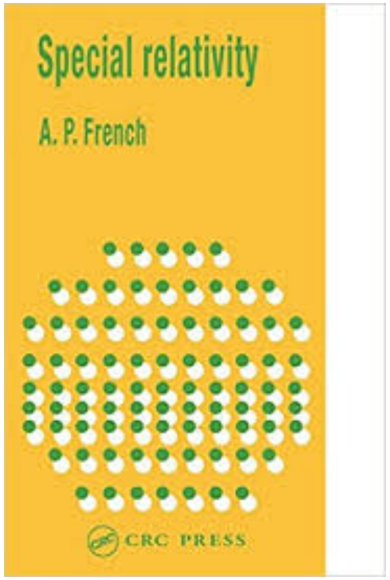
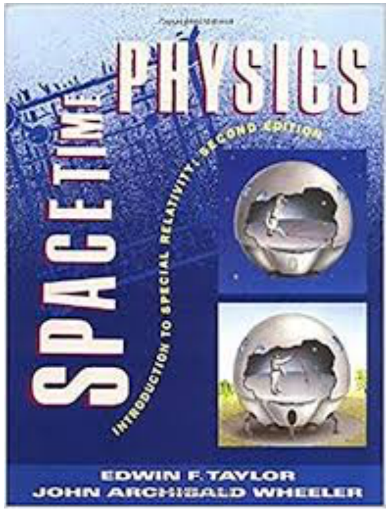
Welcome to Special Relativity!



In Weeks 6 and 7 we will study **Special Relativity**

SPECIAL RELATIVITY		
Week 6	**Mon 3 Sep** 10.30-11.30 EN303	Class 1: Frames and Events
	Tues 4 Sep 1.30-2.30 EW301	Class 2: Einstein's Postulate
	Wed 5 Sep 3.30-4.30 ATC421	**Tut 1: Special Relativity Set 1**
	Thurs 6 Sep 3.30-4.30 BA702	Class 3: Lorentz Transformations
Reading Week		
Week 7	**Mon 17 Sep** 10.30-11.30 EN303	Class 4: Space-time Diagrams
	Tues 18 Sep 1.30-2.30 EW301	Class 5: Energy and Momentum
	Wed 19 Sep 3.30-4.30 ATC421	**Tut 2: Special Relativity Set 2 (assessed)**
	Thurs 20 Sep 3.30-4.30 BA702	Class 6: Relativistic Phenomena



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Class 1: Frames and Events

In this class we will describe the framework of relativity: events, inertial reference frames, synchronized clocks and co-ordinate transformations

Class 1: Frames and Events

At the end of this session you should be able to …

- … outline the framework of **events, reference frames and synchronized clocks** used for relativity analysis
- … be familiar with **inertial frames**, and why they are special
- … state the **principle of relativity**, relating the results of experiments which take place in different inertial frames
- … describe the classical **Galilean transformation** between inertial frames, with its concept of **absolute time**, and the experimental evidence contradicting these ideas

Space-time

- In the next few classes we will study the **special theory of relativity**, a crowning achievement of modern physics

- Relativity **re-frames our basic understanding of space and time**

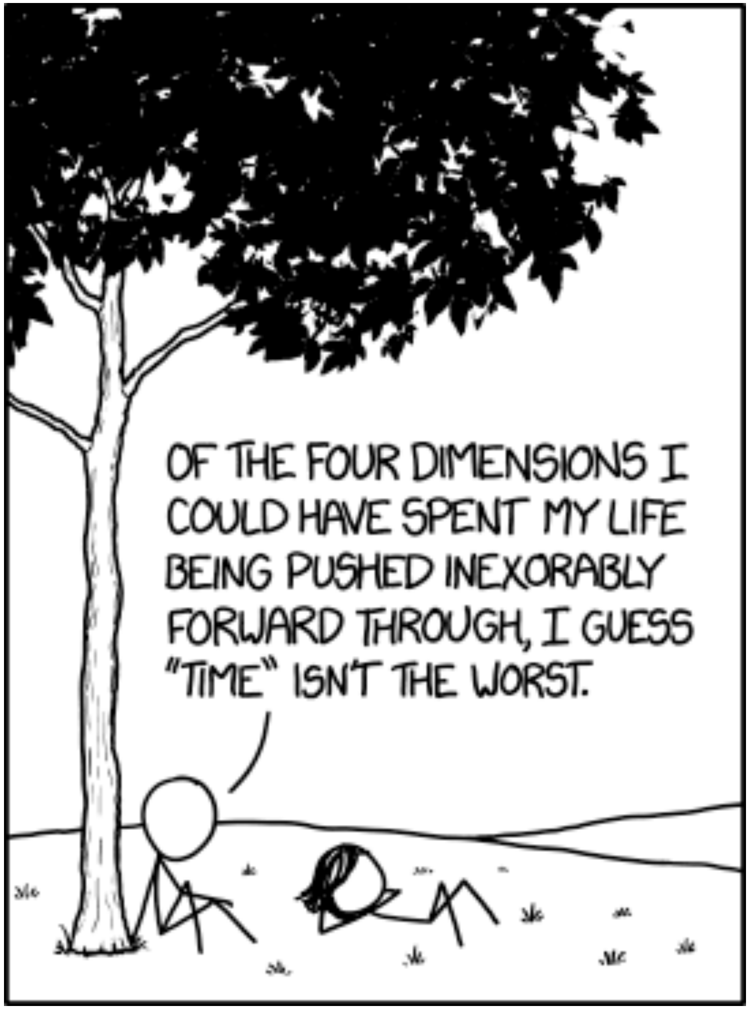
- Relativity is a unifying theory, which governs how **all laws of physics** must be constructed

- *[Our subject is called "special" relativity because it excludes gravity – that requires general relativity!]*

Space-time

- In relativity, we find that the concepts of **space** and **time** – which are separate in classical physics – become **inextricably connected**

- *Take a few minutes to think of some (everyday or physics) ways in which space and time are **different** and **similar** to each other*

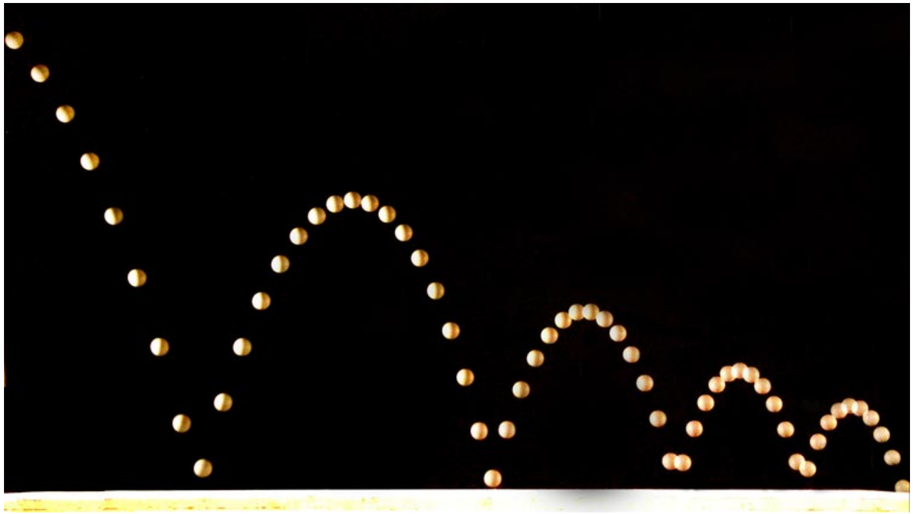


https://xkcd.com/1524/

Events

- In relativity, we analyse the world in terms of **events**
- An event is an **occurrence at a particular place and time**

https://www.nabo.com.au/whats-on/event/western-flat-fireworks

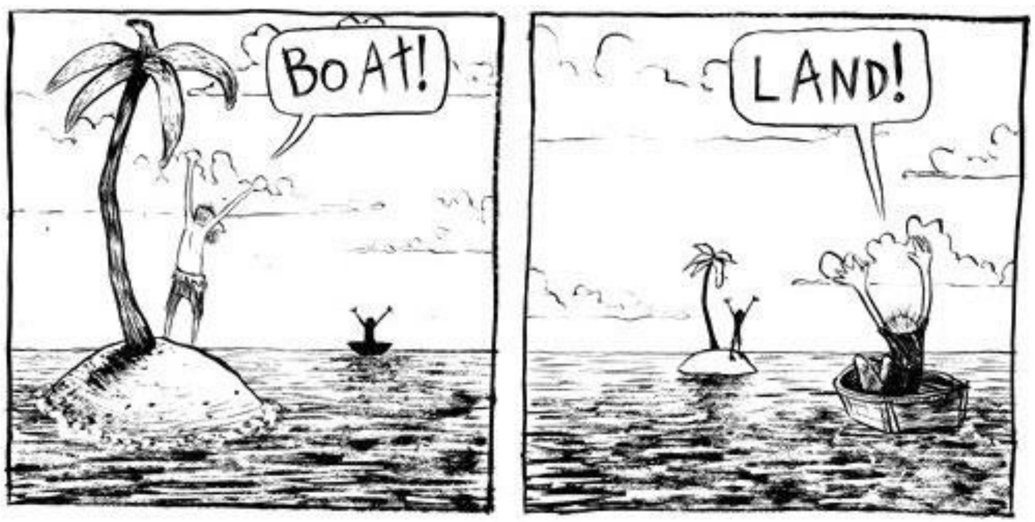


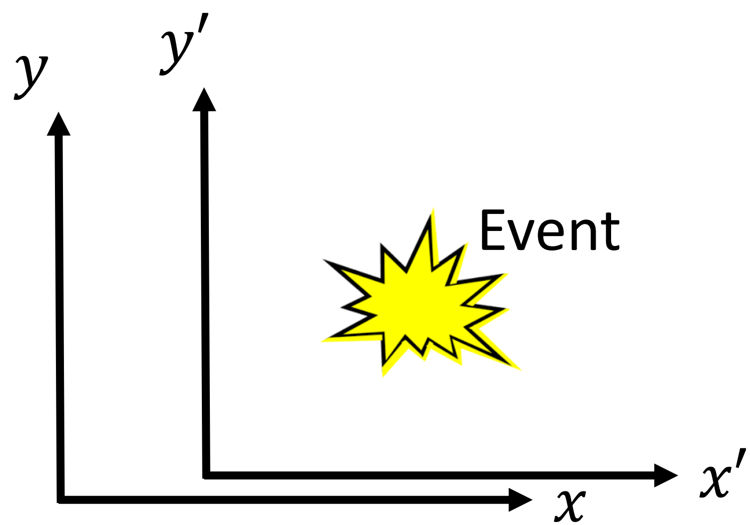
https://spaceandperspective.com/2013/02/07/motion-photography/

- An object's path can be analysed as a **sequence of events**

Reference frames

- To do physics we need to **assign co-ordinates to events**
- We do so by creating a **reference frame**, which allows the **location and time** of the events to be recorded
- *The same events can be viewed from different reference frames, which would assign them different co-ordinates!*

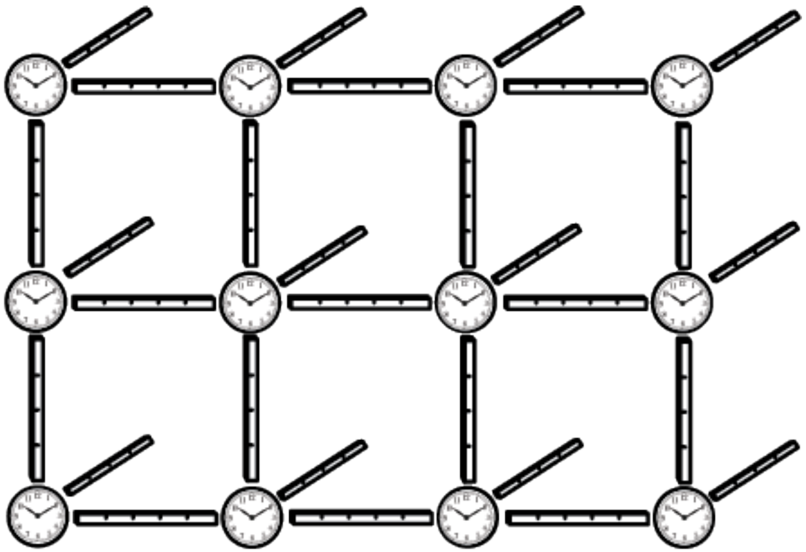




Reference frames

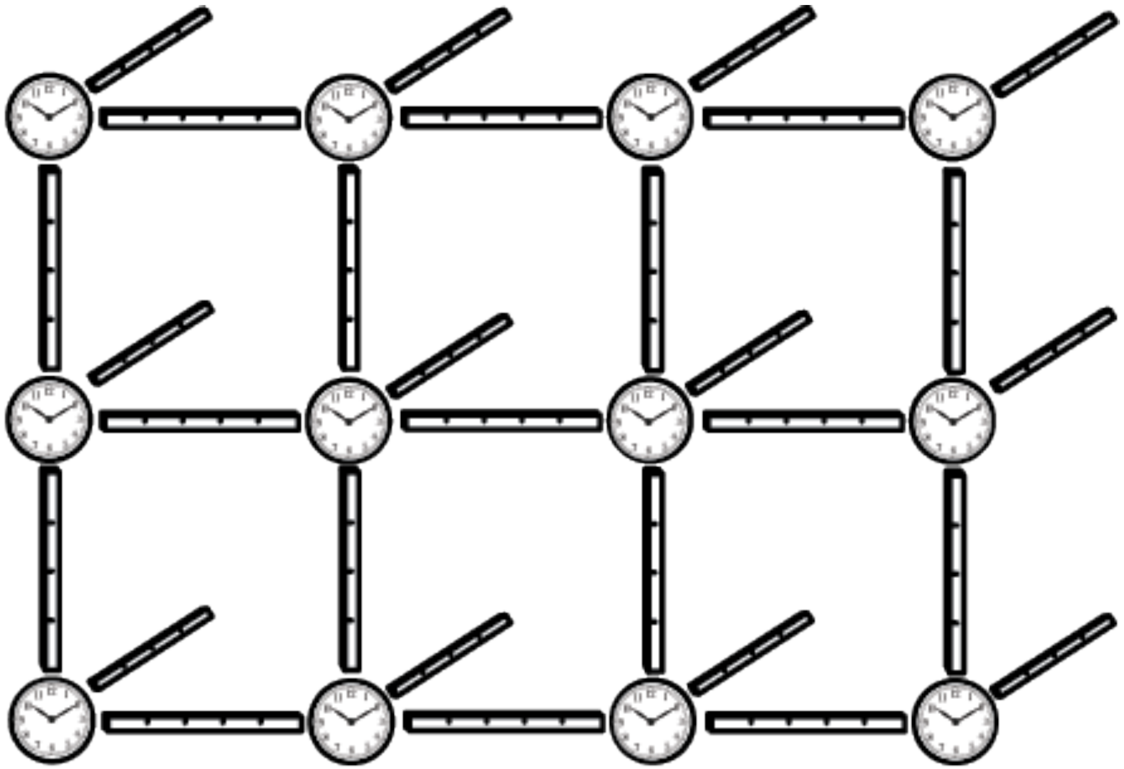
- We can think of a reference frame as being like a "jungle gym" filling space!
- The events that occur at each vertex (position in space) are recorded by a **local observer at that vertex**
- Each local observer is carrying a **synchronized clock** (which tick simultaneously, in the frame)

http://www.skywalkertrampolines.com/shop/modular-jungle-gym-playground/



http://www.pitt.edu/~jdnorton/teaching/HPS_0410/chapters/Special_relativity_principles

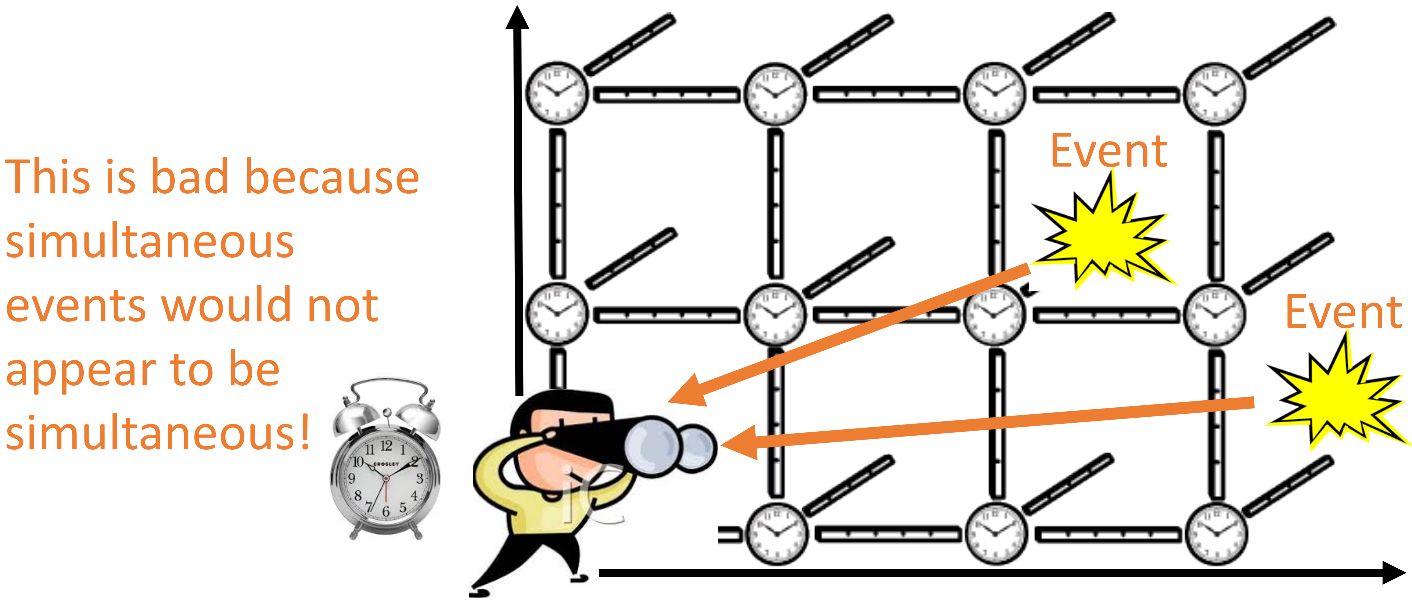
Synchronized clocks



- *Can you think of any methods which local observers at each vertex of the reference frame might use to synchronize their clocks?*

Reference frames

- Why does a reference frame have to be constructed using **many local observers**, rather than a single observer sitting at the origin?



- We need to record events **at their space-time location**, rather than worrying about the travel time of light

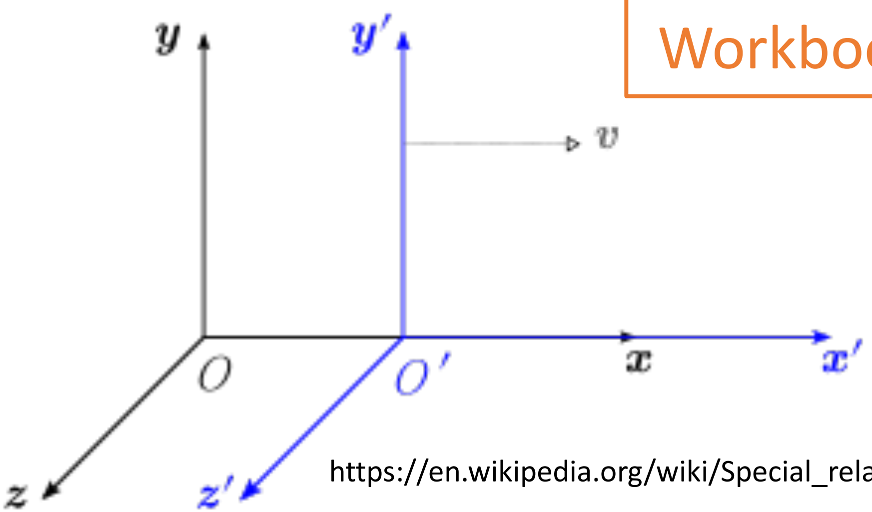
Inertial frames

- Some reference frames are special

- In an **inertial frame**, a freely-moving object – that is, an object experiencing no external forces – moves with constant velocity *(i.e., Newton's First Law holds)*

Note in the Workbook

https://www.gizmodo.com.au/2016/04/what-happens-when-you-cook-french-fries-in-space/



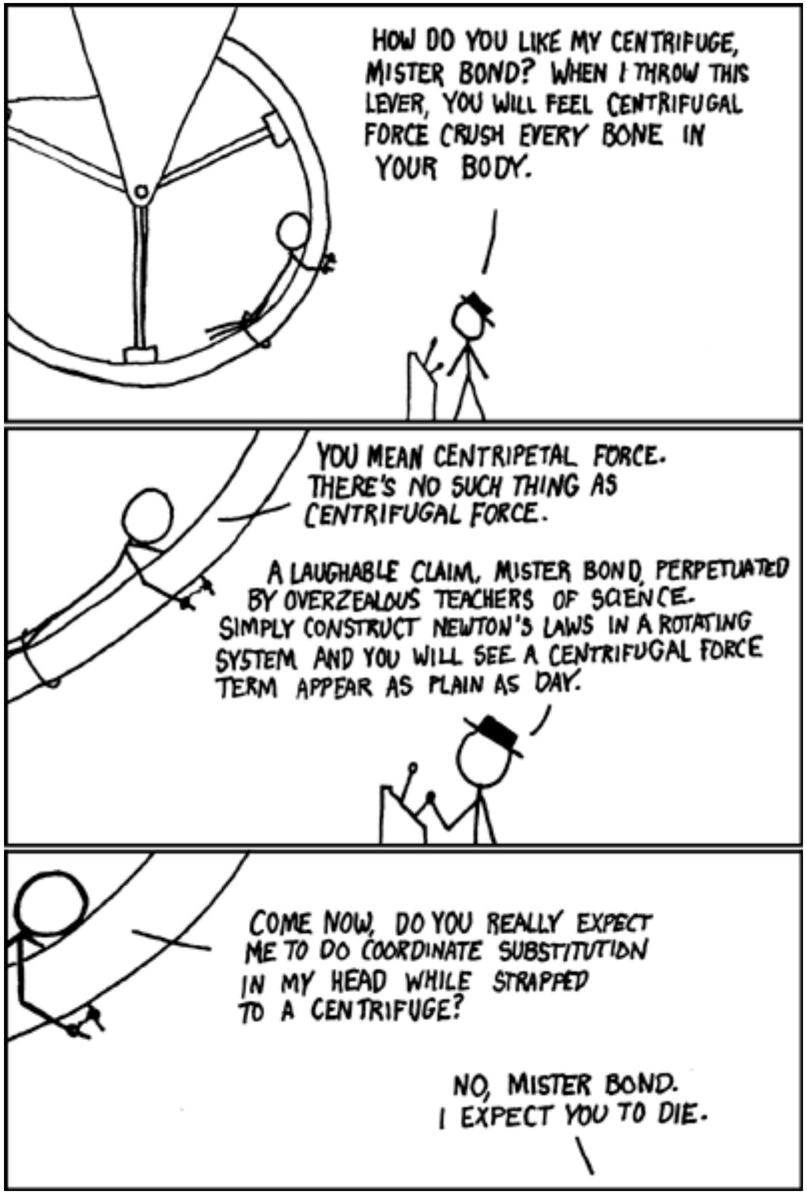
https://en.wikipedia.org/wiki/Special_relativity

- Inertial frames **move uniformly** with respect to each other

Inertial frames

- In a non-inertial frame, observers will notice **"pseudo-forces"** – that is, *effects not caused by real, physical forces*

https://www.thinglink.com/scene/877700809561735169
https://www.pinterest.com.au/bestonamusement/



https://xkcd.com/123/

Inertial frames

- A good example is to compare what you experience in an aeroplane (1) stationary on the ground, (2) taking off, and (3) during smooth flight

https://www.flysfo.com/newsletter/sfo-community-newsletter-spring-2009
https://www.adelaidenow.com.au/news/national/problems-hit-qantas-a380-london-take-off
https://www.ausbt.com.au/qantas-to-start-airbus-a380-flights-to-dallas-from-september

- *You experience a force during take-off, but smooth flight feels like being on the ground!*

Principle of relativity

- The **principle of relativity** asserts that the *laws of nature are identical in all inertial frames*, or in other words, *no experiment can distinguish one inertial frame from another*

- *“Without looking out of the aeroplane window, we can’t tell whether we’re in smooth flight or on the ground”*

https://owlcation.com/stem/What-Were-Galileos-Contributions-to-Astronomy

- This is an old idea, usually associated with Galileo. We will soon see Einstein’s twist!

Note in the Workbook

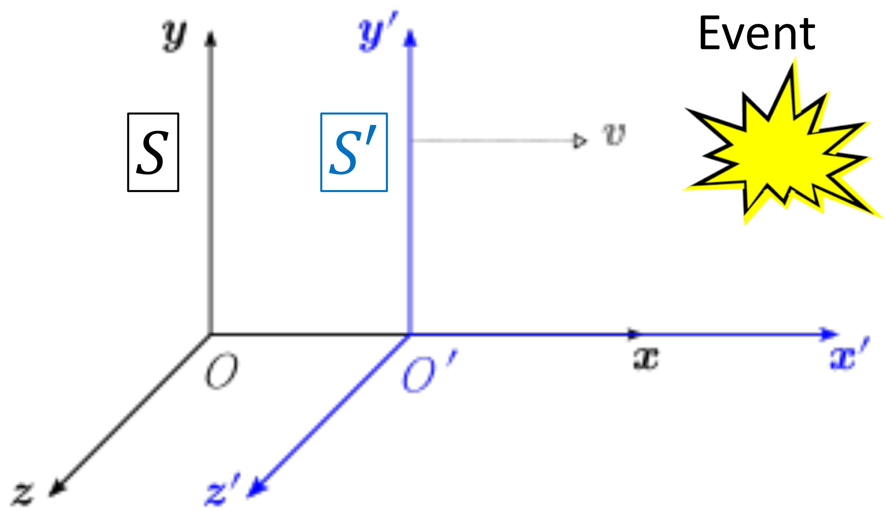
Principle of relativity

- *"The laws of nature are identical in all inertial frames"*
- A **law of nature** is a *mathematical relation relating different physical quantities*
- An example is Newton's Second Law: $\vec{F} = m\vec{a}$
- What happens if we transform to a different inertial frame, $\vec{v}'(t) = \vec{v}(t) + V_{\text{constant}}$?
- Acceleration $\vec{a} = d\vec{v}/dt$, so $\vec{a}' = \vec{a}$ and the law is unchanged!

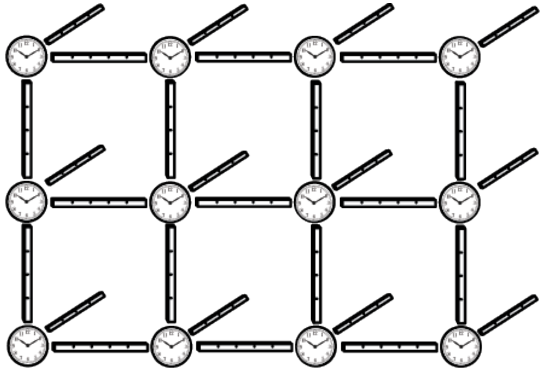
Transforming between frames

- A central question of relativity is **comparing measurements of events in different inertial reference frames**

- We will often refer to a standard arrangement of two inertial reference frames, S and S', with constant relative speed v, oriented such that the x- and x'-axes coincide

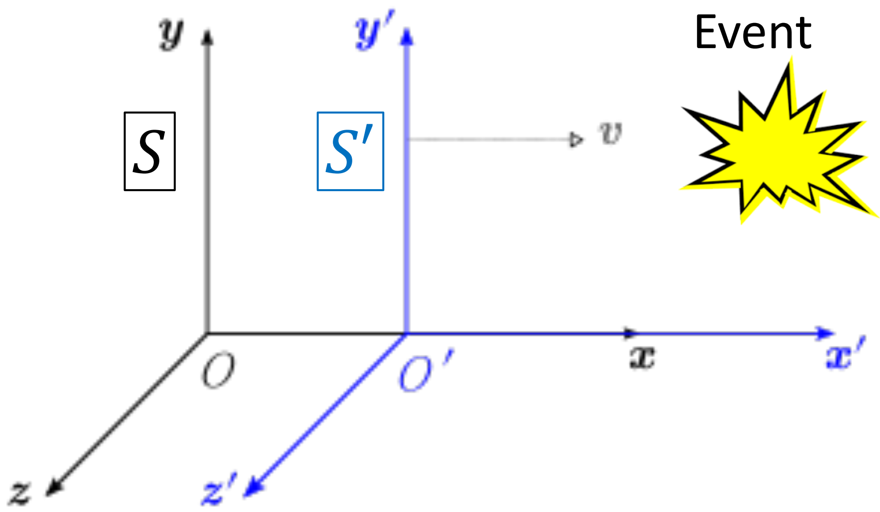


Each frame is outfitted with a standard lattice of observers with synchronized clocks



Transforming between frames

- The "old answer" for converting the co-ordinates of events between frames is provided by the **Galilean transformations**

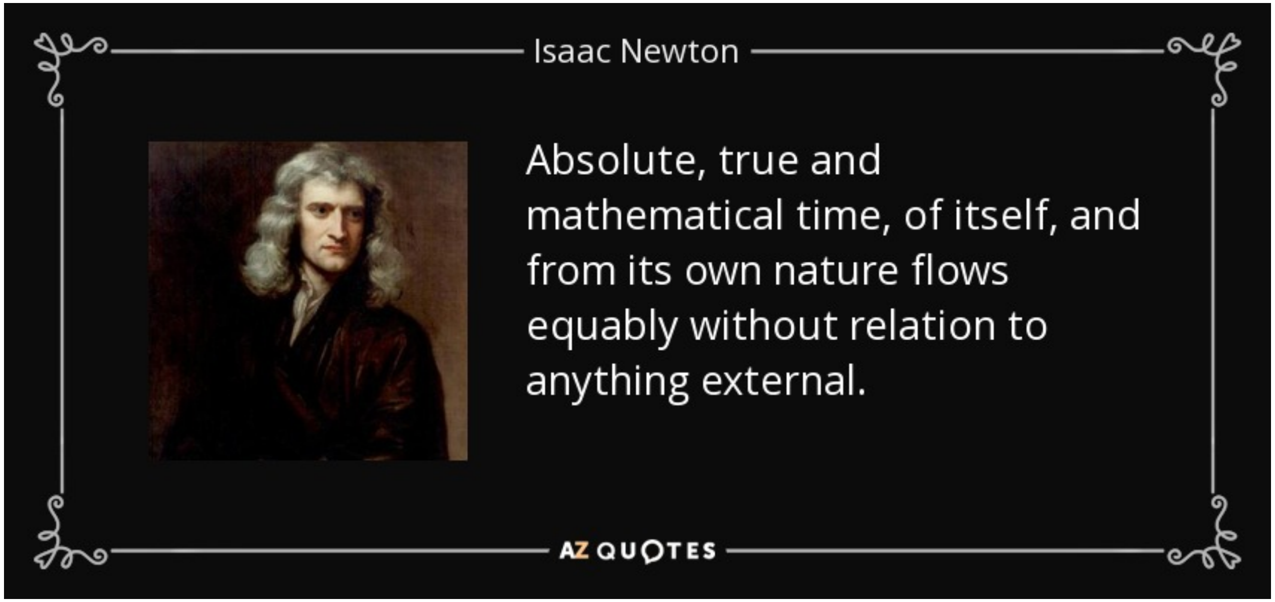


$$x' = x - vt$$
$$y' = y$$
$$z' = z$$
$$t' = t$$

- According to the Galilean transformations there is an **absolute time**, on which both frames can agree ($t' = t$)

Transforming between frames

- "Absolute time" is a deeply-ingrained classical idea, which we are about to overthrow – brace yourself!

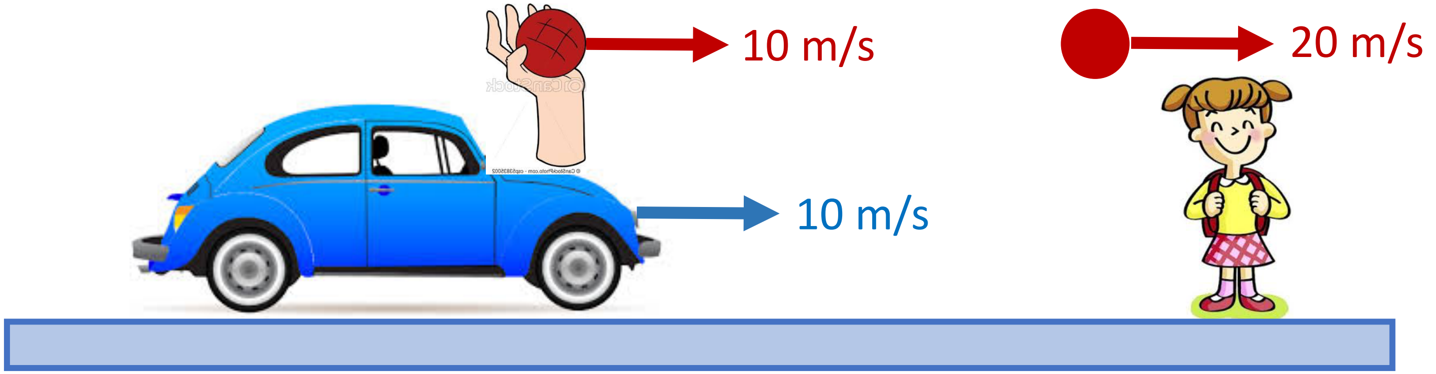


https://www.azquotes.com/quote/1342652

https://store.moma.org/magnetic-sand-hourglass/124546-124546.html

Transforming between frames

- The Galilean transformations make an important prediction that **velocities in different frames simply add and subtract**

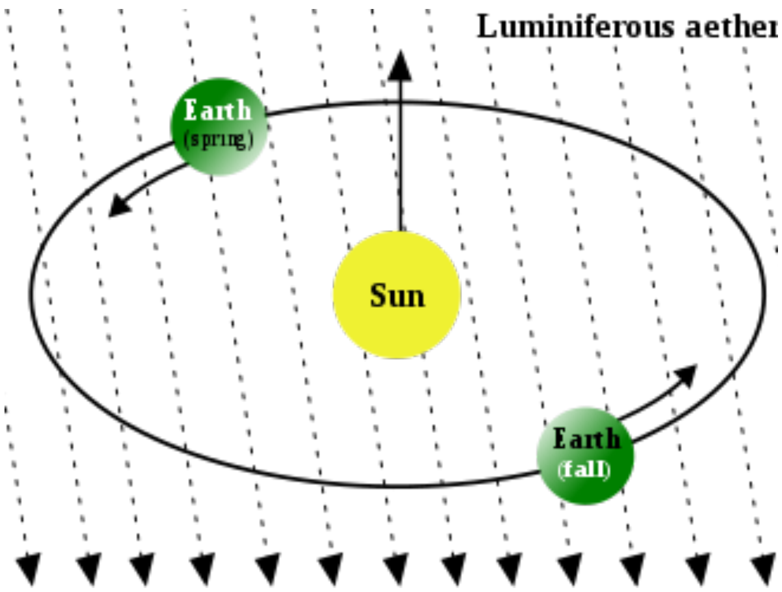


- A little over a hundred years ago, physicists realized that this is not exactly the case

Michelson-Morley experiment

- One of the key pieces of evidence against this world-view was provided by the **Michelson-Morley experiment** (1887)

- This experiment was focussed on the **role of light**, which is a critical ingredient of relativity



https://en.wikipedia.org/wiki/Luminiferous_aether

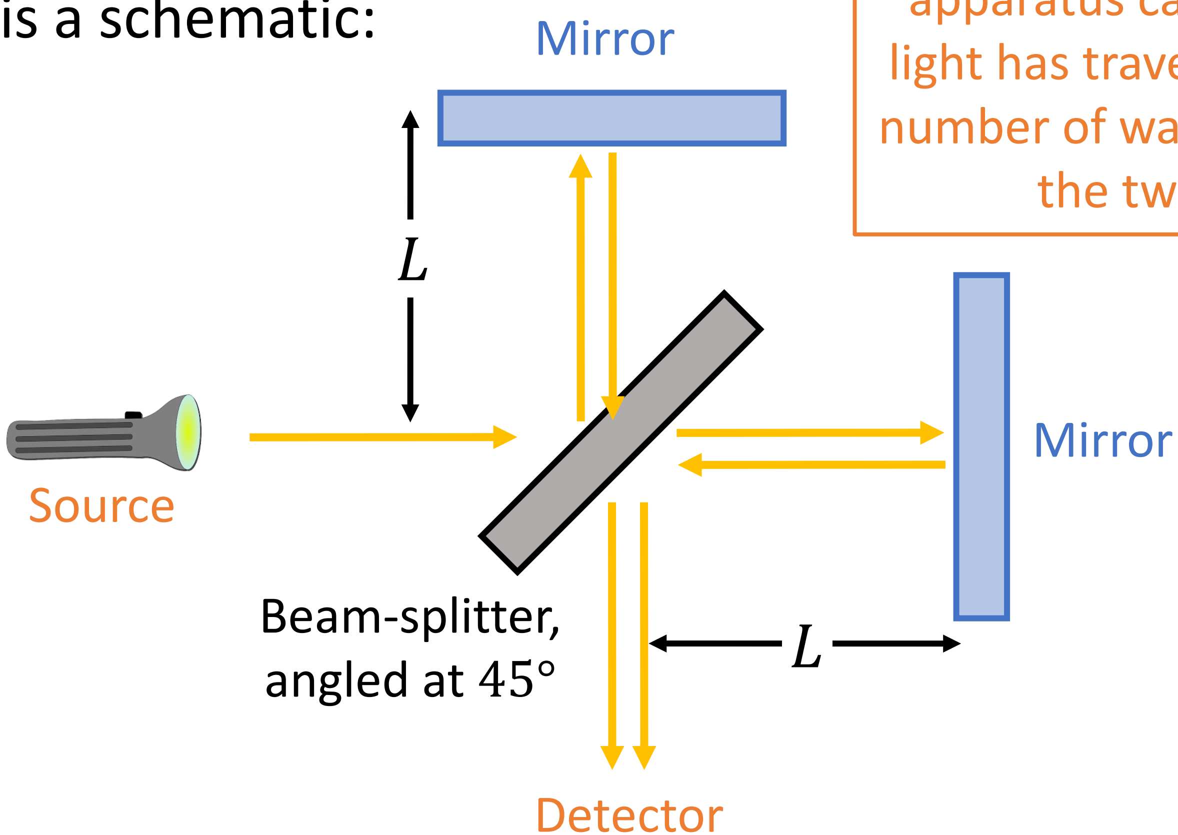
- In the late 19th century, physicists believed that light waves travelled at fixed speed in a medium, fixed in space, called the **luminiferous aether**

- Since the Earth orbits the Sun, our speed relative to the aether would change, which would cause **a change in the speed of light we measure**

Michelson-Morley experiment

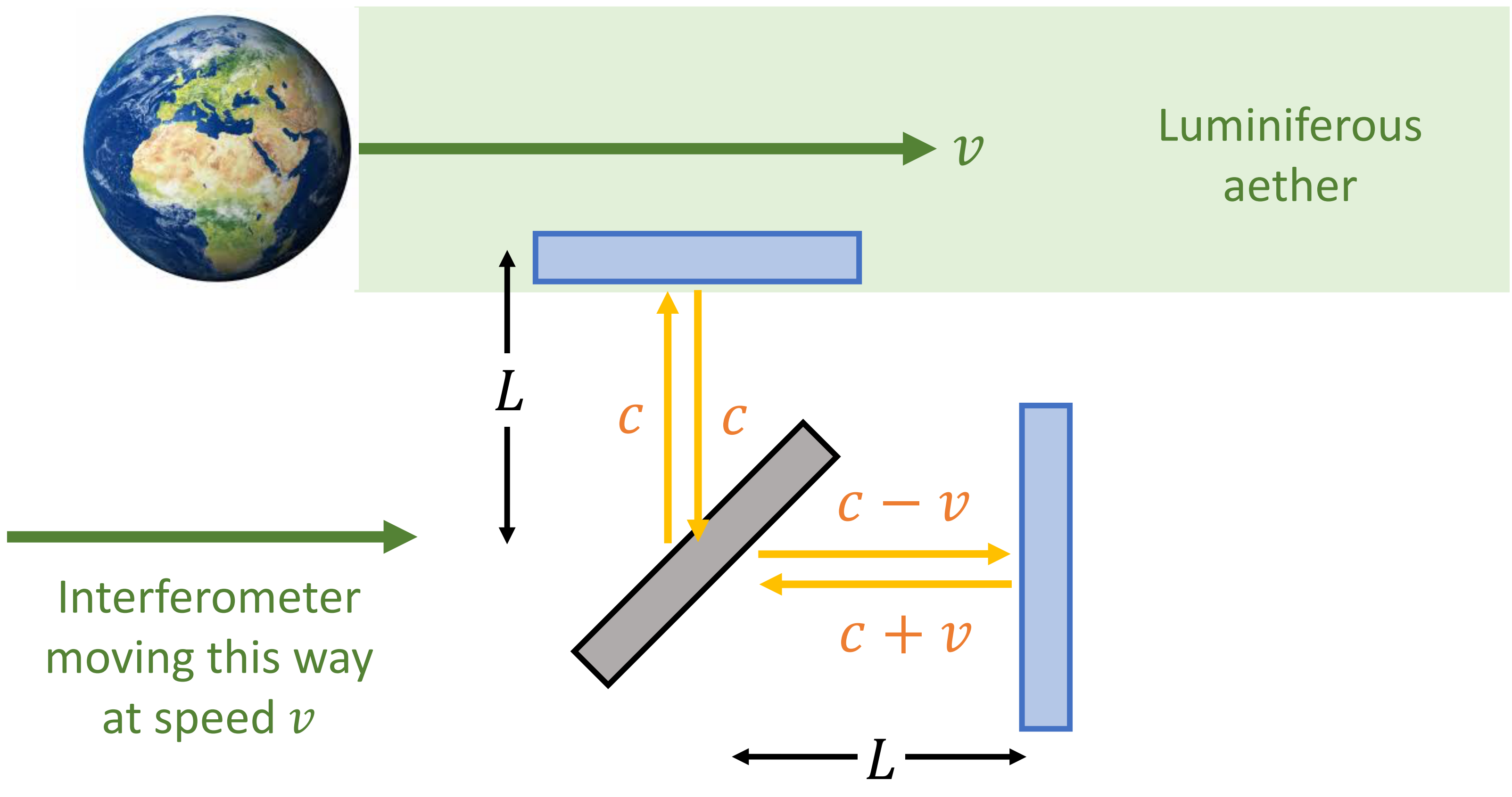
- Michelson and Morley set out to detect this change in speed using a **two-beam interferometer**
- Here is a schematic:

Using interference, the apparatus can detect if the light has travelled a different number of wavelengths along the two beams



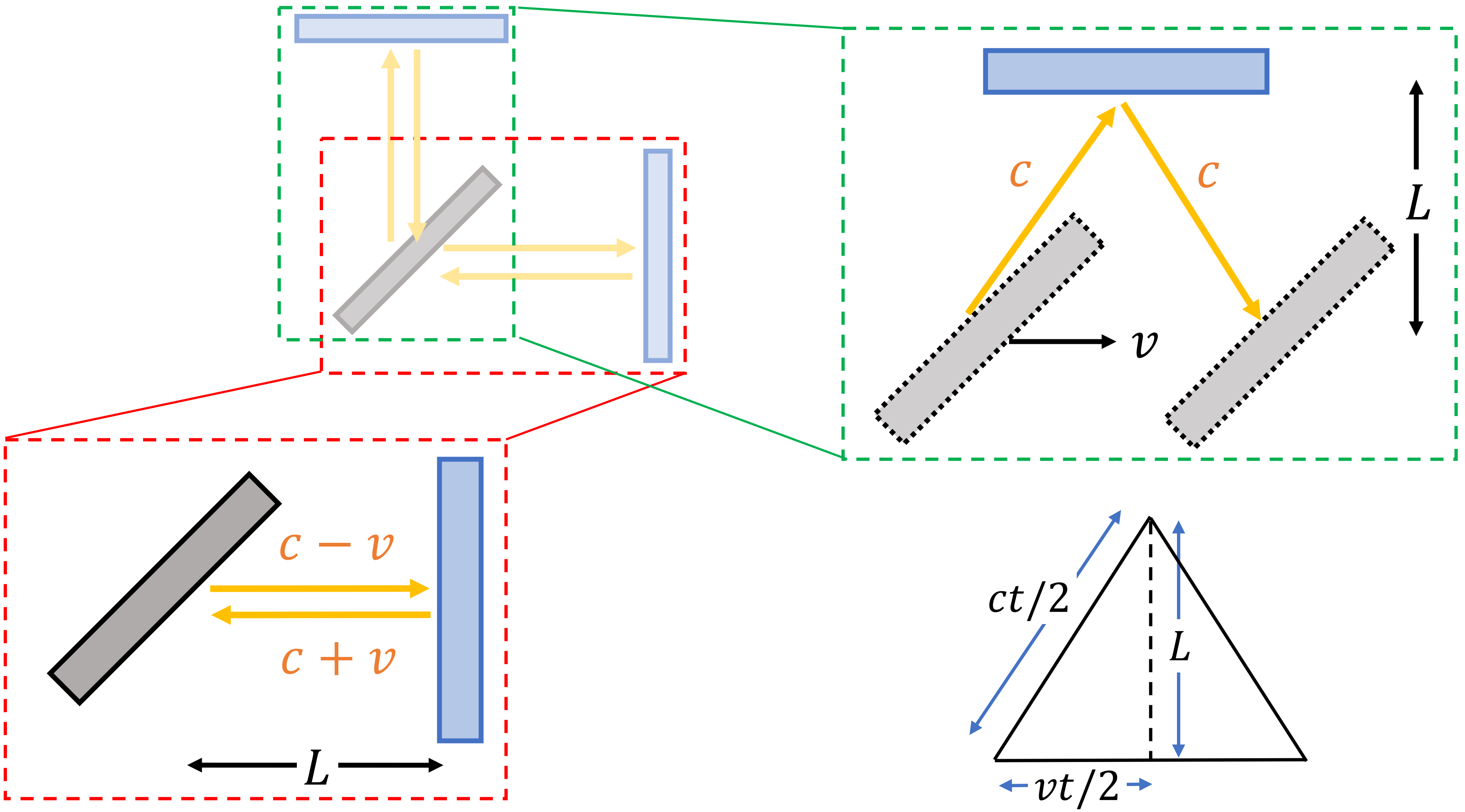
Michelson-Morley experiment

- Suppose the Earth is moving through the aether with speed v
- The speed of the light beams would be changed!



Michelson-Morley experiment

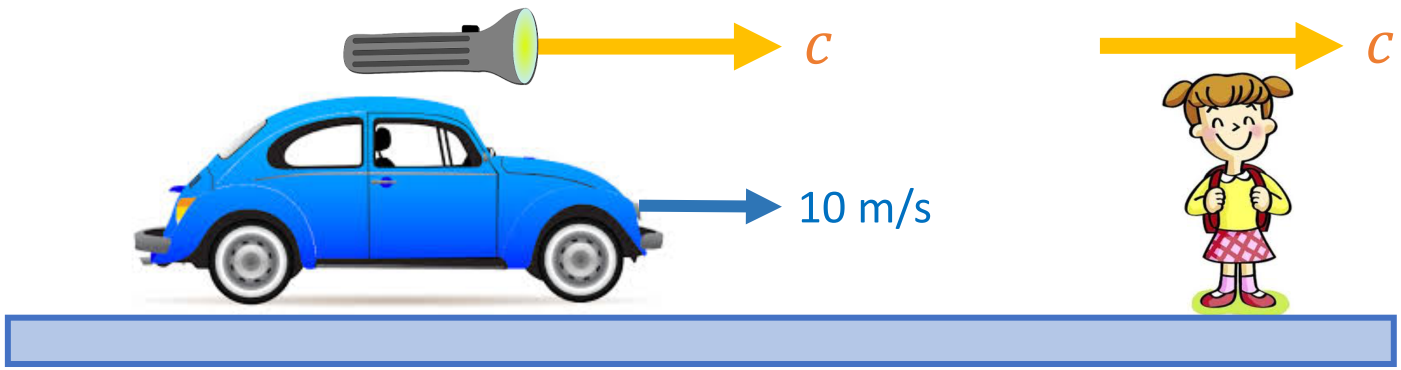
- What is the time difference between the two beams?



Michelson-Morley experiment

- The Michelson-Morley experiment produced a null result – there was **no phase difference between the two beams**

- This result supports the idea that **the speed of light is the same in all frames**, and is not modified by relative motion



- *[Michelson and Morley argued that the null result was produced because the Earth dragged along the luminiferous ether!]*

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