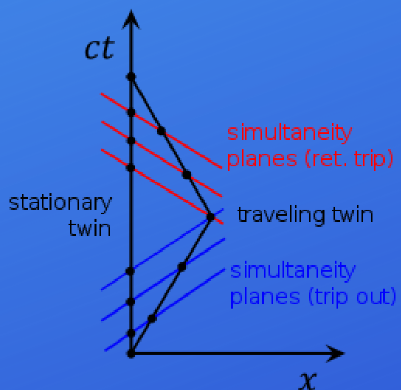
TWIN PARADOX

One twin lives on Earth while another twin flies to outer space and back at a high velocity. Each twin will think of the other twin as the moving observer in their respective reference frames. However, both of them can't be older than each other, hence the contradicting paradox.



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EXPLORING RELATIVITY

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BEGINNINGS

Inertial Frame of Reference: non accelerated reference frame

Galilean Transformations:
Position can be transformed between reference frames by
$x' = x-vt$
Velocities can be related by
$u' = u-v$

Postulates of Special Relativity:
1) The laws of physics are the same in all inertial frames of reference
2) The speed of light in a vacuum is the same for all inertial observers

Speed of Light = $3x10^8$ m/s

LORENTZ TRANSFORMATIONS

Lorentz Factor: $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$,

Galilean transformations are modified to:

$$x' = \gamma(x - vt);\ \Delta x' = \gamma(\Delta x - v\Delta t)$$

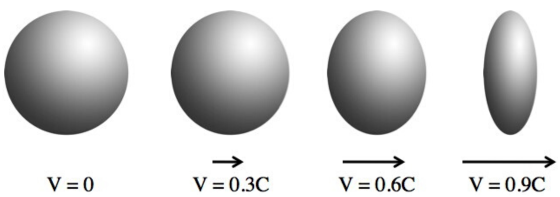
$$t' = \gamma\left(t - \frac{vx}{c^2}\right);\ \Delta t' = \gamma\left(\Delta t - \frac{v\Delta x}{c^2}\right)$$

Time Dilation:
Time slows when travelling at high speeds. Proper time is the time measured in a frame where events take place at the same point in space.

$\Delta t = \gamma\, \Delta t_o$

Length Contraction:
Length contracts when travelling at high speeds. Proper length is the length measured in a frame where the object is at rest.

$L = L_o/\gamma$



SPECIAL RELATIVITY

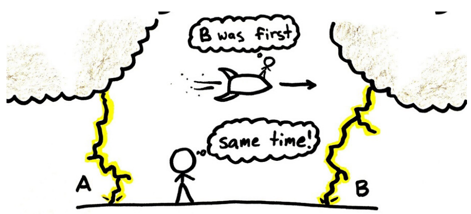
Galileo's velocity addition changes in special relativity when travelling at high speeds to:

$$u' = \frac{u - v}{1 - \frac{uv}{c^2}}$$

Simultaneity:
Events simultaneous for one observer and take place at different points in space are not simultaneous for another observer in motion relative to the first.

If two events are simultaneous for one observer and take place at the same point in space, they are simultaneous for all other observers.

Muon Decay:
Muons making it to the surface of Earth is evidence to support time dilation. If time did not slow, muons would decay quicker and travel less of a distance.



SPACETIME DIAGRAMS

The following remains equal in different reference frames:

$$\begin{aligned}
(x'^2 - c^2t'^2) &= \gamma^2(x-vt)^2 - c^2\gamma^2\left(t - \frac{v}{c^2}x\right)^2 \\
&= \gamma^2\left(x^2 - 2xvt + v^2t^2 - \left(c^2t^2 - 2tvx + \frac{v^2}{c^2}x^2\right)\right) \\
&= \gamma^2\left(x^2\left(1-\frac{v^2}{c^2}\right) - (c^2 - v^2)t^2\right) \\
&= \gamma^2\left(x^2\left(1-\frac{v^2}{c^2}\right) - c^2(1-\frac{v^2}{c^2})t^2\right) \\
&= \gamma^2\left(1-\frac{v^2}{c^2}\right)(x^2 - c^2t^2) \\
&= x^2 - c^2t^2
\end{aligned}$$

Spacetime diagrams have position on the x-axis and ct on the y-axis.

Worldline: the path a particle follows

The tangent of the angle of the worldline with the ct-axis gives the velocity in terms of c.

The speed of light makes an angle 45˚ to the ct-axis, so all worldlines must make an angle less than 45˚.