Lesson 5.2: Special Relativity

Unit 5: Special Relativity

Time Dilation:

- According to Einstein's theory of Special Relativity, a lock that is moving will run ____________.
- The "stretching" of time for a moving object relative to a stationary observer is called ______________ ________________

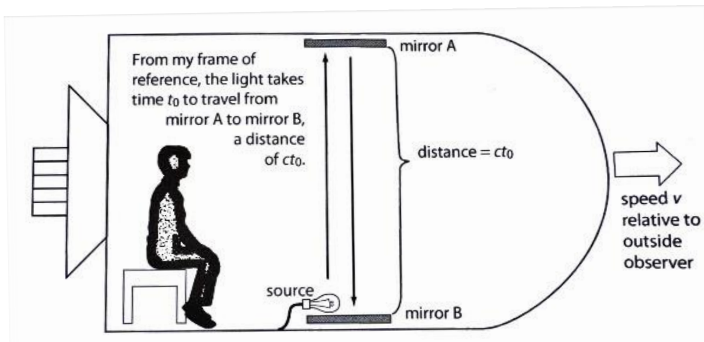


Figure 4.1.6 *This observer is inside a glass-walled spaceship watching a light beam.*

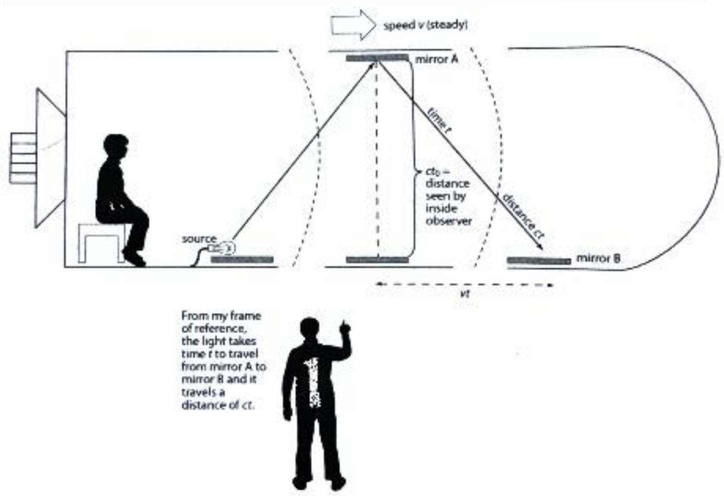


Figure 4.1.7 *The observer is outside the glass-walled spaceship watching a light beam.*

<u>Einstein's Thought Experiment:</u>

- Einstein imagines a clock where a light beam bounces between two _________
- He then asks us to imagine what it would look like to you, the __________________ observer, if the clock was moving across the classroom (or in a spacecraft).
- Maxwells equations imply that we must take the speed of light as a __________ seriously. So what?
- It is self-evident that the path of the stationary clock is __________ than the path of the moving clock.
- Since we agree that the speed of light is constant, it must take ____________ for the light beam to travel the longer path.
- Therefore, time is slower for objects in motion

Time Dilation Equation:

t = ___________________: The time measured by an observer watching something moving fast (appears longer/slower).

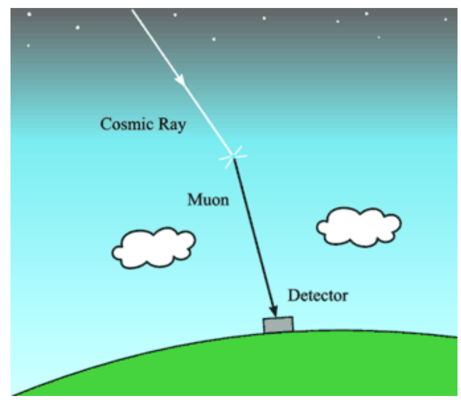
t_o = ___________________: The time measured by someone moving with the object (the "actual" time for that event).

v = _______________: the speed of the moving object relative to the observer

c = ____________________: constant 3.00×10^8 m/s

Example 1: An astronaut travels in an ultra-fast spacecraft at 0.90c (90% the speed of light). They make a round trip from Earth to the edge of the solar system and back, taking 10 years as measured on Earth.

How much time passes for the astronaut on the spacecraft?



Experimental Evidence for Time Dilation:

- Muons (an elementary particle) have half-lives of _____________
- Created ______________ above Earth during collisions between cosmic rays and atmospheric atoms
- High speed particles – ________________

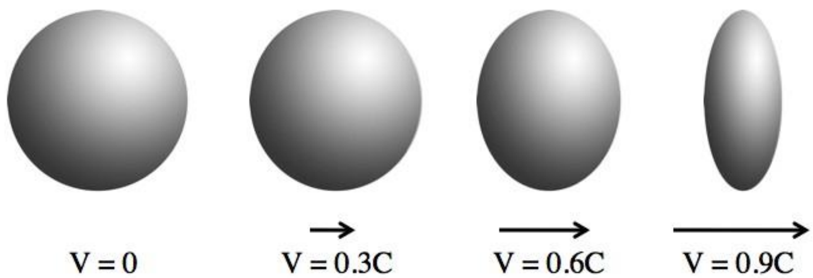
Question: How far will muons travel during their lifetime?

Consider the muon's time of travel as an observer on Earth.	Consider the muon's reference frame
Using Newtonian physics, a muon should only travel 0.6 km before decaying. However, we can detect them on Earth's surface 8 km below. How can this be? From time dilation calculation, the muon takes 16x as long from our fixed frame of reference and therefore will not decay before hitting our detector.	

Thought Experiment:

Imagine it’s 2038 and you just turned 30 years old. You have a 6-year-old daughter who you love, but you’ve been given an opportunity to board a new, near light-speed spaceship that will take you on a journey for the next 5.0 a at a speed of 0.99c. How old will you be compared to your daughter when you get home?

Loretnz (Length) Contraction:



- The length of an object is measured to be ____________ when it is moving than when it is at rest. This shortening is only seen in the ____________ of its motion.

<u>Lorentz Contraction Equation:</u> **<u>Defined Variables</u>**

Example 2: How long would a metre stick appear to be if it was moving past you with a speed of 0.995c?

Relativistic Momentum:

- Newtonian definition of momentum:

- Only works when:

We can use the relativistic form:

Mass-Energy Equivalence:

- Einstein showed that mass and energy are ______________
- Experimentally shown in 1932 when a gamma photon converted to an ____________ and _______________ (C.D Anderson)
- A small amount of mass releases a huge amount of energy (1 kg → ________________).

$$E = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}} \xrightarrow{v\to 0} E = mc^2$$

Considering the Universal Speed-Limit:

Consider the following equations. What happens to each as velocity *v*→ *c?*

$$t = \frac{t_o}{\sqrt{1-\frac{v^2}{c^2}}} \qquad l = l_o\sqrt{1-\frac{v^2}{c^2}} \qquad p = \frac{mv}{\sqrt{1-\frac{v^2}{c^2}}} \qquad E = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}}$$

Assignment: Chapter 4 Quick Checks and Review 1-11 (page 111)