The Concept of Special Relativity

A Brief Introduction by Izzy Deadyet

Sources:

[1] – Einstein, Albert. *Relativity: The Special & The General Theory, Third Edition.* Methuen & Co. Limited, 1920.

[2] – Taylor, John R., Zafiratos, Chris D., and Dubson, Michael A.. *Modern Physics for Scientists and Engineers, Second Edition.* University Science Books, 2015.

[3] – Hafele, J.C., and Keating, R.E.. "Around-the-World Atomic clocks: Predicted Relativistic Time Gains." *Science: New Series*, Vol. 177, No. 4044, 1972.

Have questions? Feel free to email me at IzzyDeadyetStories@gmail.com

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Hope you're having a nice day! :D

So you know velocity addition, yeah? If you walk forward at some speed, say 2 mph, and you throw a rubber ball in front of you at 3 mph, someone standing still and watching the ball will see it moving at 5 mph.

If you walk forward and throw that ball *behind* you, the person standing still will see the ball moving at 1 mph.

In this case, your point of view is called a reference frame, and because you see the ball move at the same speed no matter which direction you throw it in, we call it the central reference frame. The p.o.v. of your stationary friend is another reference frame, just not the central one.

Light doesn't work like this.

If you walk forward at 2mph, and you shine a flashlight in front of you, you see the light leave that flashlight at a certain speed, which for convenience, we'll call c. Your friend, standing still, will *also* see the light moving at exactly c. They'll measure the same speed if you shine the flashlight behind you.

This is because **Light is measured at the same speed in every direction, no matter how you're moving when you measure it.**

This concept is called Special Relativity [1], and it means that there is no such thing as a central reference frame for light, and the only way to define a reference frame is to define it *relative* to some other reference frame.

This, of course, has some strange implications for how time works.

Imagine you're standing on a moving train, and you shine a light upwards, towards the ceiling three meters above you. From your perspective, the light travels exactly three meters. For someone watching from outside the train, however, the light moves more than three meters, as by the time the light has hit the top of the car, the car will have moved slightly.

Because you both see light move at the same *speed*, but your friend on the ground has seen the light travel more *distance,* it must be that they have experienced more *time* between the lighting of the flashlight and the light hitting the ceiling than you have!

Then, because the light in this scenario isn't changing anything about you, the train, or your friend, we can say in general that **Fast-moving objects experience less time than slow-moving objects in a given reference frame.**

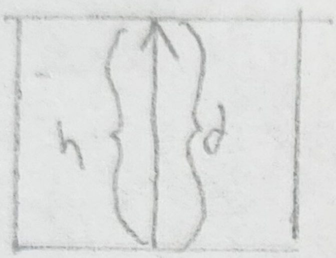
(via some fancy geometry, we can actually determine the exact amount these times differ. If a clock at rest measures time t passing, then a clock moving at speed v will measure time t'=g*t in the same interval, where g is described on the inside of the back cover [2])

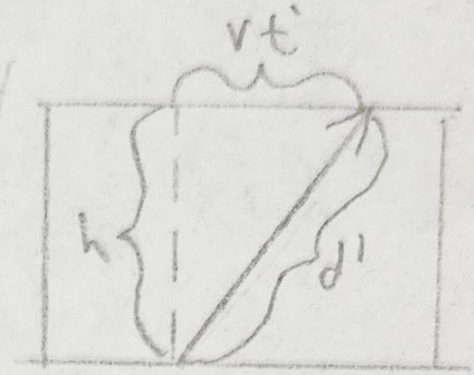
The form of g is also telling of the famous 'universal speed limit', as we can see that if an object were to move faster than light, the time it experiences would be imaginary, which is not only nonsensical

And this is provably true. In 1971, the Hafele-Keating experiment took two of the most accurate clocks ever produced, and flew one around the globe on a commercial airline. After the two clocks were reunited, the one that had traveled the globe measured a matter of 275 nanoseconds ahead of the stationary clock [3].

This theory of Special Relativity, along with General Relativity (much more complex, and not worth mentioning here), forms the backbone of our current understanding of spacetime, not as a rigid grid of lines and coordinates, but as a shifting fabric that changes based on how an observer moves through it.

train frame / ground frame





$d = h$

$d' = \sqrt{h^2 + v^2 t'^2}$

$t = \frac{d}{c} = \frac{h}{c}$

$t' = d'/c$

$$= \frac{\sqrt{h^2 + v^2 t'^2}}{c}$$

$$t'^2 = \frac{h^2}{c^2} + \frac{v^2 t'^2}{c^2}$$

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} \rightarrow$$

$$t' = \frac{1}{\sqrt{1 - v^2/c^2}} \frac{h}{c}$$

$$\boxed{t' = \frac{1}{\sqrt{1 - v^2/c^2}}\, t}$$