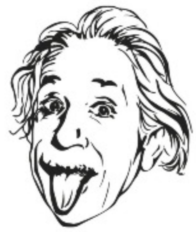
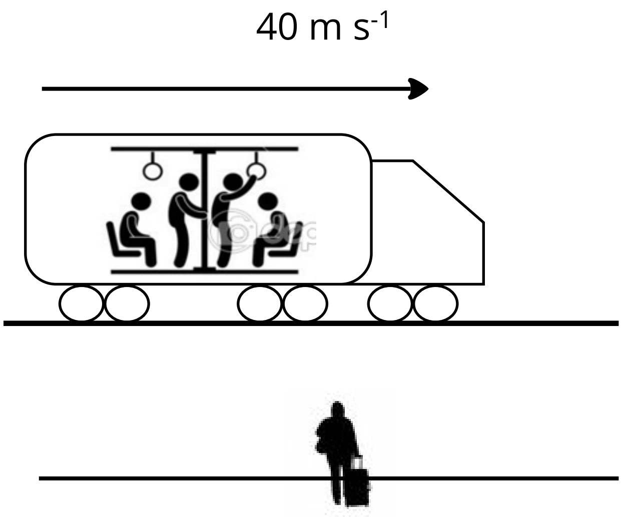
Relative Motion



Imagine you are in a train with Albert Einstein. The train is travelling at 40 m s^{-1}

If both of you are sitting together you are not moving **relative** to the inside of the train.



The speed of the passengers relative to the train is

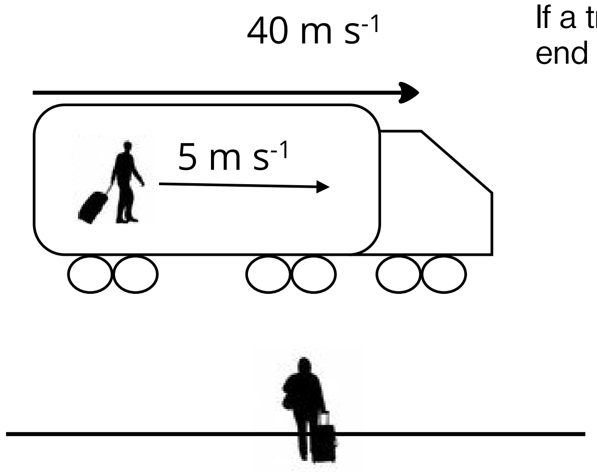
....

The speed of the passengers relative to a person standing still watching the train go by is

....

Key Point

....



If a train passenger walks with a speed of 5 ms^{-1} to the end of the train then...

The speed of the passenger relative to the train is

....

The speed of the passenger relative to a person standing still watching the train go by is

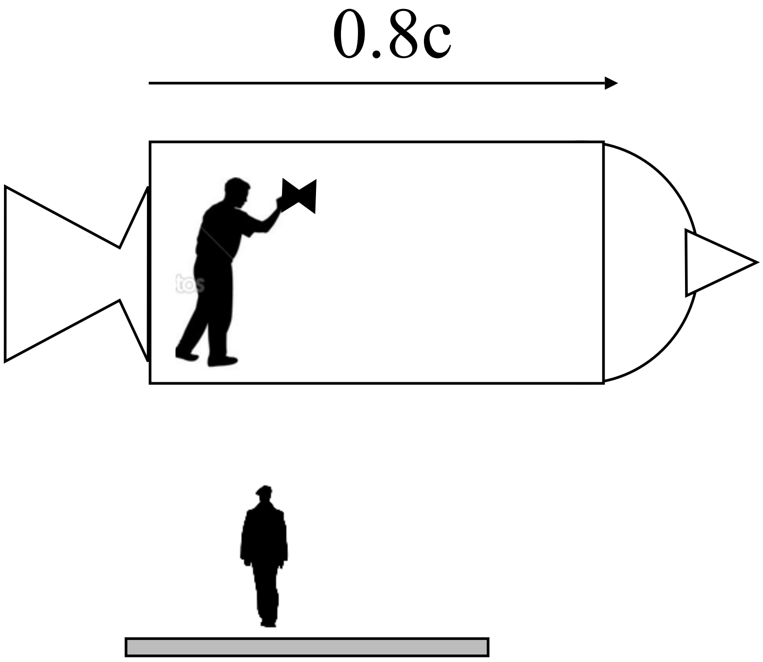
....

Inertial Reference Frame

Albert Einstein thought about relative motion when it concerned light beams. James Clerk Maxwell had come up with the idea that the speed of light was a constant. No matter where it was measured..

The speed of light was measured to be 3×10^8 m s^{-1} and is given the symbol c

Einstein came up with a beautiful thought experiment about shining beams of light in moving objects.



Imagine a person in a space ship which is travelling at 0.8 times the speed of light.

Albert sends a light pulse which travels to the front of the space ship with a speed c.

According to Newtonian relativity we can easily find out the relative speed of the light pulse.

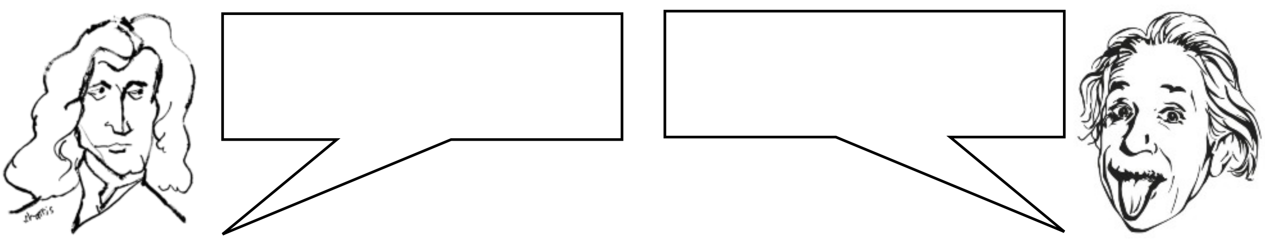
James is standing on a platform watching the moving space ship.

In Albert`s reference frame (*the space ship*) the speed of the light pulse is

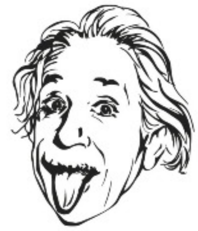
....

In James` reference frame (*the platform*) the speed of the light pulse is

....



Commonsense turned upside down!



Albert Einstein though hard about the speed of light measured by different observers in relative motion.

In 1905 Einstein proposed a theory called **Special theory of relativity**

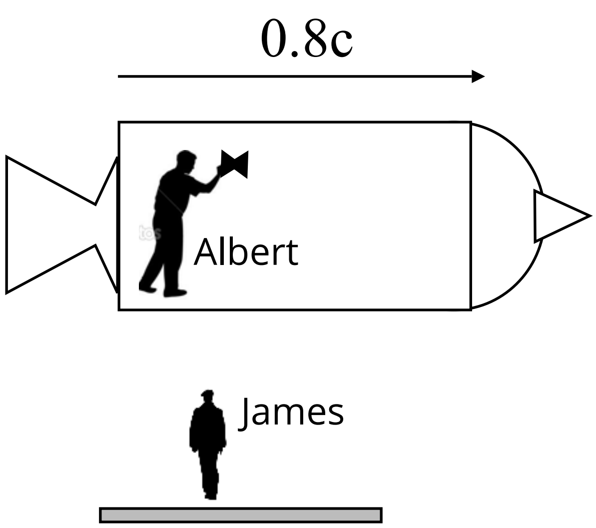
Why call it special?

It is called my special theory of relativity because it deals with the special case of non accelerating frames of reference, ie, spaceships, jets, cars and ships that are **NOT ACCELERATING**

Key Points

In these non accelerating reference frames the laws of physics are always the same.

The speed of light is always the same regardless from which frame of reference it is measured. Moving or not



The speed of the light pulse in Albert`s reference frame (inside the space ship is

....

The speed of the light pulse measured by James in his reference frame (the platform) is;

....

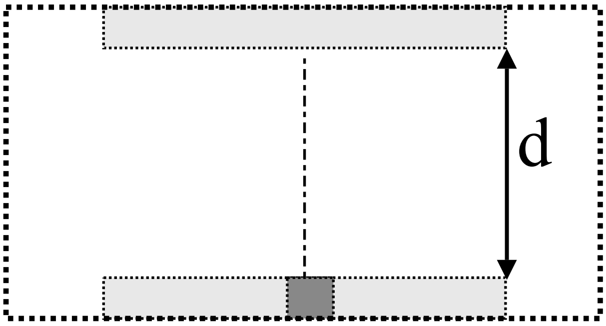
If the speed of light is the same for all observers then spacetime must change for each observer.

Albert Einstein created a thought experiment. The German translation of a thought experiment is called a gedankenexperiment!

Albert`s light clock is made up of a transmitter and a mirror.

A light pulse is transmitted upwards and reflected off a top mirror.

It then makes its way down and when received a flash of light was made.

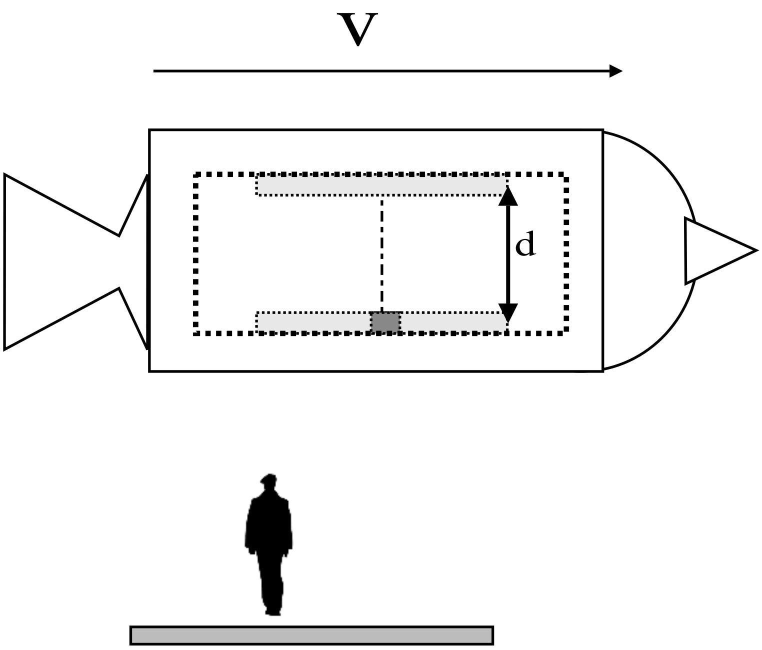


Time between each flash:

....

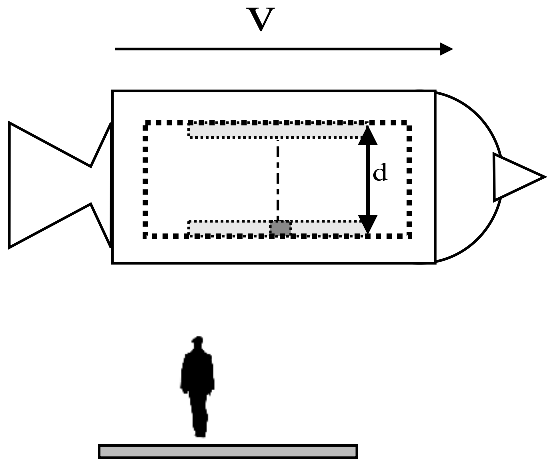
Now in Albert`s thought experiment he imagined placing this clock in a moving spaceship travelling at a speed v.

Would the time between flashes be any different to an observer watching the clock go by?



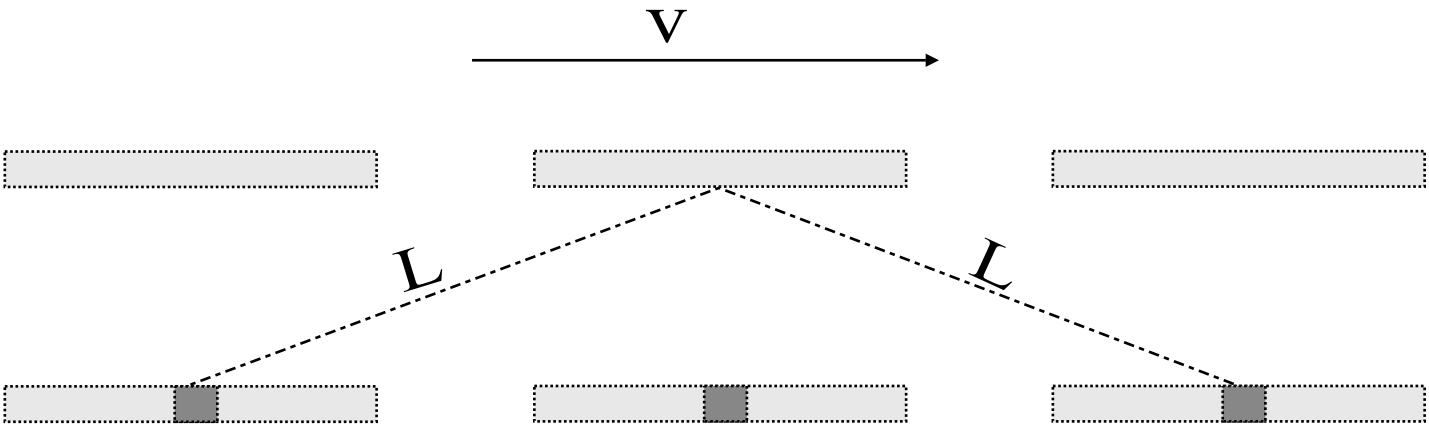
The result of the thought experiment is fascinating.

The speed of light will be constant! No matter the frame of reference.



How will the clock look like to the observer?

To see how the clock looks we will strip away the spaceship and just focus on the clock.



The path of the light beam from the observer`s reference frame is NOT straight up and down but traces out a LONGER path.

Remember the speed of light must be constant for both reference frames.

Conclusion.

In order for the speed of light to be the SAME in both reference frames The observer must conclude that the time of the pulse must be longer for him.

In other words time must run slower in the moving spaceship according to the observer

....

....

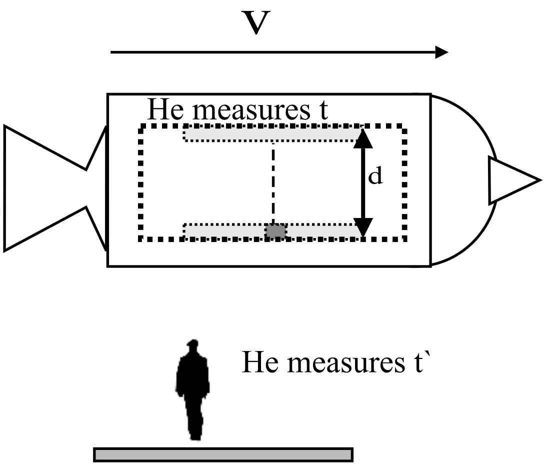
Time Dilation

Albert Einstein`s thought experiment with his imaginary clock showed that the observer measures the time on the moving clock to be **slower** than if it was measured at rest.

The time measured in the same reference frame as the moving spaceship is called the **proper time.**

The time measured by the stationary observer is called the simply the **measured time.**

These relativistic effects only start to show up at speeds near that of light.



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

t`	
T	
V	
C	

Example

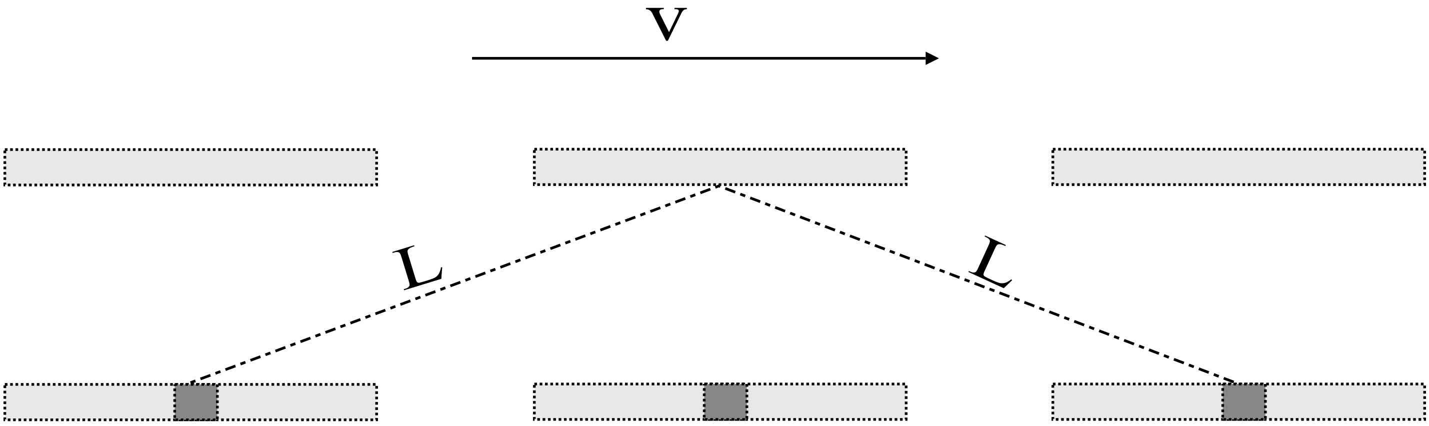
A clock on a spaceship travelling at **0.9c** measures the time of an event to last for 10 seconds.

Determine the length of time that the event lasts when measured from a stationary observer.

Mathematical Proof of this time dilation.

http://goo.gl/JimvIi

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



Time Dilation in reality.

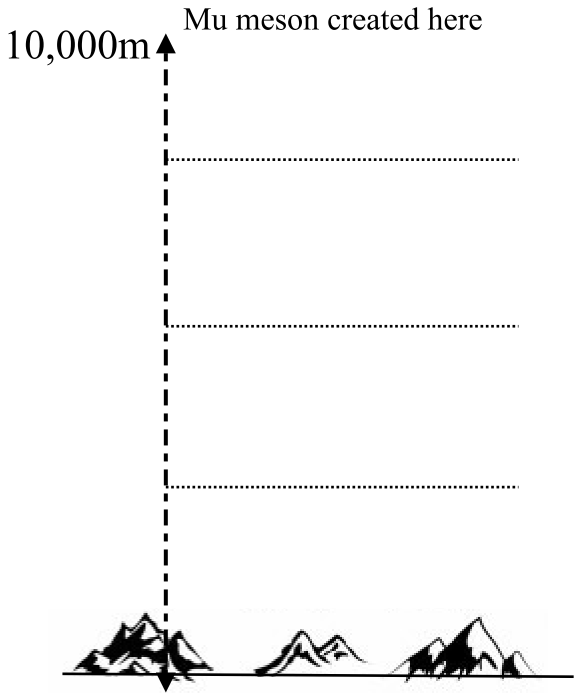
A real example of time dilation occurs in the decay of unstable particles travelling at the near the speed of light.

One example is the particle called a mu-meson.

This is a particle that is created in the atmosphere thousands of metres above the Earth`s surface.

The mu-meson exists only for 2×10^{-6} s.

They travel at the speed of 0.998c.



The distance travelled by the mu -meson is

Find the measured time of the mu-meson`s as measured by an observer at rest

What is the distance travelled by the measured in the Earth`s reference

What does it look like for the mu-meson.

In the reference frame of the Earth the mu-meson travels 9,472 m and lives for 3.16×10^{-5} seconds.

But what does it look like in the reference frame of the mu-meson.

It still only lives for 2×10^{-6} s and travels at the speed of 0.998c so how can it be detected so far down

The answer to solve this paradox is that the distance from the mu-meson`s creation to the Earth must be only 599 metres!

For this to happen then distance is also affected by relative motion

Length contraction.

Not only is time dilated but length is contracted.

When an object moves with speeds near the speed of light all lengths appear smaller!

$$l' = l\sqrt{1 - \frac{v^2}{c^2}}$$