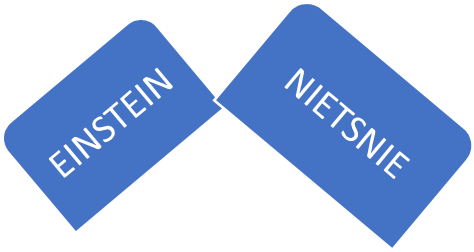
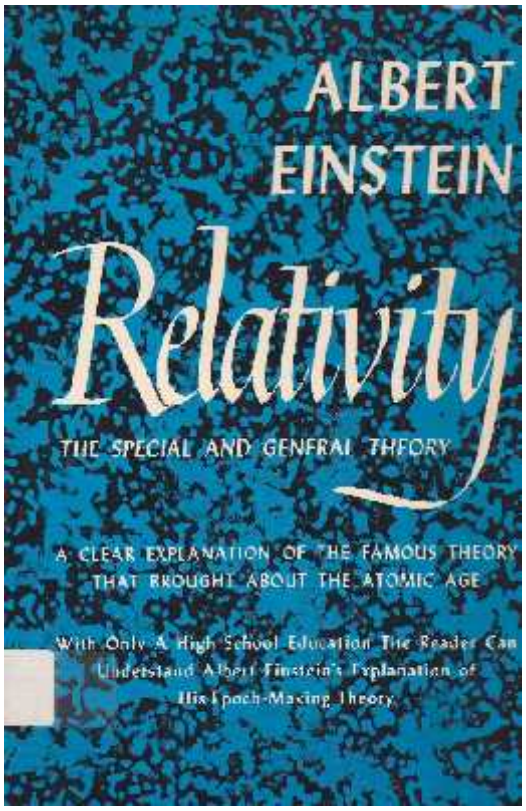
A Discussion on The Relativity of Simultaneity





by

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Background

In order to explain Einstein's Theory of Relativity I have chosen first to report what Einstein had to say about it. He does this in about 29 pages but we are only going to look at two pages. Einstein spends these pages on definition, procedure, and result. Seems pretty simple and this is the reason to start with the author. So, if someone asks what Einstein's Theory of Relativity is, then this paper will give the quickest way to come up with an answer. The book[1] may be a better place to look, start, and read than this rendering as it says on the cover "A clear explanation of the famous theory…" and "With only a high school education the reader can understand…his epoch-making theory."

The theory is as fascinating today as it was when he wrote it.

Task

The task is to explore Einstein's "Special" Theory of Relativity by reviewing the information in Chapter IX of his book titled "The Relativity of Simultaneity" written in 1916. Einstein discusses a train traveling through a train station and at the midpoint of the station two strikes of lighting simultaneously hit the front and rear of the train. An observer in the train sees both strikes. An observer at the train station midpoint also sees the simultaneous lighting strikes. The question is "did both observers see the same two strikes at the same time?" Let us read what Einstein says exactly in his book. You will probably read this more than once but this explanation is not that difficult. You must see how the observer in the train sees the flash (***B***) ahead of him first, then he sees ***A***. When this picture comes clear to you, you have a handle on the theory! This is how Einstein tells it…

[1] Albert Einstein. (1961). *Relativity: The special and the general theory* (R.W. Lawson, Trans.). New York, NY: Crown Publishers. (Original work published 1916)

Railway Embankment

Chapter IX starts on page 25 and because his thought experiment is short, I will render all of it here.

"We suppose a very long train travelling along the rails with the constant velocity ***v*** and in the direction indicated in Fig. I. People travelling in this train will with advantage use the train as a rigid reference-body (co-ordinate system): they regard all events in

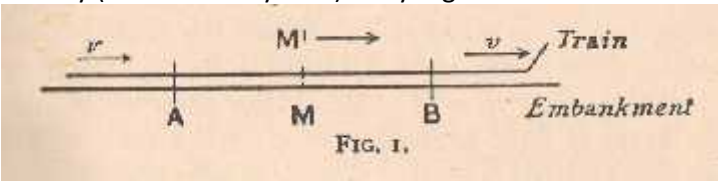


FIG. 1.

reference to the train. Then every event which takes place along the line also takes place at a particular point to the train. Also the definition of simultaneity can be given relative to the train in exactly the same way as with respect to the embankment. As a natural consequence, however, the following question arises:
Are two events (e.g. the two strokes of lightning ***A*** and ***B***) which are simultaneous with *reference to the railway embankment* also simultaneous *relatively to the train*? We shall show directly that the answer must be in the negative.

When we say that the lightning strokes ***A*** and ***B*** are simultaneous with respect to the embankment, we mean: the rays of light emitted at the places ***A*** and ***B***, where the lightning occurs, meet each other at the mid-point ***M*** of the length ***A*** (→) ***B*** of the embankment. But the events ***A*** and ***B*** also correspond to positions ***A*** and ***B*** on the train.

Let ***M'*** be the mid-point of the distance ***A*** (→) ***B*** on the travelling train. Just when the flashes [as judged from the embankment] of lightning occur, this point ***M'*** naturally coincides with the point ***M***, but it moves toward the right in the diagram with the velocity ***v*** of the train. If the observer sitting in the position ***M'*** in the train did not possess this velocity, then he would remain permanently at ***M***, and the light rays emitted by the flashes of lightning ***A*** and ***B*** would reach him simultaneously, i.e. they would meet just where he is situated.

Now in reality (considered with reference to the railway embankment) he is hastening toward the beam of light coming from ***B***, whilst he is riding on ahead of the beam of light coming from ***A***. Hence the observer will see the beam of light emitted from ***B*** earlier than he will see that emitted from ***A***. Observers who take the railway train as their reference-body must therefore come to the conclusion that the lightning flash ***B*** took place earlier than the lightning flash ***A***. We thus arrive at the important result:

Events which are simultaneous with reference to the embankment are not simultaneous with respect to the train, and vice versa (relativity of simultaneity). Every reference-body (co- ordinate system) has its own particular time; unless we are told the reference-body to which the statement of time refers, there is no meaning in a statement of the time of an event" (pp. 25-26.) [highlights mine.]

How did you do?

Did the observers see the two lightning strikes at the same time? If not, who is correct?

This short video (02:03) will give as clear a picture of the event as I have seen. Course, there are more out there but this one is the easiest to grasp – and the shortest. As a way to 'check your answer' on his train car and lightning strikes look at:

Simultaneity - Albert Einstein and the Theory of Relativity

https://www.youtube.com/watch?v=wteiuxyqtoM (2:03)

"Both observers are correct from their frame of reference.

This is a fundamental result of Special Relativity.

From different referent 'range' there can never be agreement on simultaneity of event."

At this point you should be able to explain to ~~your grandkids~~ an interested person what Einstein started with to explain his 'Special' Theory of Relativity. This means this paper is really over with and now is a good time to move on; however, I do have a couple of items under the rubric of "Finishing the Paper" and "Tell me some more about this genius Albert Einstein." So here is the rest of the story…

Just a minute – or just a 'light second' (how many miles is that?)

Yes, I have some questions. The first answer on a light second is:

Constant light velocity (straight line) is **186,282.39 miles/sec** or, exactly, **299,792,448 meters/sec.**

My second question is why did he start in his book with "The Relativity of Simultaneity" and not on "The Theory of Relativity"? So what is the deal? Glad you asked. This will help us get to the overall question of his theory of "Relative - to what?"

**Some general comments, references, and suggestions **

Notice on the cover of the book it says "The Special and General Theory." What this means is Einstein's theory is actually in two parts: The "Special" applies only to constant-velocity motion (speed of light) and The General Relativity Theory is applied to accelerated motion and gets into a static and

homogeneous gravitational field. Time and space (mean the same thing), then mass and energy, and this of course, leads to his famous $E = mc^2$ (this equation is for a stationary object).

The note here goes back to his 1905 fourth paper and to his 2nd postulate "…the velocity of light was independent of the motion of its source[2]." Isaacson embellishes this event in his book by pointing out Einstein telling a colleague Michele Besso he was going to give up on the key to this problem but then told him the next day: *"I've completely solved the problem."* As he later explained "the constancy of the velocity of light is not consistent with the law of the addition of velocities. The result was that I had to spend almost one year in fruitless thoughts" (p. 122).

Einstein works his way to solving "the" problem in his book by first discussing lessons like: Space and Time in Classical Mechanics, The Galileian System of Co-ordinates, On the Idea of Time in Physics, and to Chapter IX, the one we are reading now, on The Relativity of Simultaneity. He moves on to discuss, for sure beyond the scope of this paper, examples like The General Theory which includes The Gravitational Field, Gaussian Co-ordinates, and Four-dimensional Space.

<u>The real joy of reading about Einstein</u>

Einstein will grow on you the more you read about him. He will become a very likeable fellow. Isaacson is as good a place to start as there is for looking at the man as a person but still holding up his genius life. The Isaacson book is crammed full of details and they even made a movie from it. The sentiment for this is in Chapter 1: "The Light-Beam Rider" on page 2:

> Looking back at a century that will be remembered for its willingness to break classical bonds, and looking ahead to an era that seeks to nurture the creativity needed for scientific innovation, one person stands out as a paramount icon of our age: the kindly refugee from oppression whose wild halo of hair, twinkling eyes, engaging humanity, and extraordinary brilliance made his face a symbol and his name a synonym for genius. Albert Einstein was a locksmith blessed with imagination and guided by a faith in the harmony of nature's handiwork. His fascinating story, a testament to the connection between creativity and freedom, reflects the triumphs and tumults of the modern era.[3]

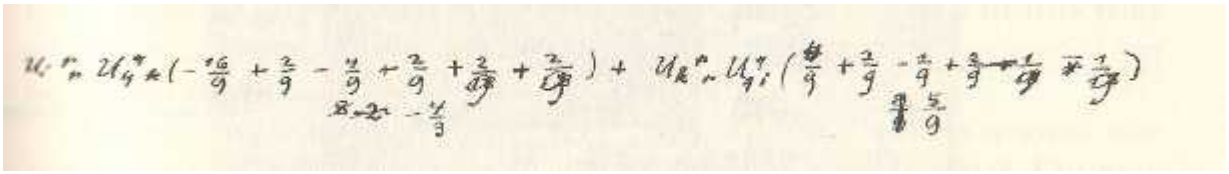
[2] Walter Isaacson. (2007). *Einstein: His life and universe.* New York, NY: Simon & Schuster Paperbacks.
[3] This quote is in the book and noted at this Web site:
https://ew.com/tv/2017/01/05/geoffrey-rush-albert-einstein-genius-trailer/

The rose reflects the story of Einstein's acceptance to be made a professor at the University of Berlin in 1913. "With puckish amusement" (Isaacson, p. 179) he wore a red rose to reveal his acceptance -.he said he would wear a white rose if he declined.

Tick Tock, Space-Time, Tick Stop

This title should be used to address Einstein as a 16-year-old boy in 1895 imagining riding his bicycle along side a light beam. "A decade later came his miracle year…which laid the foundations for the two great advances of twentieth-century physics: relativity and quantum theory" (Isaacson, p. 3),

"Also by his bed were twelve pages of tightly written equations, littered with cross-outs and corrections. To the very end, he struggled to find his elusive unified field theory. And the final thing he wrote, before he went to sleep for the last time, was one more line of symbols and numbers that he hoped might get him and the rest of us, just a little step closer to the spirit manifest in the laws of the universe" (Isaacson, p. 543)



Additional References

The two Einsteins: Behind the scenes – National Geographic
https://www.youtube.com/watch?v=P0WDE5LHZSU (3:08)

The Extraordinary Genius of Albert Einstein - Full Documentary HD – history.com
https://www.youtube.com/watch?v=Uvpw6Jh1WGQ (1:29:52)

Time Dilation - Einstein's Theory Of Relativity Explained! See at 2:50 for lightning/train.
https://www.youtube.com/watch?v=yuD34tEpRFw (8:14)

Principle of Relativity: All frames of reference are equally valid. There is no way to determine If you are moving or at rest, only the relative motion between objects Is physically meaningful.
https://www.youtube.com/watch?v=EI2OPCdGXkw (at 1:50 of 9:35)