Physics 102 - February 3, 2014

- New ranking system
- New journal submission
  comment submission system
- Journal 1, 2, 3, ... → BB your # for wk → Submit to Journ 1, 2, 3, ... → BB your ranking requests → Submit to ranking journal → Comments

last Time

kinematic variables

x, v, a, t

$\frac{\Delta x}{\Delta t} \sim \frac{m}{s}$

$\frac{\Delta v}{\Delta t} = \frac{\Delta\left(\frac{\Delta x}{\Delta t}\right)}{\Delta t} \sim \frac{m}{s^2}$

Two Teams, Two Measures Equaled One Lost Spacecraft

By ANDREW POLLACK

LOS ANGELES, Sept. 30 — Simple confusion over whether measurements were metric or not led to the loss of a $125 million spacecraft last week as it approached Mars, the National Aeronautics and Space Administration said today.

An internal review team at NASA's Jet Propulsion Laboratory said in a preliminary conclusion that engineers at Lockheed Martin Corporation, which had built the spacecraft, specified certain measurements about the spacecraft's thrust in pounds, an English unit, but that NASA scientists thought the information was in the metric measurement of newtons.

The resulting miscalculation, undetected for months as the craft was designed, built and launched, meant the craft, the Mars Climate Orbiter, was off course by about 60 miles as it approached Mars.

"This is going to be the cautionary tale that is going to be embedded into introductions to the metric system in elementary school and high school and college physics till the end of time," said John Pike, director of space policy at the Federation of American Scientists in Washington.

Lockheed's reaction was equally blunt.

"The reaction is disbelief," said Noel Hinners, vice president for flight systems at Lockheed Martin Astronautics in Denver, Colo. "It can't be something that simple that could cause this to happen."

The finding was a major embarrassment for NASA, which said it was investigating how such a basic error could have gone through a mission's checks and balances.

"The real issue is not that the data was wrong," said Edward C. Stone, the director of the Jet Propulsion Laboratory in Pasadena, Calif., which was in charge of the mission. "The real issue is that our process

Continued on Page A16

ON MICHAEL FERTIK'S 21st, CONGRATS, THE 1st of many appearances on this page! — ADVT.

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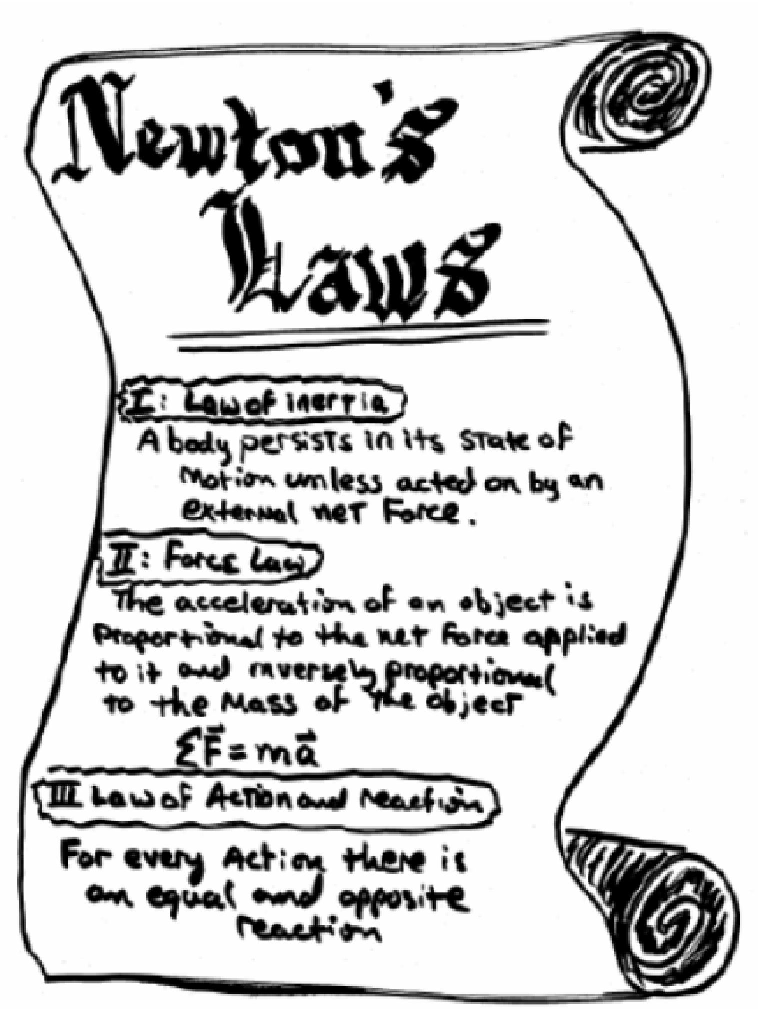


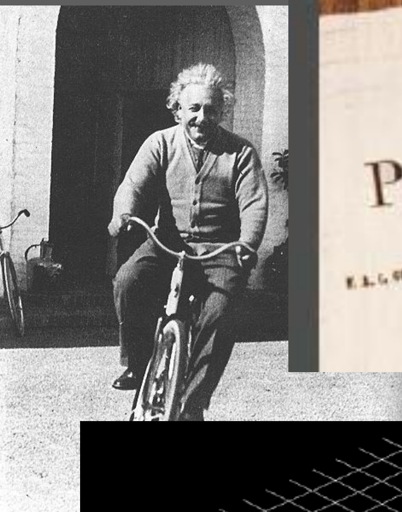
x, v, a, t

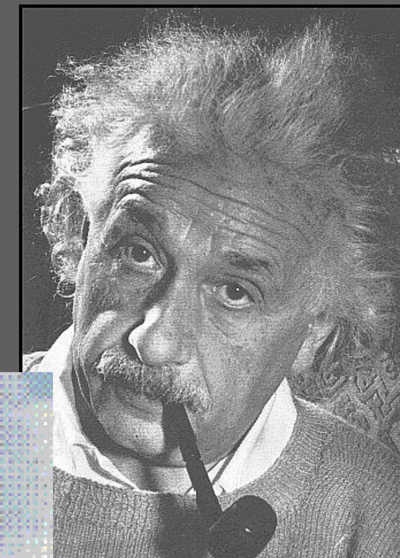
+

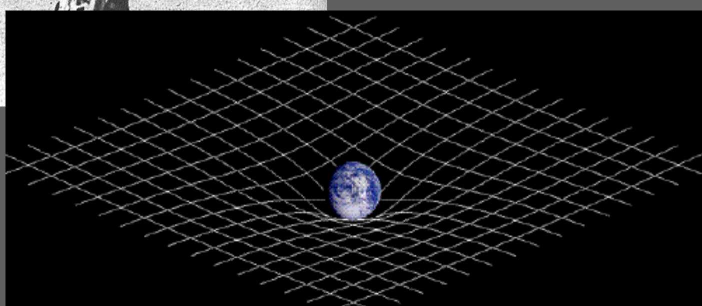
$F = ma$, Newton's laws

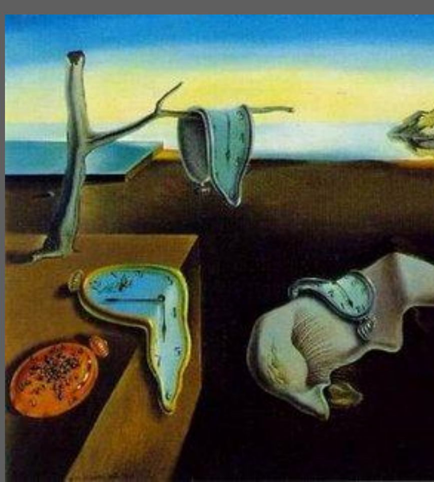
Deterministic

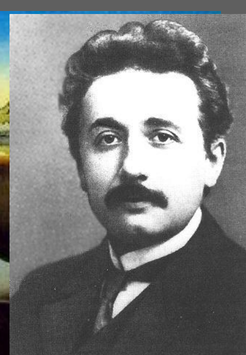
Relativity: the warping of space, time, and minds

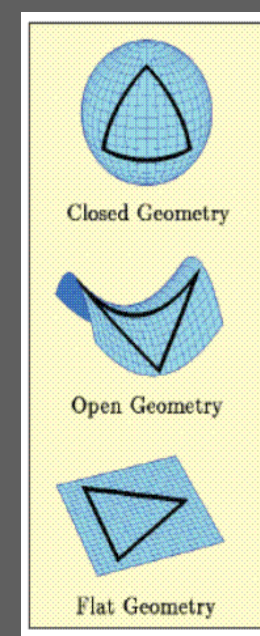




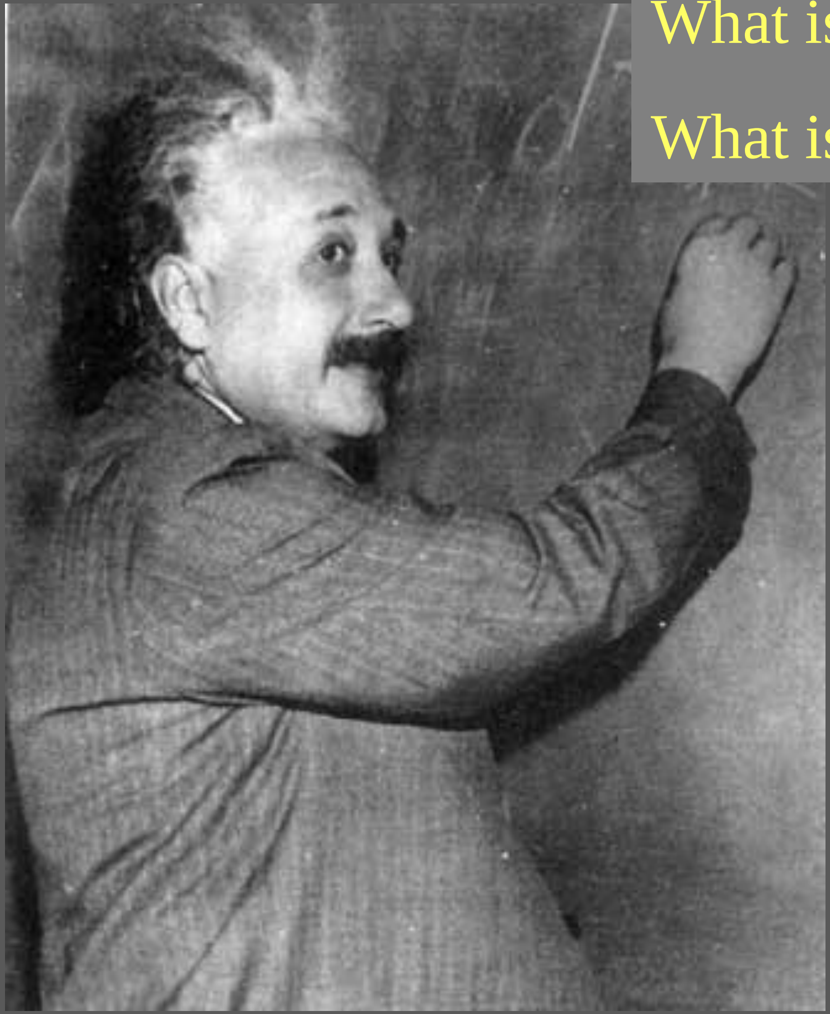








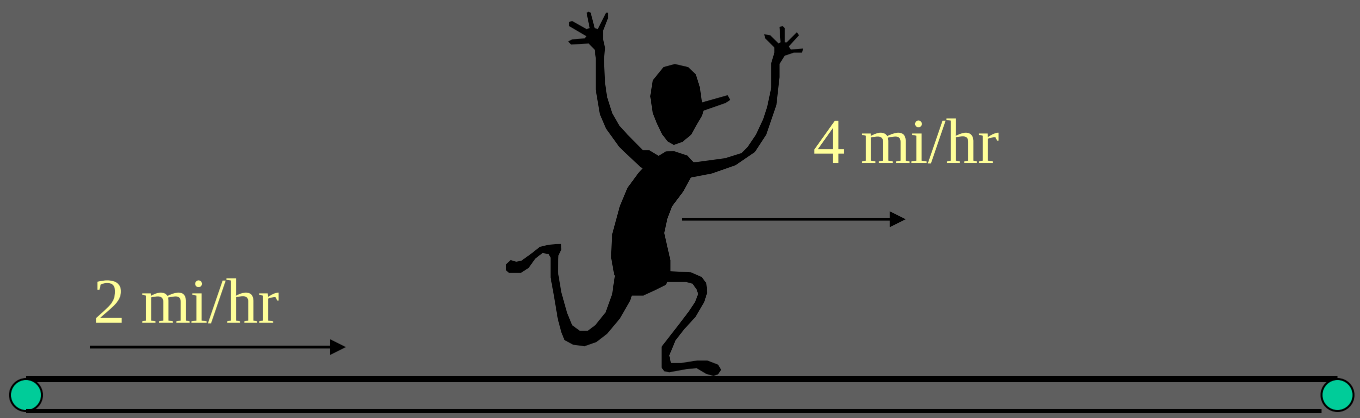
Steve Manly
Department of Physics and Astronomy
University of Rochester



What is time??

What is space??

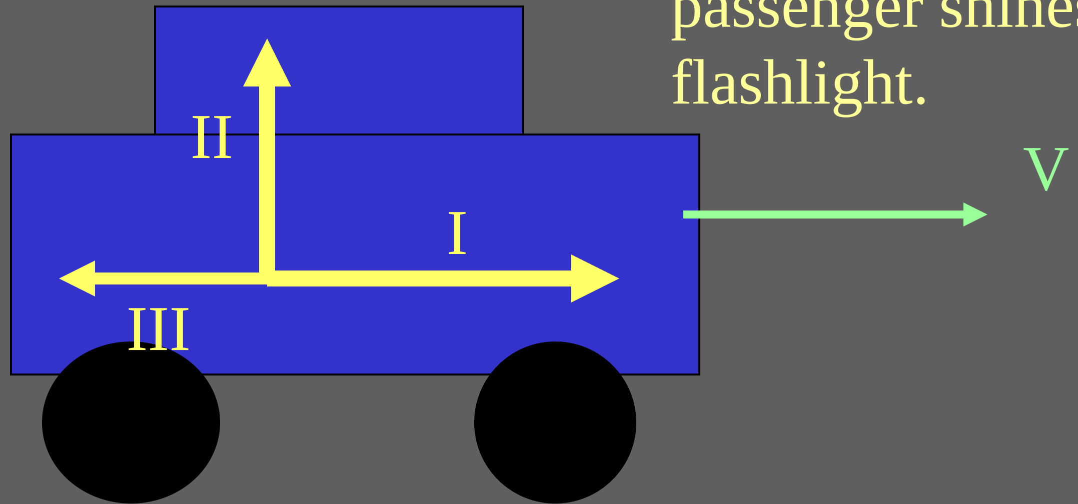
Speed with respect to you is 4 mi/hr



Speed with respect to you is 2 + 4 = 6 mi/hr

The speed of light is greater for beam I, beam II or beam III?

Car moves while passenger shines a flashlight.



Experiment says the speed of light is the same in all directions!!

waves

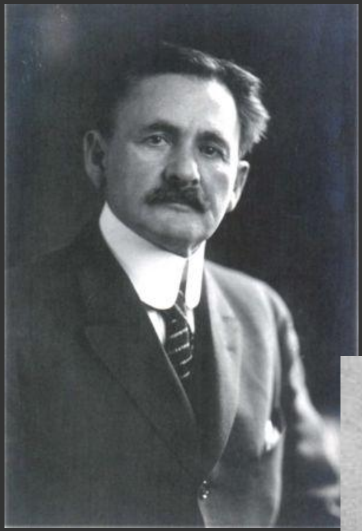
Photo credit: Andrew Davidhazy

Michelson-Morley experiment

1881 – A.A. Michelson in Berlin

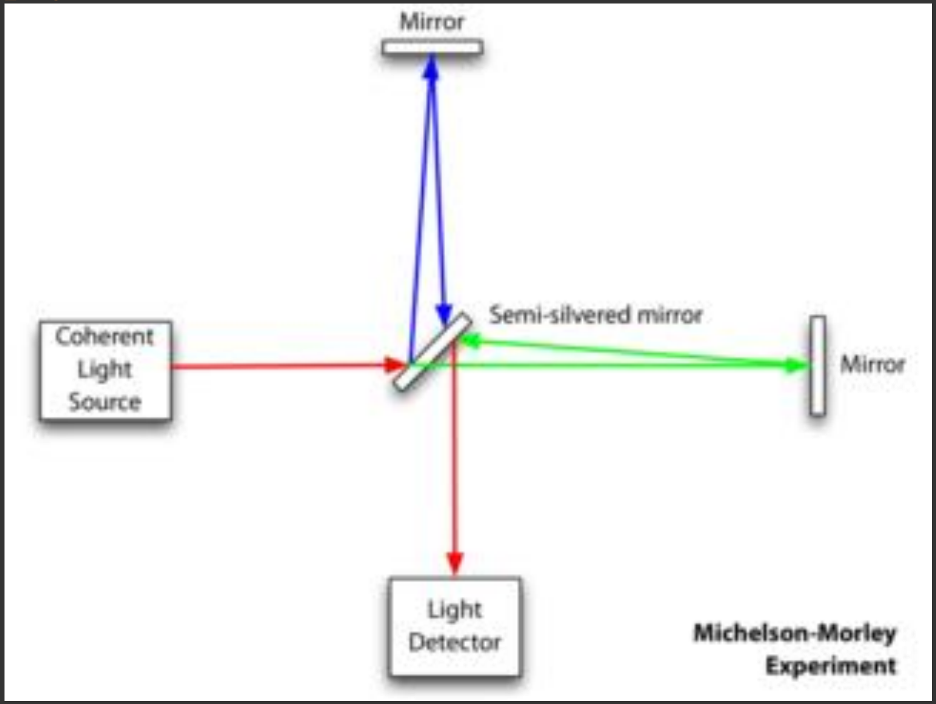
1887 - A.A. Michelson and E.W. Morley in US (Case Western)

1907 Nobel Prize in physics



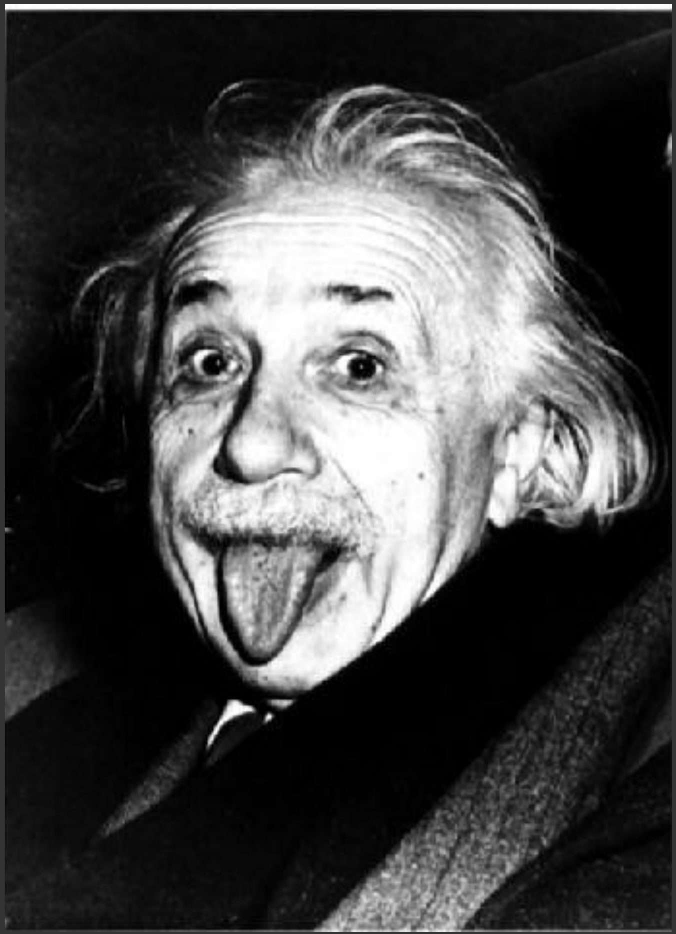
Michelson

Morley



Weird, huh? What does it mean for the real world?

Enter our man Einstein!



Instead of trying to “save the current paradigm”, Einstein bowed before the experiment.

What if it is true??

Two postulates:

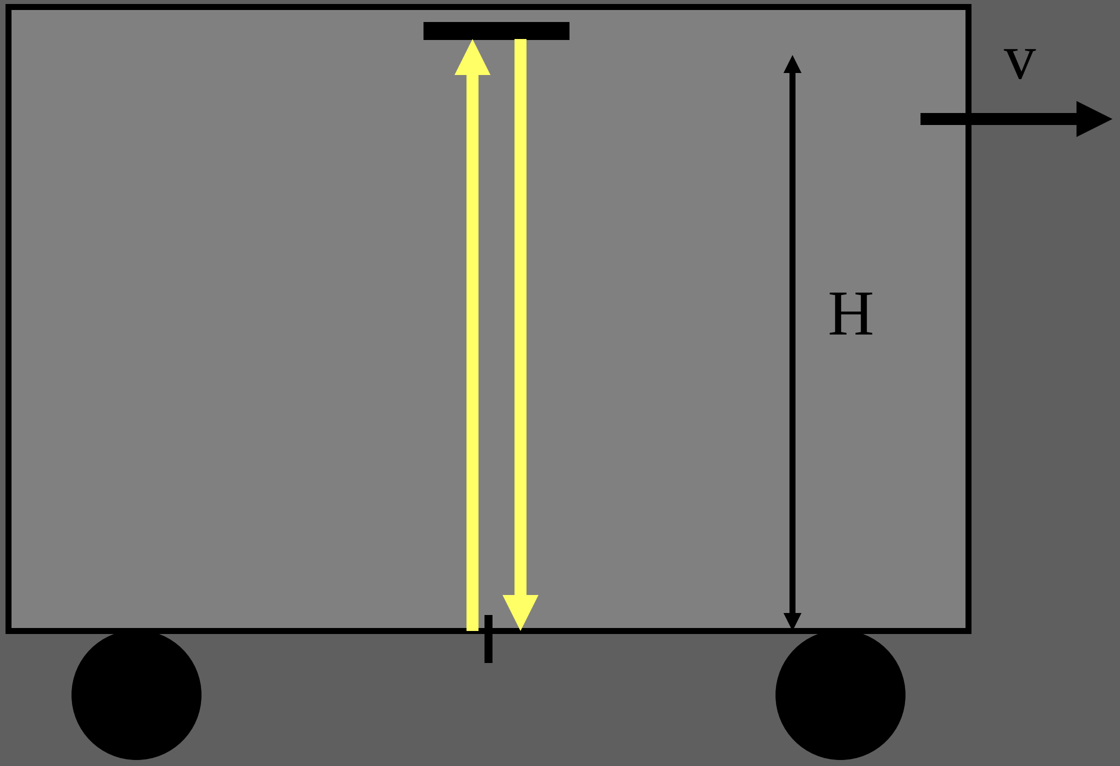
1) Michelson-Morley is correct. Speed of light is the same in all inertial reference frames

2) Physics is the same in all inertial reference frames

Point of view of observer

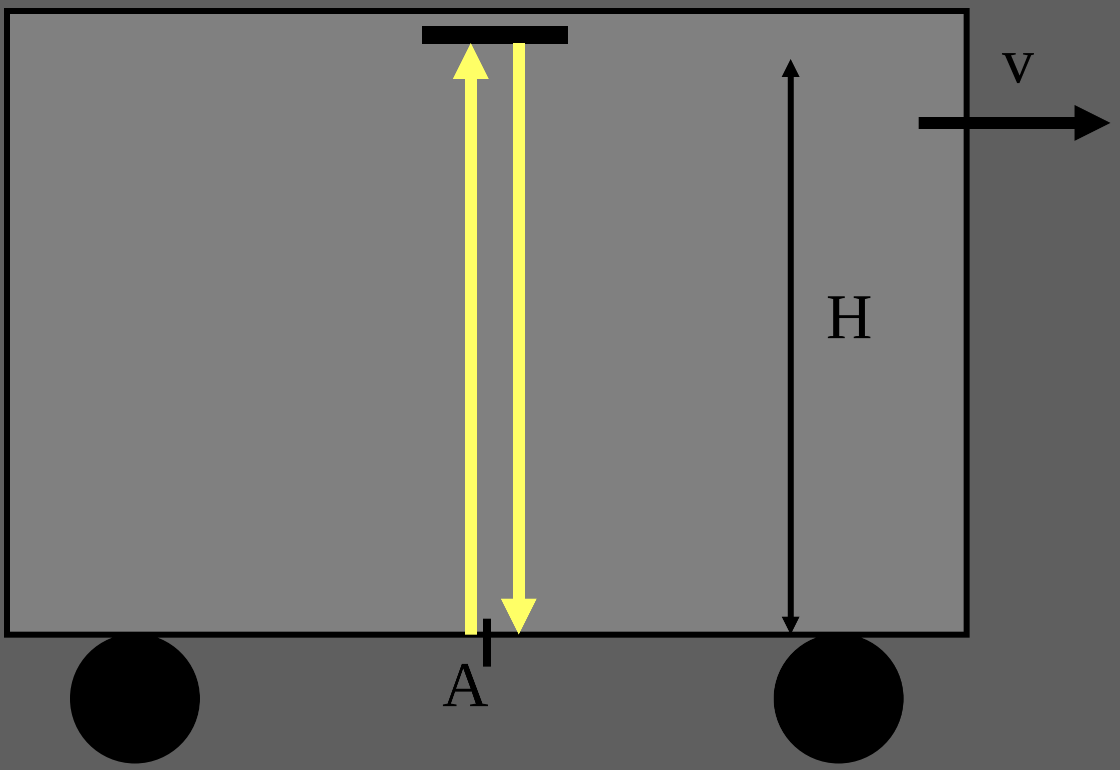
Moving at constant speed

Einstein thought experiment:
Consider a beam of light that is emitted from the floor of a train that bounces off a mirror on the ceiling and returns to the point on the floor where it was emitted.

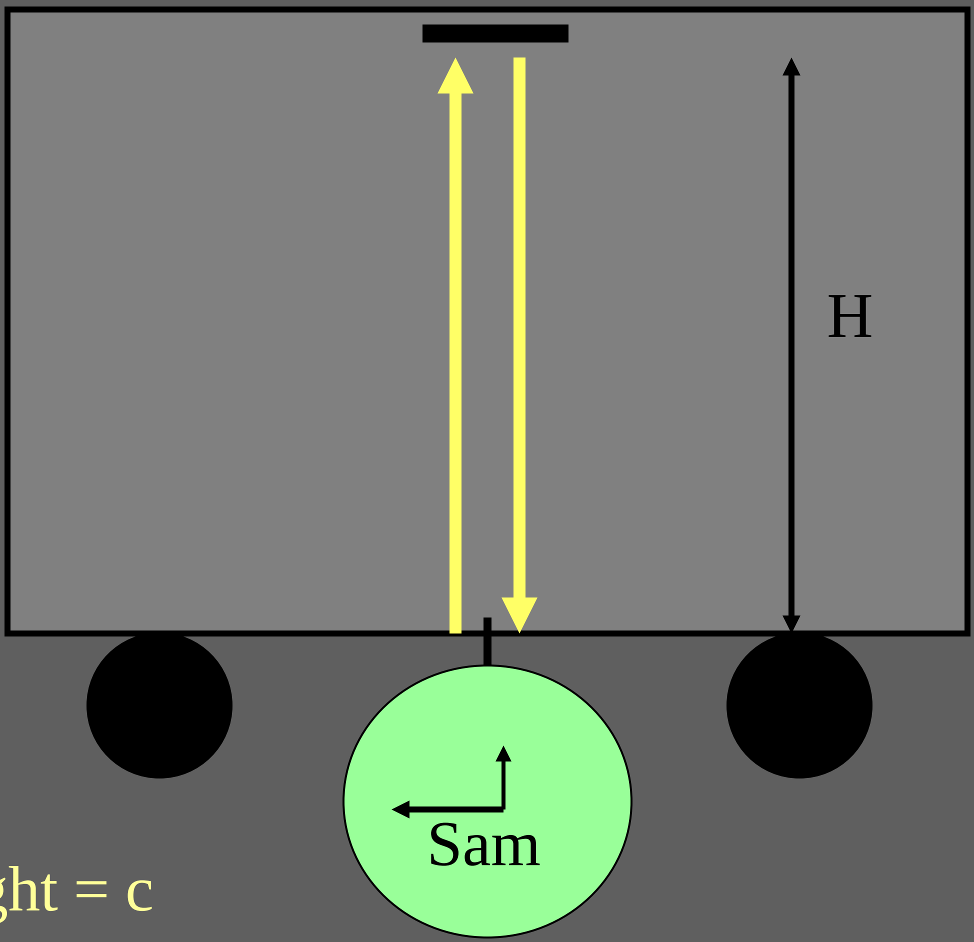


Fact: Light is emitted and detected at point A.

This fact must be true no matter who makes the measurement!!!!



Sam is on the train



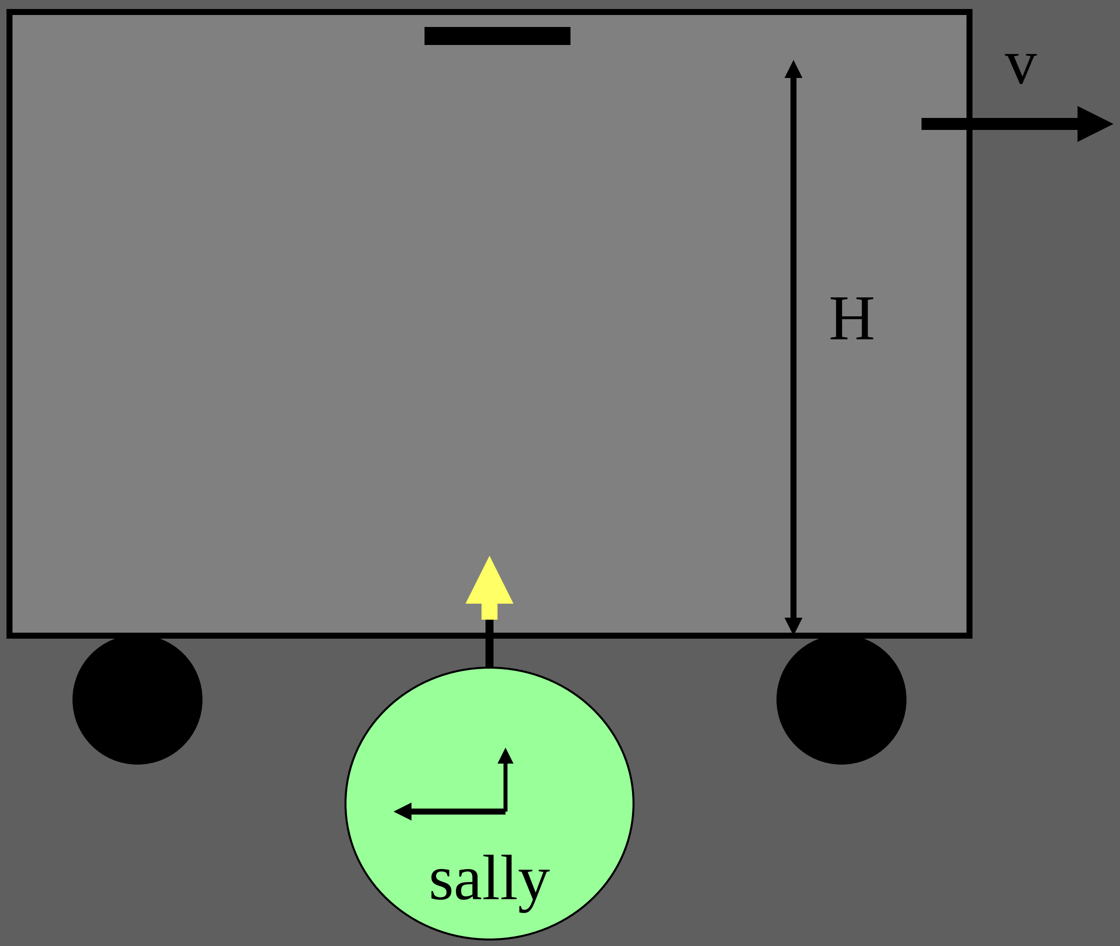
Velocity of light = c

c = distance/time

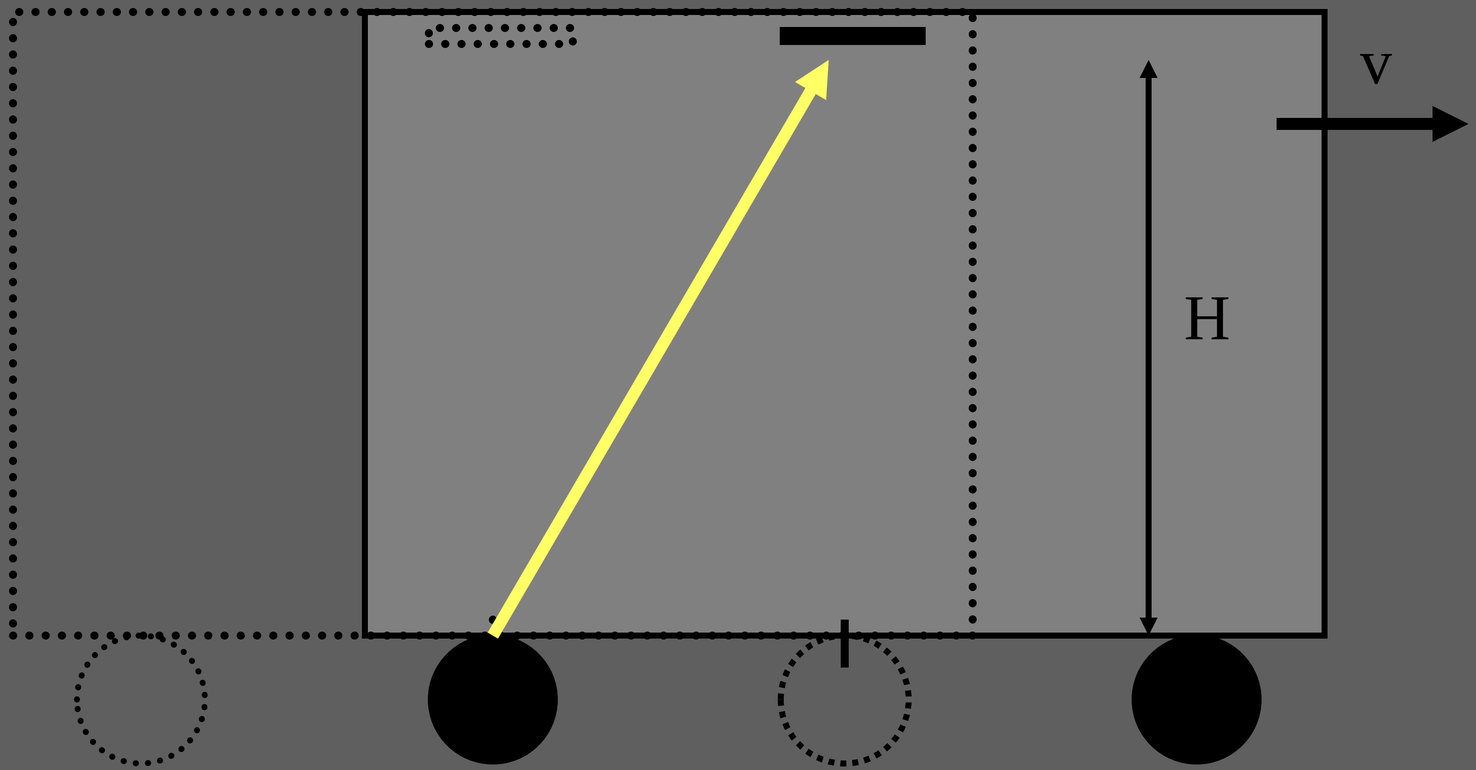
$c = 2H/T_{sam}$

$T_{sam} = 2H/c$

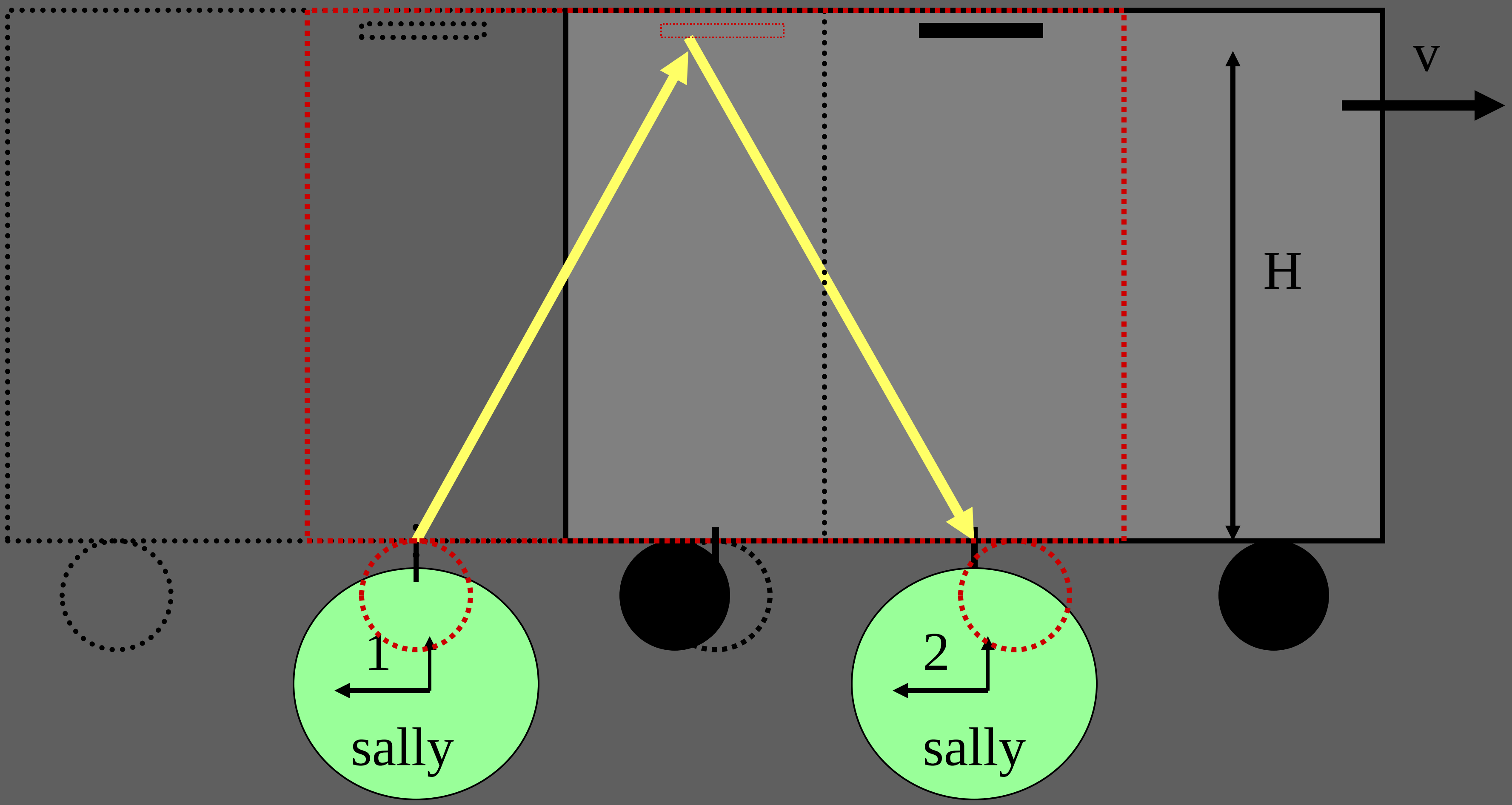
Sally watches the train pass and makes the same measurement.



Light is emitted


v
H

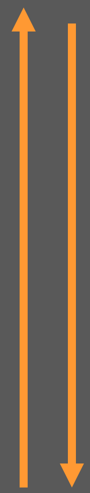
Sally is standing still, so it takes two clocks.



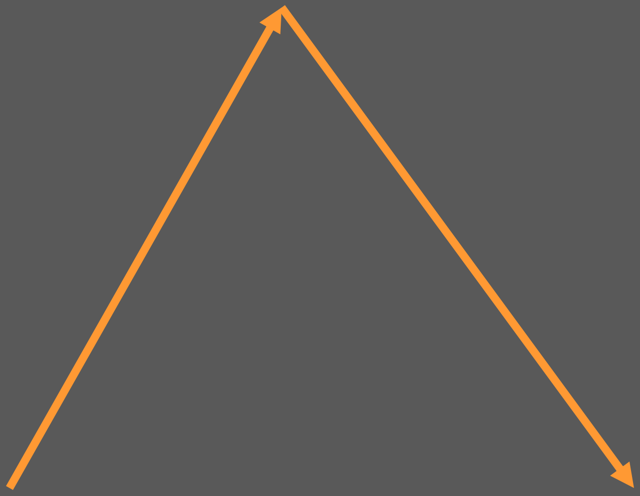
Light is emitted

Light returns

Sam



Sally

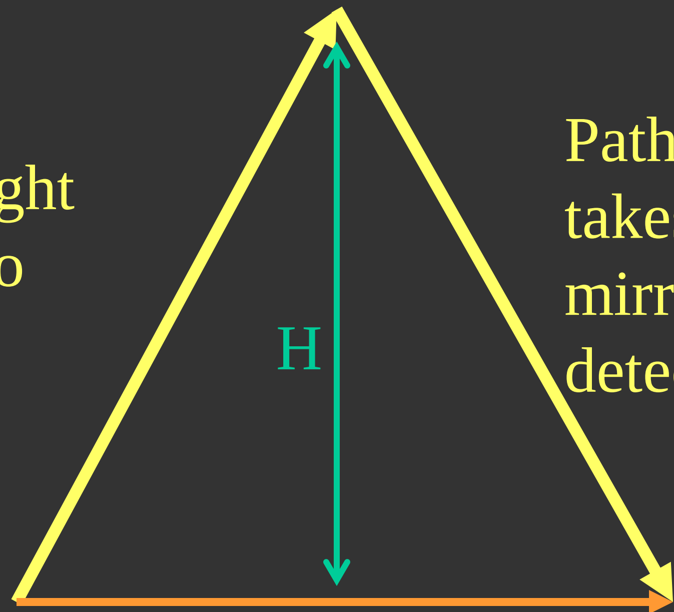


Sally sees the light traveling further. If light travels at a constant speed, the same "event" must seem to take longer to Sally than Sam!

Time is relative … not absolute!!

From Sally's point of view

Path light takes to mirror



Path light takes from mirror to detector

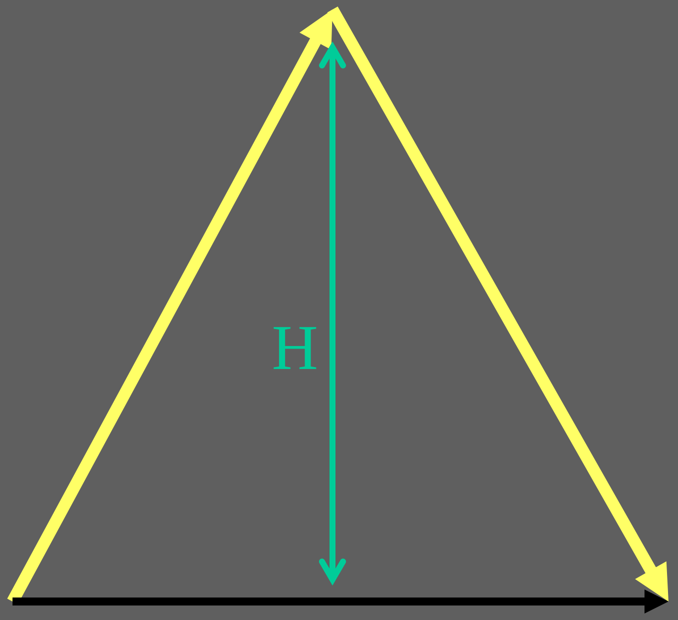
Distance train travels while light is traveling

$= VT_{sally}$

$$D = \sqrt{H^2 + (\frac{1}{2}vT_{sally})^2}$$

Makes use of Pythagorian theorem

From Sally's point of view



c = distance/time = $2D/T_{sally}$

$T_{sally} = 2D/c$

Sam (on train)

Sally (on ground)

$2H/T_{sam} = c$

$c = 2D/T_{sally}$

$$c = \frac{2}{T_{sally}}\sqrt{H^2 + (\frac{1}{2}\mathrm{v}T_{sally})^2}$$

$$\frac{2H}{T_{sam}} = \frac{2}{T_{sally}}\sqrt{H^2 + \left(\frac{1}{2}\mathrm{v}T_{sally}\right)^2}$$

$$\left(\frac{2H}{T_{sam}}\right)^2 = \left(\frac{2H}{T_{sally}}\right)^2 + \left(\frac{2}{T_{sally}}\right)^2\left(\frac{1}{2}\mathrm{v}T_{sally}\right)^2$$

$$\left(\frac{2H}{T_{sam}}\right)^2 = \left(\frac{2H}{T_{sally}}\right)^2 + \mathrm{v}^2$$

$$\left(\frac{1}{T_{sam}}\right)^2 = \left(\frac{1}{T_{sally}}\right)^2 + \frac{\mathrm{v}^2}{(2H)^2}$$

Recall $2H/T_{sam} = c$ or $2H = cT_{sam}$

$$\left(\frac{1}{T_{sam}}\right)^2 = \left(\frac{1}{T_{sally}}\right)^2 + \frac{\mathrm{v}^2}{(cT_{sam})^2}$$

$$c^2 = \frac{c^2 T_{sam}^2}{T_{sally}^2} + \mathrm{v}^2 \quad \longrightarrow \quad T_{sally} = \left[\frac{1}{\sqrt{1-\left(\frac{\mathrm{v}}{c}\right)^2}}\right] T_{sam}$$

Sam (on train)

Sally (on ground)

$2H/T_{sam} = c$

$c = 2D/T_{sally}$

$$c = \frac{2}{T_{sally}}\sqrt{H^2 + (\frac{1}{2}\mathrm{v}T_{sally})^2}$$

A bit of algebra.

$$T_{sally} = \left[\frac{1}{\sqrt{1-\left(\frac{\mathrm{v}}{c}\right)^2}}\right]T_{sam}$$

This number is >1.

It becomes larger as

v approaches c.

Think about it!

Sam and Sally measure the time interval for the same event.

The ONLY difference between Sam and Sally is that one is moving with respect to the other.

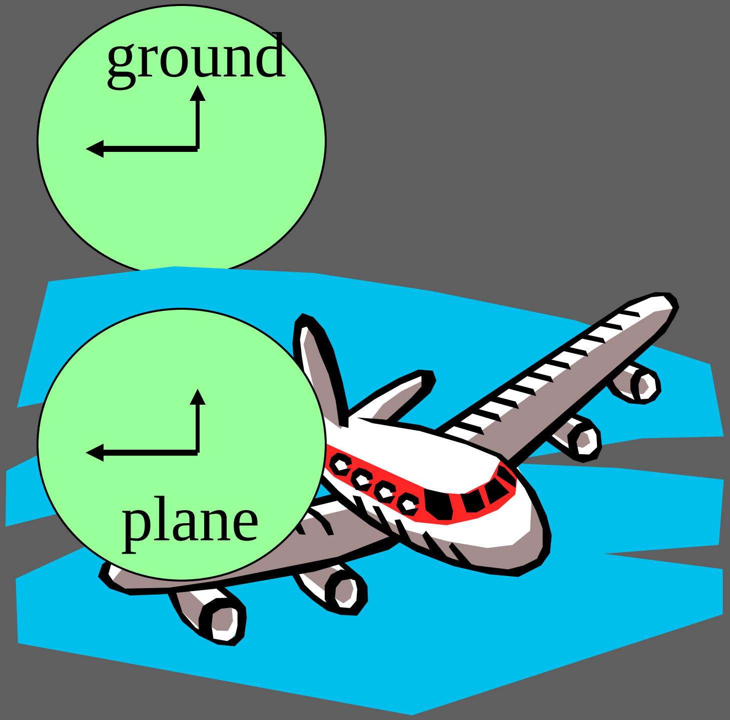
Yet, $T_{sally} > T_{sam}$

The same event takes a different amount of time depending on your “reference frame”!!

Time is not absolute! It is relative!

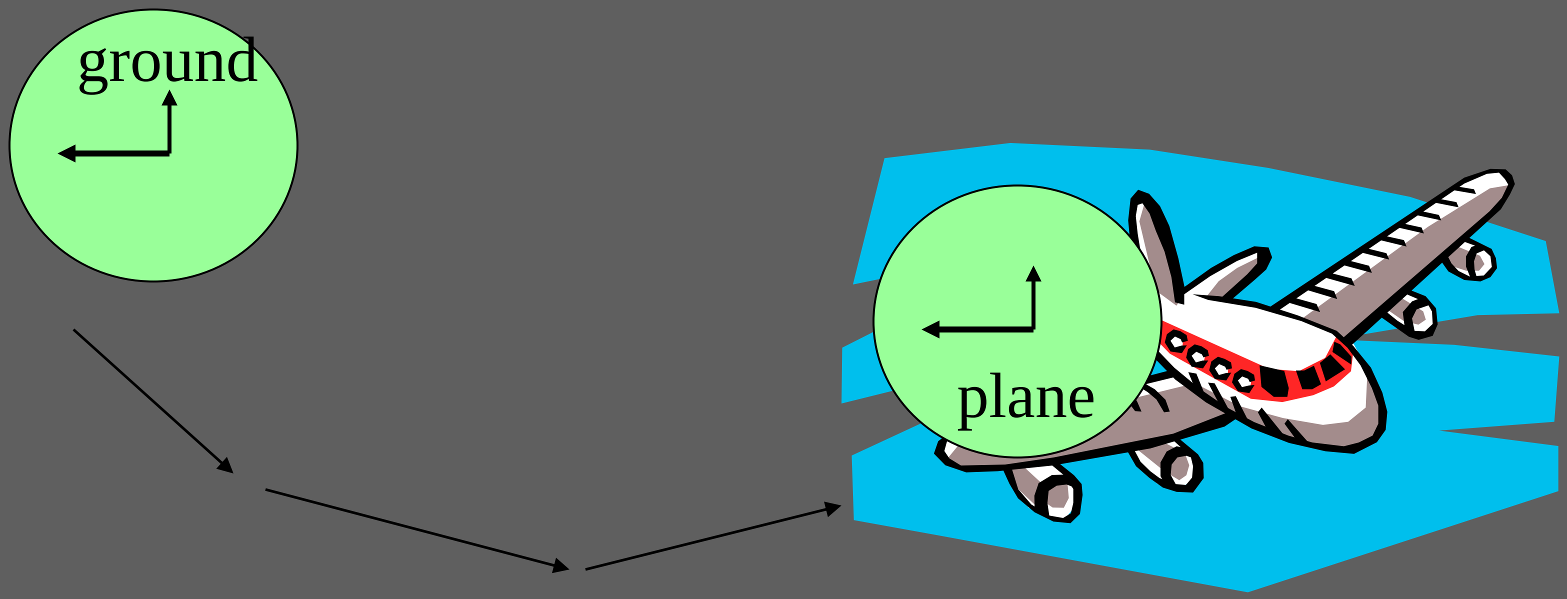
Can this be true??

Experiment says YES!

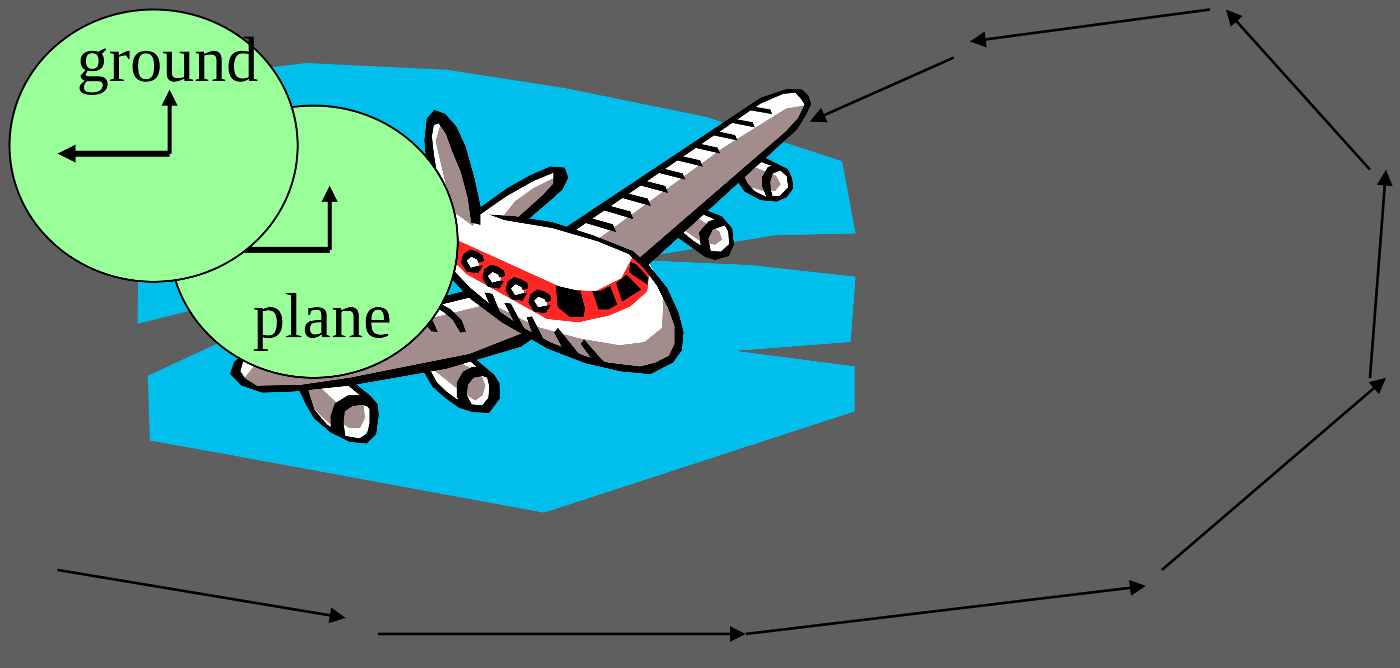


Can this be true??

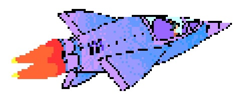
Experiment says YES!



Less time elapsed on the clocks carried on the airplane



V=0.98c



Lifetime=70 years on spaceship

Earth at rest

How long does person appear to live to astronomers on earth?

$\gamma > 1$

$$t_{earth} = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}}\, t_{spaceship}$$

"Proper Time"

$$t_{earth} = \frac{1}{\sqrt{1-\left(\frac{.98c}{c}\right)^2}}\,(70 \text{ years})$$

$$t_{earth} = (5)(70 \text{ years})$$

$$t_{earth} = 350 \text{ years!}$$