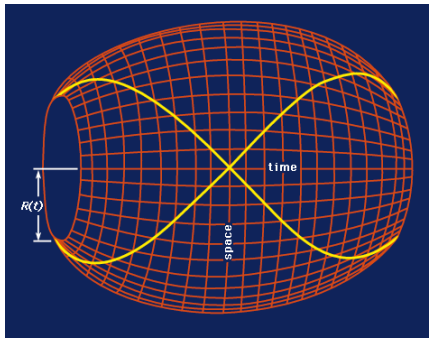
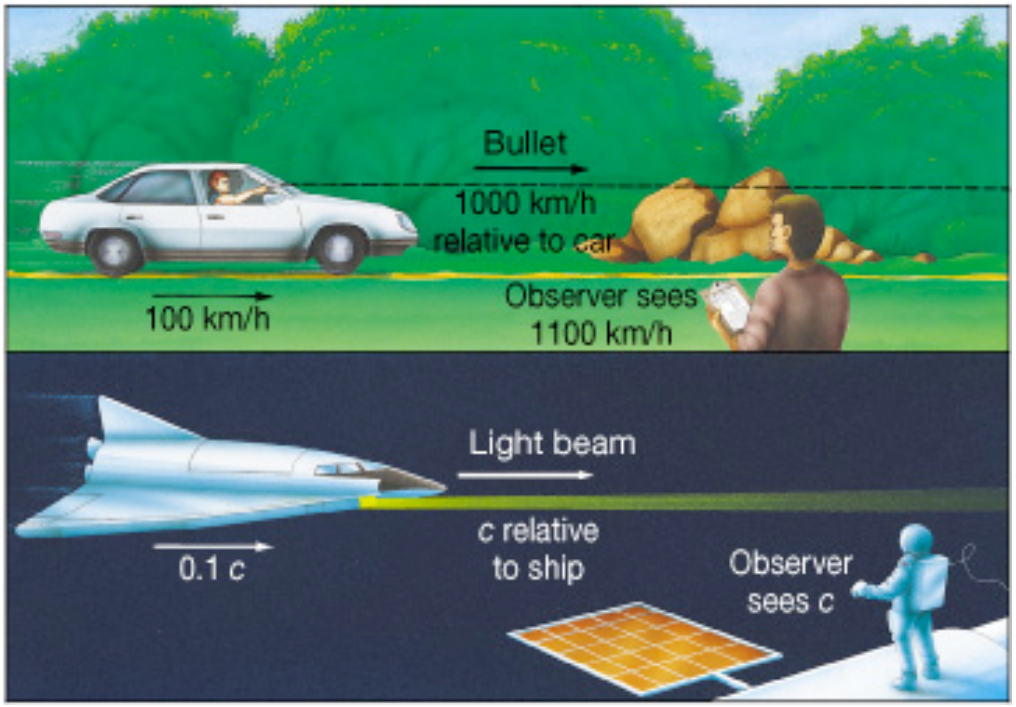
Special Relativity

- Various experiments starting in the late 1800s suggested that the speed of light was constant, *independent of the motion of the observer*.
- This is very counter-intuitive.



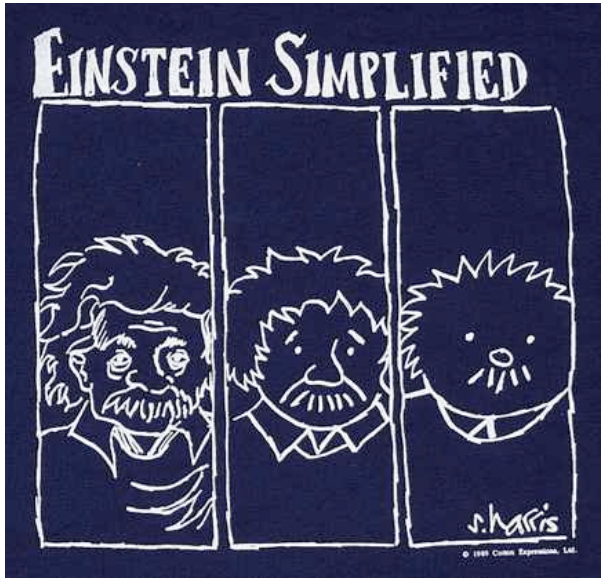


- The spaceship traveling in the same direction of a photon measures the photon zooming away at the speed of light NO MATTER how fast the spaceship is traveling!

Special Relativity

- Einstein (and others before him) decided to take the speed of light as an invariant and not make any assumptions about the two properties that go into determining speed:

Space and Time



Time Dilation and Length Contraction

- The invariance of the measured speed of light independent of the motion of the observer can be understood if:

(1) Clocks run more slowly as speed increases.

(2) Metersticks shrink as speed increases.

Say What?

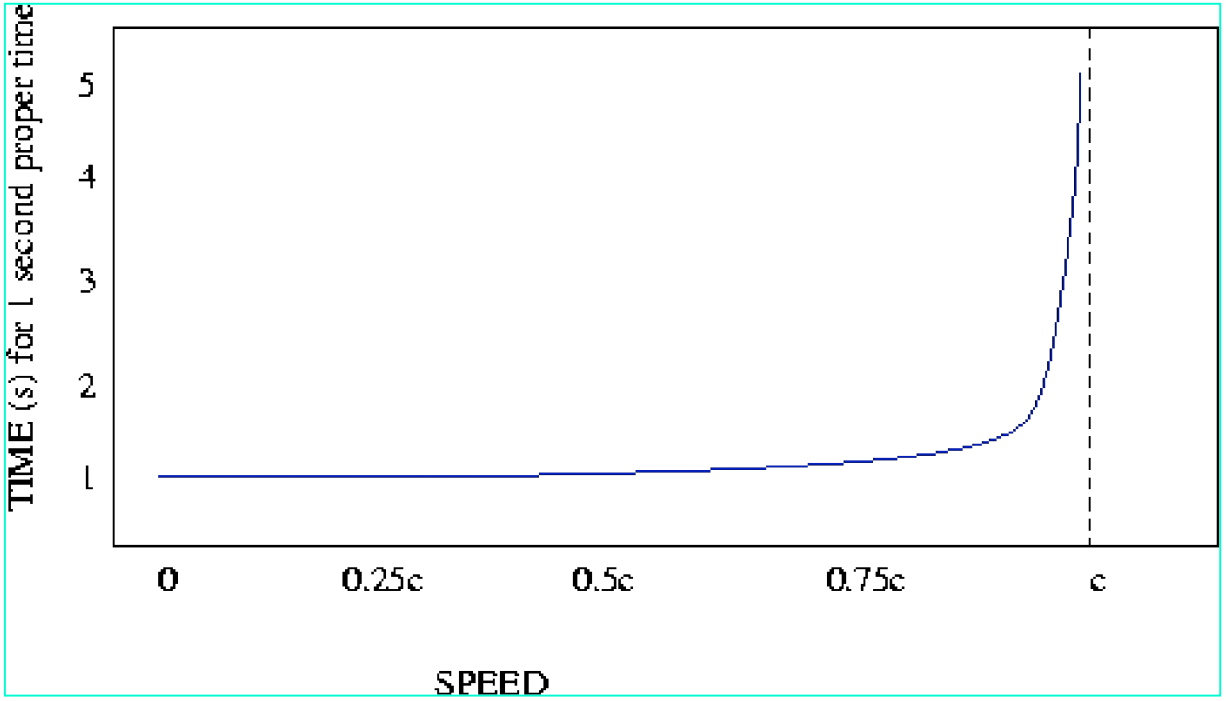
Time Dilation

- As your speed with respect to another observer increases, your watch runs more slowly than the observers. This is called `time dilation'

$$T = \frac{T_0}{\sqrt{1-(v/c)^2}}$$

Note, when v<<c, $T=T_0$

Time Dilation



- As v approaches c, v/c -> 1 and the denominator goes to zero. Dividing by zero gives infinity.

As v approaches c, time grinds to a stop!

- Q. Suppose you measure an event that lasts for 1 second by your watch. What will your friend in a spaceship moving at 0.98c measure as the duration of the event?

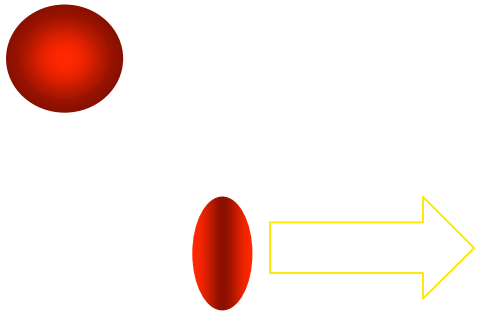
$$T = \frac{T_0}{\sqrt{1-(0.98)^2}} = 5.02T_0$$

- Time has been stretched by a factor of 5 for your friend.

Length Contraction

- In the same way, metersticks (space) contracts in the direction of motion.

$$L = L_0\sqrt{1-(v/c)^2}$$



- But wait, there's more!

Mass

- Mass grows with speed.

$$M = \frac{M_0}{\sqrt{1-(v/c)^2}}$$

Constant Speed of Light

- The shrinking rulers and slowing clocks conspire to let observers in any moving frame measure the same speed of light.

The Reason Travel to other Galaxies will be Difficult

- The slowing clocks and increasing mass conspire to make it impossible for objects with mass to ever reach the speed of light.
- The increasing mass requires an ever-larger force to accelerate to larger speed and the force needed would become infinite. (F=ma)
- Even if you could find the force, your clock would slow and slow and the last step would take and infinitely long time

Is this right?

- Yes! There are many tests of Special Relativity.
- In particle accelerators mass increase and time dilation effects are routinely measured
- There have been tests flying very accurate clocks in high-speed jets that show time dilation directly.
- We might not be here if not for time dilation in the frame of cosmic rays called muons.