Lecture 1

Thursday, 9 January 2020 9:43 AM

"Common sense is a collection of prejudices aquired by age 18"
— Einstein

Hey, I am Rajashik Tarafder. You can call me Ray. And welcome to your favourite and most memorable course at Caltech.

Before, we jump into the gory details of physics, let me share some basic information:

TA's Information

Email ID: rtarafder@caltech.edu
Rec Hours: 1-2 PM M/R, 155 Arms
Office Hours: 7-8 PM Tuesdays, 4th Floor Lauritsen
Website: rtarafder.co.in/teaching.html.
I will be posting all materials from the rec session here.

Like any course, I am heavily dependent on your feedback to get things right. So I will really appreciate it if you can drop me a line or two after classes at a feedback form on the website. I will love it even more when you let me know that you have enjoyed the class.

About me

I am a second year Graduate student and did my undergraduate from India. I used to do Astrophysics but am now working on Quantum Gravity. If you want to learn about these areas, feel free to ask me questions. No guarantees on my ability to answer them.

To learn a bit more about you, I shall pass some index cards and it would be awesome if you want to write down your names, pronouns, something interesting about you and something you wish to learn from me.

Text

I shall be primarily following David Morin's book 'Special Relativity for the Enthusiastic Beginner' for the first part of the course and for the second half, we shall refer to Purcell and Morin's book on 'Electricity & Magnetism'.

Why care about this course?

Well, Special Relativity and Electromagnetism between them constitute the very spirit of Mordern Physics. An elegant theory with its root in empiricism and a giant leap with analytics which has changed the way we look at the world like nothing else. Special Relativity itself owes its advent to our understanding of Maxwell's equations of electromagnetism. On the other hand, the succes and validity of STR led to much of 20th century physics such as GR, QFT, String Theory among others. I will try to present a short note on this towards the end of our discussion on Special Relativity.

STR has a 100 years of outlandish claims behind it and nothing to prove it wrong so far.

In terms of the course, we shall have about 3-4 weeks of STR between us and the rest of the term shall concentrate on electrostatics. When we start electrostatics, you will encounter Multivariable calculus and we will see if we can devote a class to it.

A Brief Brief History of Special Relativity

Relativity itself is nothing new. Infact, it was so well understood even in the 1600s that Newton described his laws in terms of inertial frames i.e. all frames with no acceleration and separated by a relative velocity. In fact, you may have yourself seen relativity in action. For example, if you rode the Shinkansen in Japan, you could practically use it as a perfect inertial frame. This applicability of Newtons laws was a giant leap in understanding the universe.

Therefore, towards the end of the 19the century, physicists (the proud bunch we are) were confident that we had a near complete understanding of the universe. By this time, Maxwell had already provided us the theory of electromagnetic radiation. Using these, we calculated the speed of light. It was found to be $c = 299\,792\,458$ m/s. For pretty much throughout this course, we will approximate it to 3×10^8 m/s.

Note:- Physicists like to use a different set of units called natural units with $c = 1$. However, the value of c is unimportant to us. We only want to see what happens if c is infinite.

But Maxwell's laws had a problem. We know that the speed of light was c. But in which reference frame?

Physicists initially proposed that Maxwell's equation held only when described in a all prevading medium called ether. All light travelled through this medium as sound travelled through air. This led to the Michelson Morley experiment that Dave described in class.

* Mention Lorentz Fitzgerald suggestions.

However, Einstein was not amused. He tried to look at the equations in a slightly different way. He asked what if

Postulates

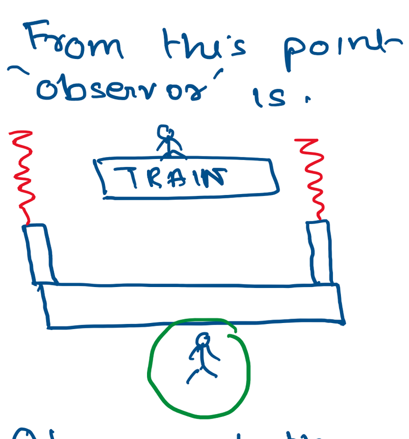
1> *Newton was right and* laws of physics are the same in all inertial frames
2> The speed of light is same in all reference frames.

The second postulate is a consequence of the first. And using these two alone, we will work out the crazy claims of STR.

So lets try to answer Einstein on what happens if the above two postulates hold.

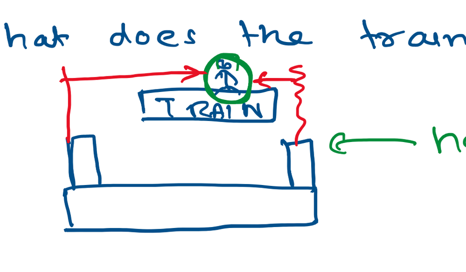
Loss of Simultaneity

From this point onward, we will always define who the 'observer' is.



Observes both together

What does the train observor see?

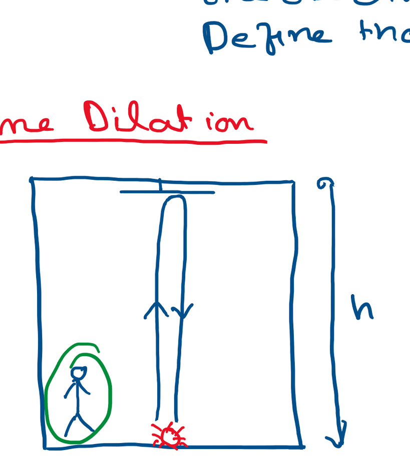


Can we change the order of events?

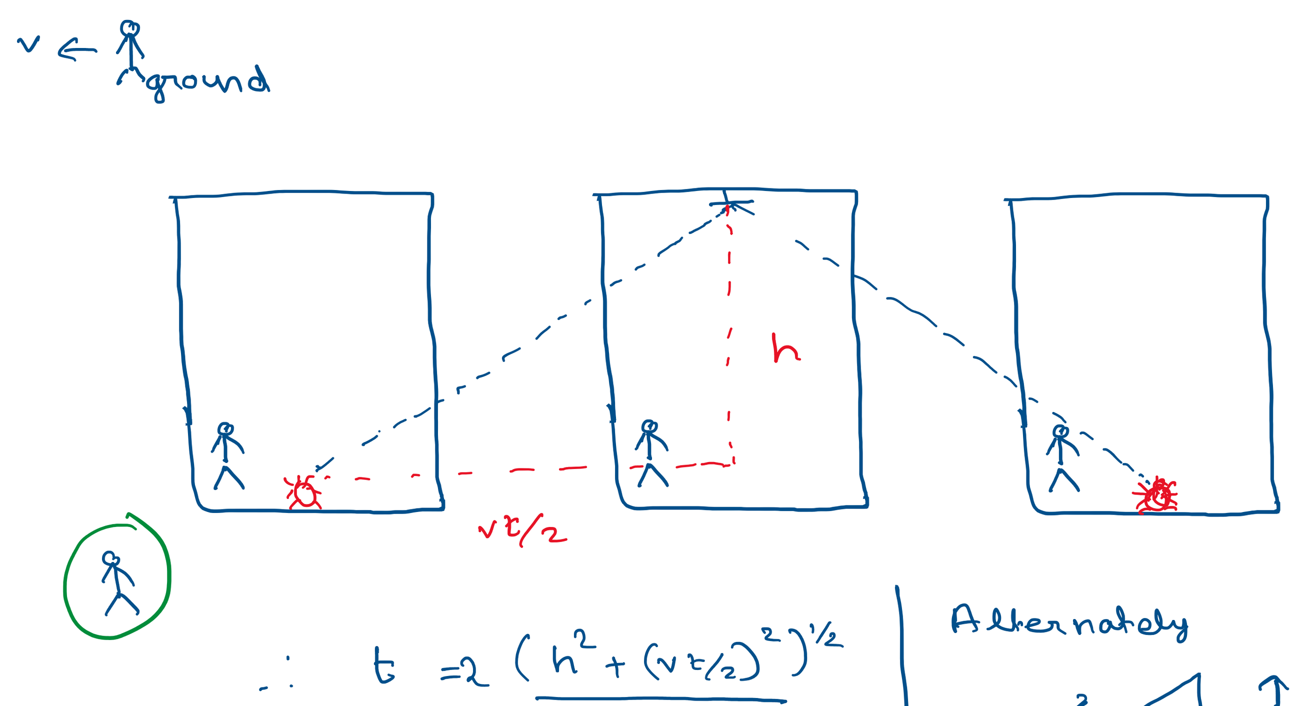
We will see later that this is not the full story. But we will be to ourselves for the time being.

Takeaway: Description of events in STR always depends on the observor.
Define that first.

Time Dilation



$t' = 2h/c$



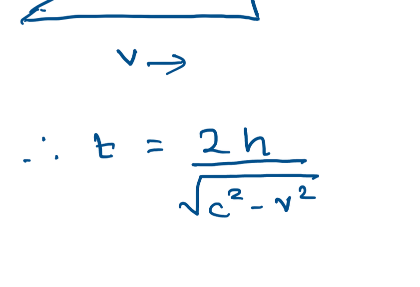
$$\therefore\ t = \frac{2\left(h^2 + (vt/2)^2\right)^{1/2}}{c}$$

$$\Rightarrow \frac{c^2t^2}{4} = h^2 + \frac{v^2t^2}{4}$$

$$\Rightarrow \sqrt{(c^2 - v^2)}\, t = 2h$$

$$\Rightarrow t = \frac{2h}{\sqrt{c^2 - v^2}}$$

Alternately



$$\therefore\ t = \frac{2h}{\sqrt{c^2 - v^2}}$$

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

↑ γ

$\gamma = 1$ if $v = 0$

otherwise

$\gamma > 1$ for any other v.

" Interpret time dilation and how both frame see each other dilated".
"Is there a contradiction"

We will see later why that is the case, but for now it is essential to remember that time dilation can only be applied when the events takes places at the same place in some frame.

Let's look at a problem from Helliwell

⊛ Two π^+ mesons are created, one at rest and one moving at $v = (4/5)c$. Each decays in 2.5×10^{-9} s in its own rest frame. Find
a> lifetime of moving pion as measured in lab
b> lifetime of pion at rest in lab as measured by moving pion.

a> $t = \gamma t'$

$$= \frac{1}{\sqrt{1 - \frac{16}{25}}}\ 2.5\text{ ns}$$

$$= \frac{5}{3}\ 2.5\text{ ns}$$

$$= 4.17\text{ ns}$$

b> the same.