although time dilation may occur. Causality in the SR framework imposes that no object can travel faster than light. In fact, if one event creates another event, and this creation takes place very rapidly, with a speed superior to the speed of light, then the observer may see the creation before the creator, which violates the principle of causality: effects cannot precede their causes.

The effect of time dilation imposes that time passes slower the faster one goes. To illustrate this effect, a thought experiment has been suggested at the beginning of the 20th century. If a twin rides in a speeding spaceship (World 1) to some distant star in our Galaxy, the Milky way (World 2), and then returns to Earth (still in World 2), he will find himself younger than his brother who remained on Earth all the while. This thought experiment is referred to as the "Twin Paradox". In other words, let us suppose that "twin A" enters World 1, and travels within World 2 at a speed of $v=0.866\ c$ (c: speed of light in a vacuum), while his twin brother, "twin B", remains stationary in World 2, outside World 1. After 10 years of traveling within World 2, "twin A" returns to Earth and exits World 1 (which is part of World 2), only to discover that he is 10 years younger than "twin B", who aged 20 years during the journey of "twin A". In the "Twin Paradox", the interaction between World 1 and World 2 is disregarded. In this article, we intend to investigate this interaction and conclude whether it can be a decisive factor for the survival of SR itself.

According to the aforementioned thought experiment, not only does "twin A" become 10 years younger than "twin B", World 1 also becomes 10 years younger than the rest of World 2, supposed to be stationary. Everything residing in World 1, including the remaining fuel, is younger than the rest of World 2.

According to his perception and his clock, "twin A" has spent 10 years in World 1 traveling inside World 2. In reality, however, he and World 1, in its entirety, traveled for a period of 20 years. For this purpose, the fuel should be enough to last 20 years of consumption. However, since the remaining fuel is inside World 1, its age increased by only 10 years after the journey. If the fuel pump, which is also part of World 1, has been designed and fabricated on Earth to have a lifespan of 15 years, is it enough to cover the travel? Or should it be replaced during the journey, although it has not, according to the principle of time dilation, surpassed its designed lifespan? If, instead of fuel, World 1 uses solar energy extracted from different suns in World 2, the same questions arise concerning the physical characteristics (lifespan, ...) of the solar panels. This paper will address such questions relating to the interaction between World 1 and World 2.

3. The Interaction between the Worlds

Again, in this context, “world” defines a system where time runs in a certain way. We have chosen this term because an individual automatically imagines two different worlds in order to be able to conceptualize two systems with two different running wheels of time.

Energy is time-dependent, since it is linked to power through time:

$$E = P \quad t \tag{1}$$

The power *P* is a characteristic of the object (or person). For example, the muscles of a human being give us an idea of his/her power. The energy, *E*, is equivalent to the work of this power (muscles) during a period of time. A resistor, *R*, under a voltage, *V*, and fed by a current, *I*, receives a power of:

$$P = V \quad I = R \quad I^2 = V^2 / R \tag{2}$$

Let us suppose that the resistor with its electric source are traveling at a speed of v=0.866 x *c*. In other words, the actors *R*, *I*, and *V* entered World 1 and began the journey. Let us also suppose that World 1 is not thermally hermetic, ensuring that all the energy dissipated from the traveling resistor, *R*, spreads in the environment, meaning World 2. After the passing of a time of ΔT (1 hour, for example) in World 1, World 2 will be $\Delta T'=2\,\Delta T$ older (2 hours) than it was, meaning ΔT older than World 1.

Given that the actors *R*, *I*, and *V* do not depend on the speed, they should dissipate the thermal energy during the time interval ΔT (travel period seen by World 1):

$$E = E_0 = \Delta T \quad V \quad I = \Delta T \quad R \quad I^2 = \Delta T \quad V^2 / R \tag{3}$$

This energy is dissipated in the environment (World 2), which is stationary during the travel period 2ΔT. Thus World 2 perceives the double of the quantity of Eq. 3, namely:

$$E = 2 \quad E_0 = 2\Delta T \quad V \quad I = 2\Delta T \quad R \quad I^2 = 2\Delta T \quad V^2 / R \tag{4}$$

since World 2 was constantly receiving heat during $2\,\Delta T$ in an uninterrupted manner and not during ΔT only. We can observe in equations (2) to (3) that Ohm's and Joule's laws are still valid, but the paradox is that the dissipated energy *E* is for the same situation equal to E_0 and to $2E_0$, because the interacting actors (resistor and environment) are subject to two periods of time: ΔT and $2\,\Delta T$. The question remains, how can we solve this paradox? Attempting to solve this paradox within the framework of SR, leaves only three possibilities:

1. The actors, *R*, *I*, and *V*, will behave, at speed *v*, in a different manner compared to the situation at speed v_0=0 m/s.
2. Energy, *E*, will be calculated differently at speed *v*.
3. The law of energy conservation is not valid anymore at speed *v*.

The paradox arises due to the fact that time dilation implies that time in World 1 dissociates itself from the time in World 2, although both worlds interact in a continuous way. This interaction allows for two scenarios to be occurring (superimposing) at the same time (same situation): ΔT or $2\,\Delta T$. Quantum mechanics [18] also allows similar paradoxes when considering that micro-particles (quantum objects) may have two or more states at the same time. According to the laws of quantum mechanics, these states are superimposed. One electron may have two speeds or two positions in space at the same time. Could quantum mechanics explain this paradox, bearing in mind that 1) quantum superimposition is explained by the probability (probability density, probability wave, ...) as well as uncertainty (Heisenberg's uncertainty principle), and that 2) the paradox, ΔT or $2\,\Delta T$, has a macro rather than microscopic manifestation, and is not subject to probability and uncertainty?

The same paradox is valid when analyzing the behaviour of temperature. Since the dissipated energy will cause a warming of World 2 by a certain temperature. It is obvious that the increase of temperature during $2\,\Delta T$ is higher than the increase of temperature during only ΔT. Thus, possibility 3, mentioned above, should be generalized to encompass more laws of physics and not only energy conservation.

Expanding on the interactions between both worlds, let us consider another thought experiment, which I simply named, the *Interaction Paradox*. In this experiment, I would like to bring forth four scenarios. The experiment observes the interface between two words having different time clocks.

4. The Interaction Paradox

In order for a pizza to be ready (for consumption), it needs to be cooked for $\Delta T' = 20\ minutes$ under a temperature of $T_0 = 100^{oC}$. To maintain this temperature for this period of time, the stove should be fed fuel at a flow rate of $f_r = 0.3\ liter/hour$. In this case, the pump's rotary knob, with which the fuel's flow rate is adjusted accordingly, should be set at level 3, for example. After $\Delta T' = 20\ minutes$, the quantity of fuel pumped into the hose and provided to the heat source is $Q = \Delta T' \text{ x } f_r = 0.1\ liter$. Energy transferred to the pizza during this heating period, namely $\Delta T'$, and for the temperature $T=T_0$, is $E=E_0$. Here, we supposed that all actors are stationary ($v_0=0$ m/s): room, observer, pizza, heat source, hose, and fuel.

4.1. Scenario 1:

The first scenario (scenario 1) depicts the system illustrated in Figure 1, where World 1 is the traveling pizza, and World 2 is the room, including the heat source and the observer who is waiting for the pizza to be cooked. The heat source (stove) is stationary as depicted in Figure 1. The pizza is rotating with a linear speed of $v_1=0.0001\ c$, where c is the speed of light in a vacuum. Since the speed of the pizza is tremendously inferior to the speed of light, time dilation is negligible, and therefore, $\Delta T'=\Delta T= 20\ minutes$ is necessary to have the pizza ready to eat. In other words, the energy necessary for cooking the pizza is $E=E_0$. In this scenario, there is no paradox.

4.2. Scenario 2:

Let us now consider scenario 2. The pizza is rotating at a speed (tracing the circumference) that is comparable to the speed of light in vacuum. As a result, the pizza's age is inferior to the heating period. To be more precise, the following formula of time dilation is valid:

$$\Delta T' = \frac{\Delta T}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{5}$$

Given that the speed of the pizza is $v_2 = 0.866\,c$, the age of the pizza will be half of the duration of the heating, meaning that after a heating period of $\Delta T' = 20$ *minutes* the pizza perceives only a cooking period of $\Delta T = 10$ *minutes*. Now, when considering scenario 1 and scenario 2, the paradox is manifested by, among others, the following questions:

1. In scenario 2, after *20 minutes* of heating, is the pizza ready to be consumed? We understand that in scenario 1, the pizza is ready to be eaten since the age of both the pizza and the heating is $\Delta T' = 20$ *minutes*, which is the time required to cook the pizza.
2. Since the stove was heating the pizza in an uninterrupted way for a period of $\Delta T' = 20$ *minutes*, the pizza was in contact with the heat for also a period of $\Delta T' = 20$ *minutes*; and therefore, the stove was releasing an energy amount E on the pizza. As such, what is the amount of energy received by the pizza: E or $E/2$?
3. If the stationary stove releases the amount of energy E on the pizza, and the pizza is perceiving $E/2$, where did the remainder of the energy, $E/2$, go? Was it ($E/2$) released into the environment; and thus, making the room warmer?
4. The pizza is $\Delta T = 10$ *minute*-old, however, the fire flame (stationary) was touching the pizza for $\Delta T' = 20$ minutes. Does the effect of the flame on an object depend on its speed?

4.3. Scenario 3:

I would like to propose two other scenarios. In scenario 3, both the heat source (including the fuel container) and the pizza are traveling at the same speed $v_3 = 0.866\,c$. In this case, no paradox is imposed, as the pizza will be ready for consumption after it has reached the age of $\Delta T = 20$ *minutes*.

The stationary person, to be served, must wait for $\Delta T' = 2\Delta T = 40$ *minutes* for the pizza according to the time dilation formula.

4.4. Scenario 4:

In scenario 4, while both the heat source and the pizza are traveling at the same speed, $v_4 = 0.866$ *c*., a stationary fuel container feeds the stove's pump. The hose connected to the pump is traveling at the same speed, $v_4 = 0.866\ c$, and has its end submerged in the stationary fuel container. According to Einstein's theory and the aforementioned time dilation formula, the observer should wait for $\Delta T' = 2\Delta T = 40$ *minutes* to have the pizza ready for consumption. The paradox is manifested by, among others, the following questions:

1. As mentioned above, to maintain a temperature of $T = 100^{oC}$, the rotary knob of the pump should be set at level 3, and fuel of a quantity of $Q = 0.1$ *liter* is required to cook the pizza. When the stationary observer reaches an additional age of $\Delta T' = 20$ *minutes*, the pump is only $\Delta T = 10$ *minute* older. However, the age of the fuel in the stationary container is $\Delta T' = 20$ *minutes*. The hose is stretched between the fuel and the pump at all times, and the rotary knob of the pump is fixedly set at level 3. Thus, the quantity of fuel received by the pump is $Q = \Delta T' \text{ x } f_r = 0.1$ *liter*, which is sufficient to cook the pizza. Nonetheless, the pizza is not ready to eat, as its age is only $\Delta T = 10$ *minutes* after all. The paradox question is: How could the pizza be not ready for consumption, when all necessary conditions have been satisfied: $T = 100^{oC}$ and $Q = \Delta T \text{ x } f_r = 0.1$ *liter*.
2. The pump is working normally at level 3 and extracts the fuel quantity $Q = 0.1$ *liter*. The stove is working normally and is ensuring a temperature of $T = 100^{oC}$. However, the pizza needs an additional period of time to be ready for consumption. Precisely, it needs as much

time as the time already spent. The question is: Where did half of the energy provided by the fuel quantity *Q*, meaning Q/2=0.05 *liter*, go?

5. Conclusion

I am writing to readers to share the paradoxes I have noticed in SR, particularly concerning the time dilation formula. To the best of my knowledge, the aforementioned paradoxes have never been set forth before. It would be interesting to investigate whether these paradoxes can be explained through SR itself, or if they may expose the limitations of the theory or certain aspects of it. While I do not claim to have the solutions, I believe that a discussion surrounding the *Interaction Paradox* is worthwhile.

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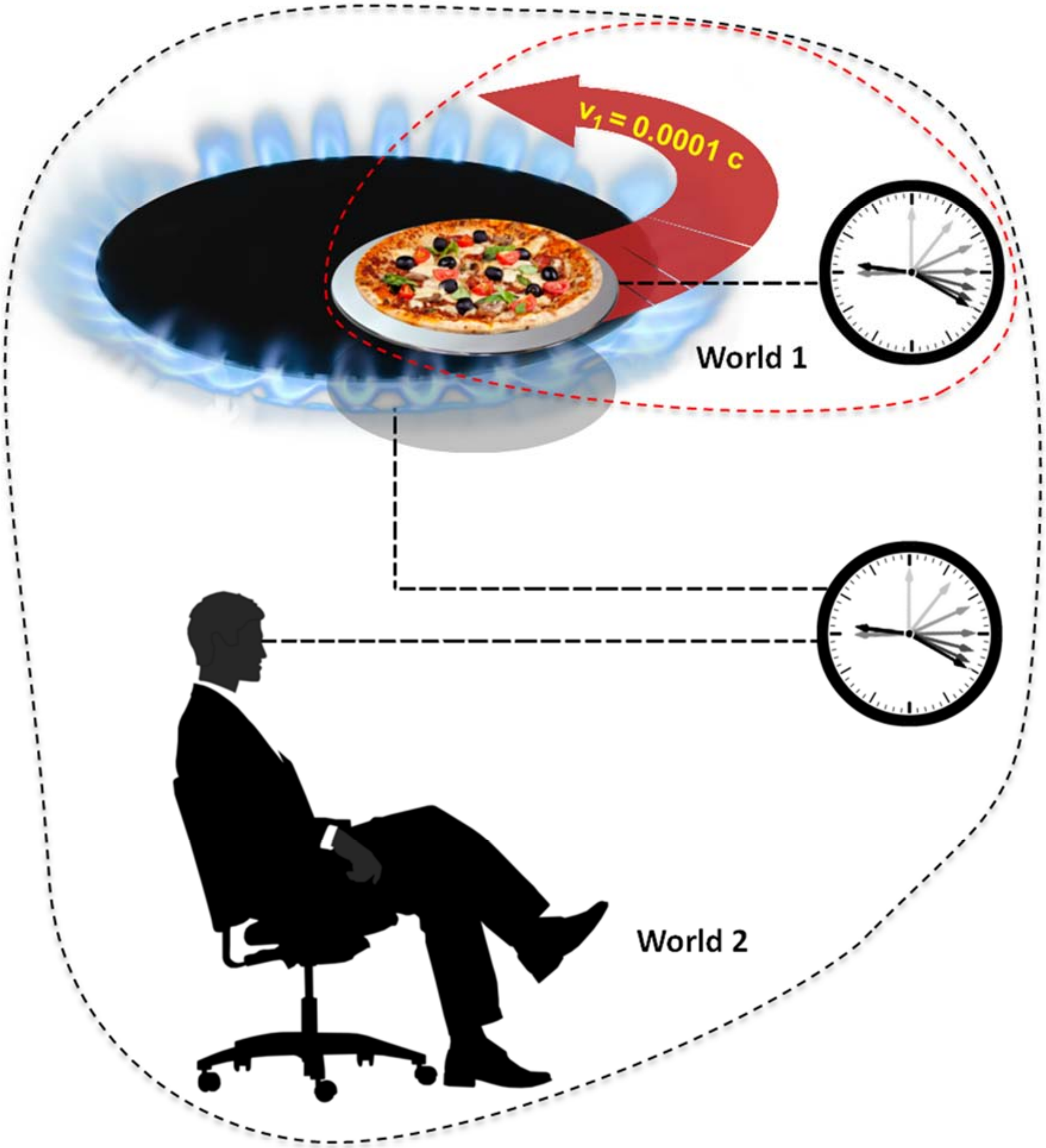

Figure 1: Scenario 1: A stationary observer is observing a stationary stove, and a pizza traveling at low speed