Physics 100 – January 28, 2009

- How did Mon Recitation go?
- Wed Recitation time confusion...
- Posted Prob. Set 2
  Prob Set 1 Solns
  last 2 lects

What is the "Essence" of the force ??
Who knows . . . Let's play Pretend

gravitational Field

At each point in space

gravitational $\frac{\text{Force}}{\text{Mass}}$

(Magnitude + direction)

That would be felt by a little test mass at that Point

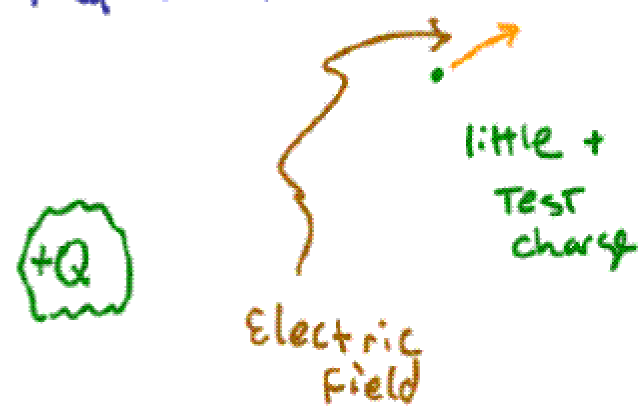
Electric field

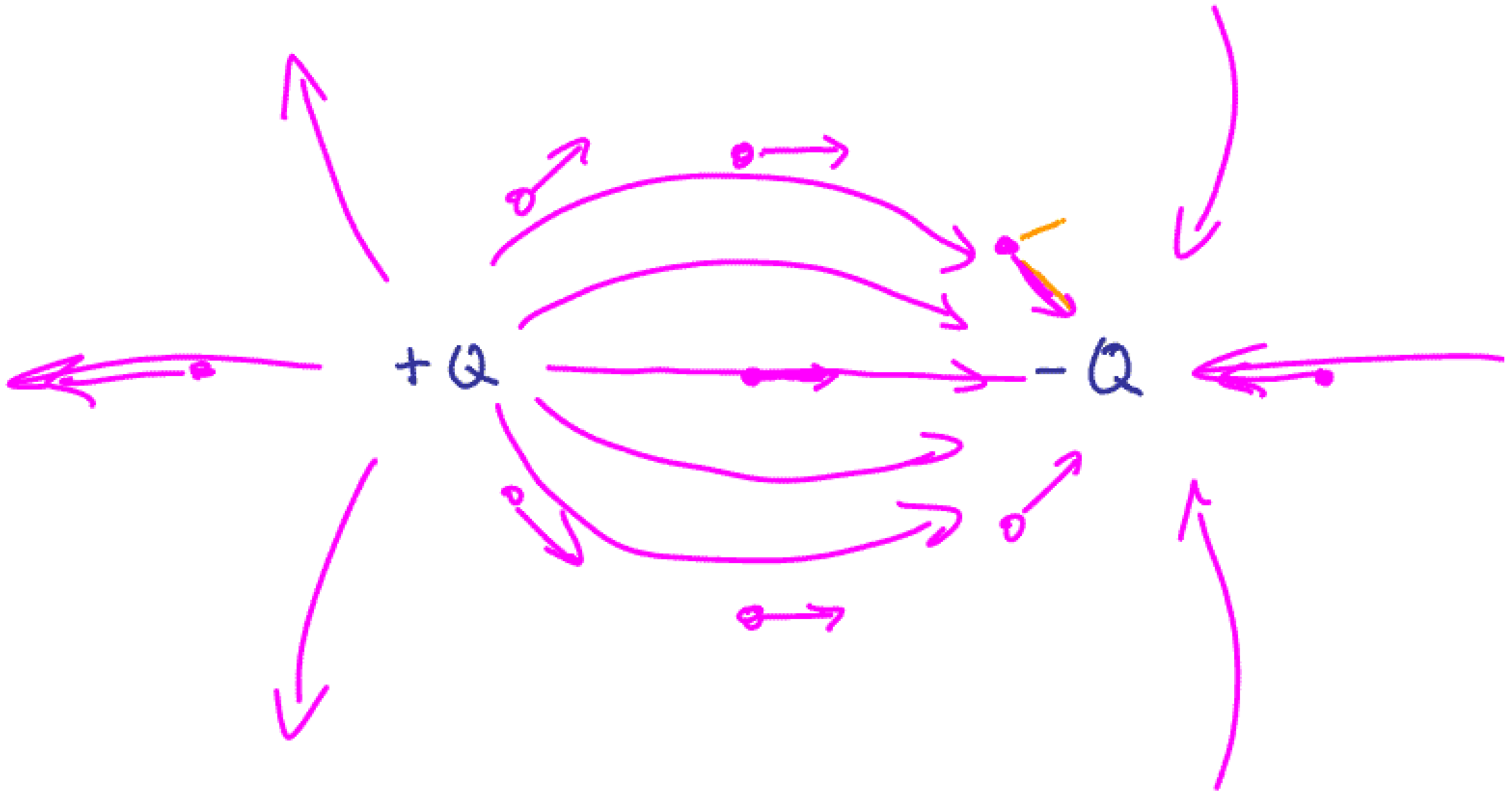
At each point in space

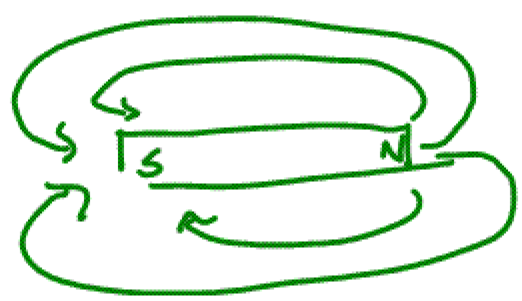
Electric $\frac{\text{Force}}{\text{charge}}$

(Magnitude + direction)

That would be felt by a little + test charge at that Point




+Q
-Q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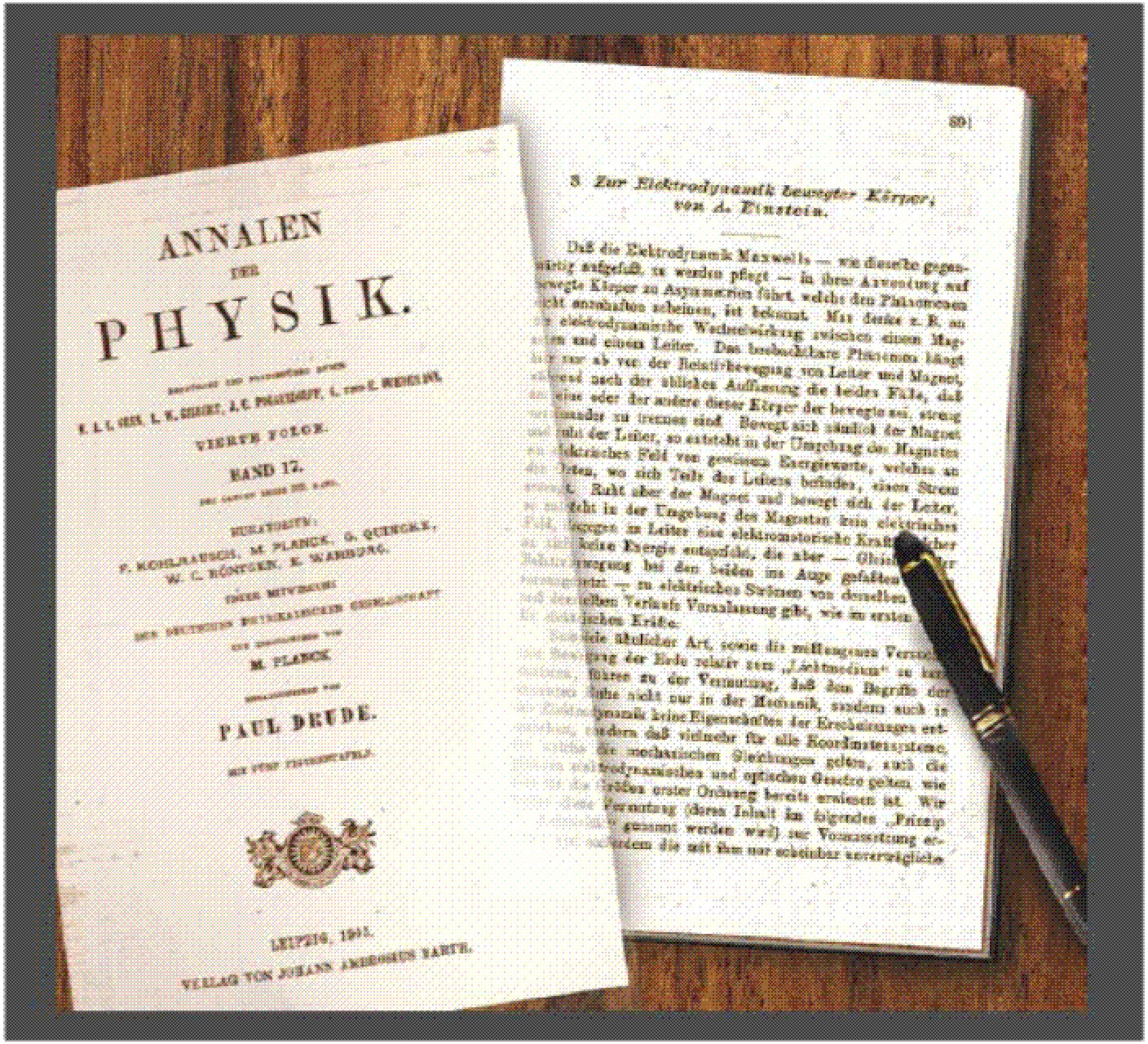
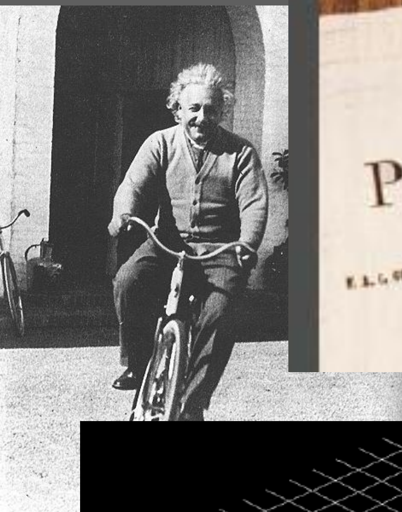

ANNALEN
DER
PHYSIK.
VIERTE FOLGE.
BAND 17.
M. PLANCK
PAUL DRUDE.
LEIPZIG, 1905.
VERLAG VON JOHANN AMBROSIUS BARTH.
891
3. Zur Elektrodynamik bewegter Körper;
von A. Einstein.

Relativity: the warping of space, time, and minds



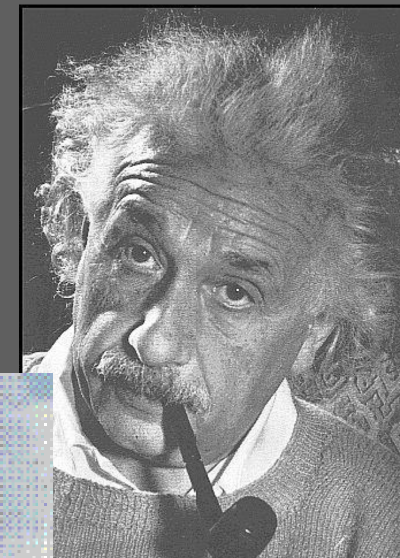

ANNALEN DER PHYSIK.

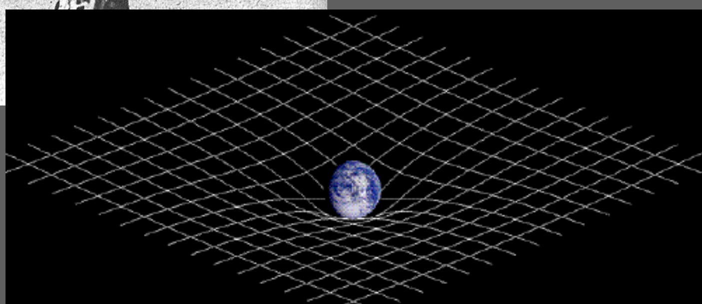
VIERTE FOLGE.

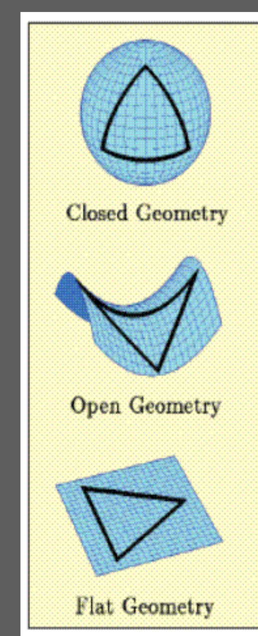
BAND 17.

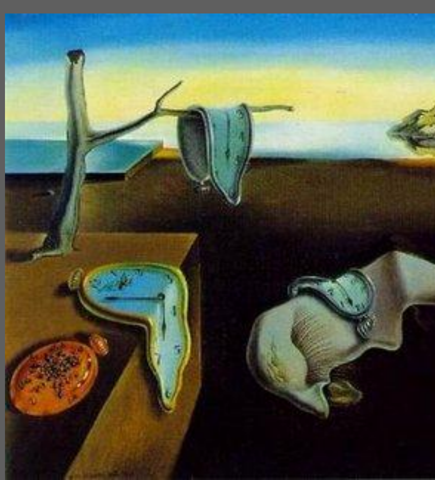
3. Zur Elektrodynamik bewegter Körper; von A. Einstein.

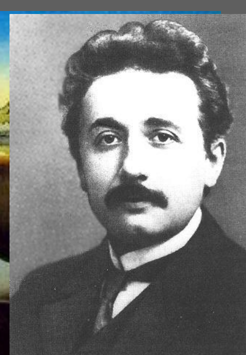
Daß die Elektrodynamik Maxwells — wie dieselbe gegenwärtig aufgefaßt zu werden pflegt — in ihrer Anwendung auf bewegte Körper zu Asymmetrien führt, welche den Phänomenen nicht anzuhaften scheinen, ist bekannt. Man denke z. B. an die elektrodynamische Wechselwirkung zwischen einem Magneten und einem Leiter. Das beobachtbare Phänomen hängt hier nur ab von der Relativbewegung von Leiter und Magnet, während nach der üblichen Auffassung die beiden Fälle, daß der eine oder der andere dieser Körper der bewegte sei, streng voneinander zu trennen sind. Bewegt sich nämlich der Magnet und ruht der Leiter, so entsteht in der Umgebung des Magneten ein elektrisches Feld von gewissem Energiewerte, welches an den Orten, wo sich Teile des Leiters befinden, einen Strom erzeugt. Ruht aber der Magnet und bewegt sich der Leiter



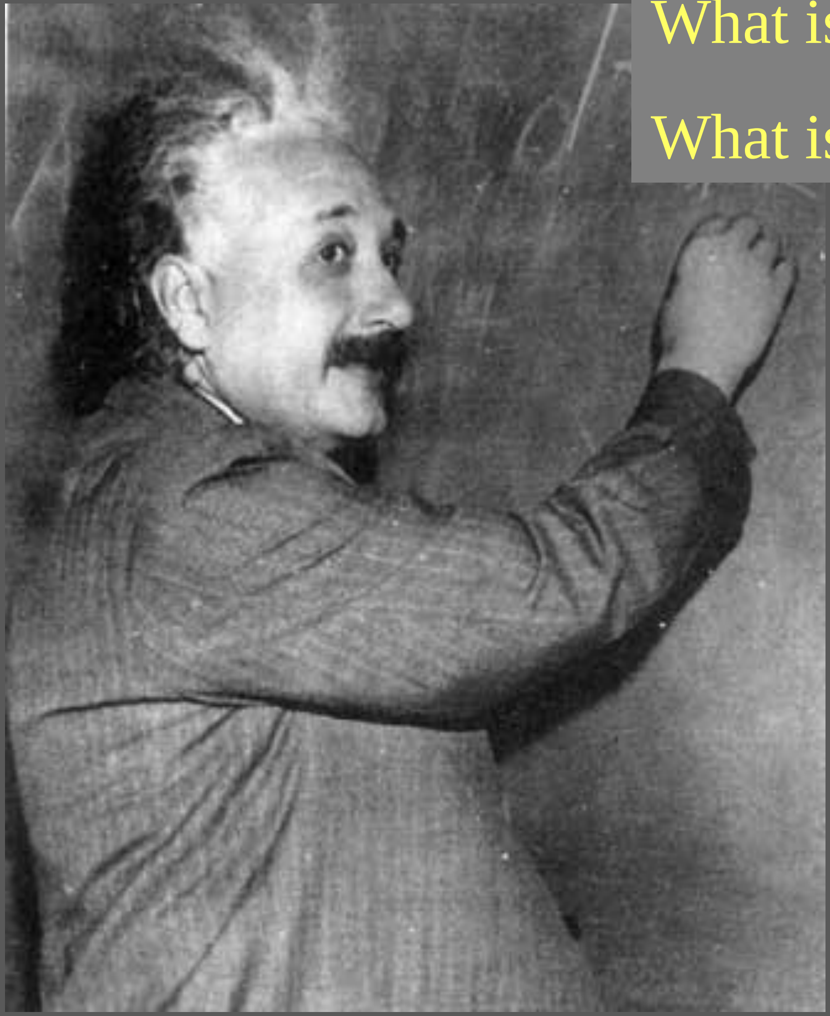








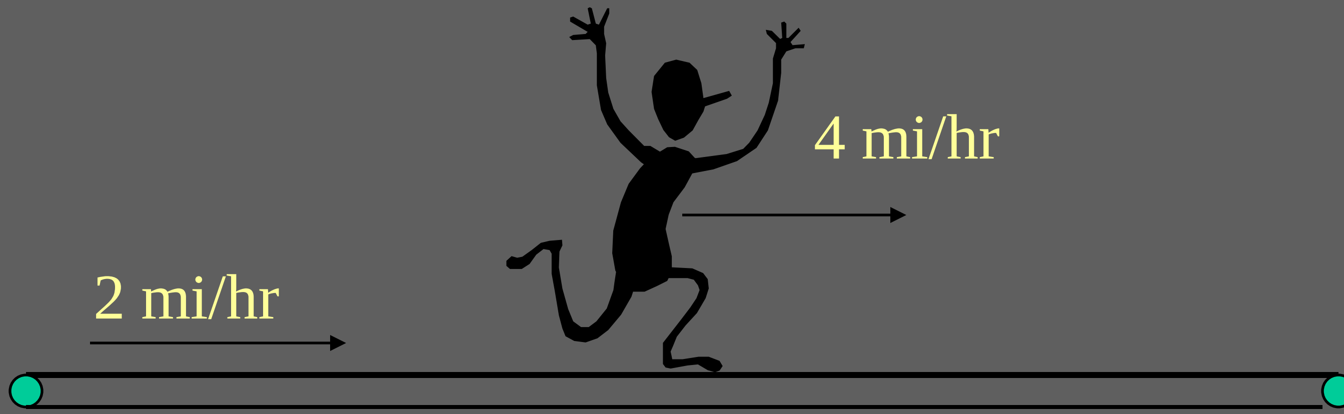
Steve Manly
Department of Physics and Astronomy
University of Rochester



What is time??

What is space??

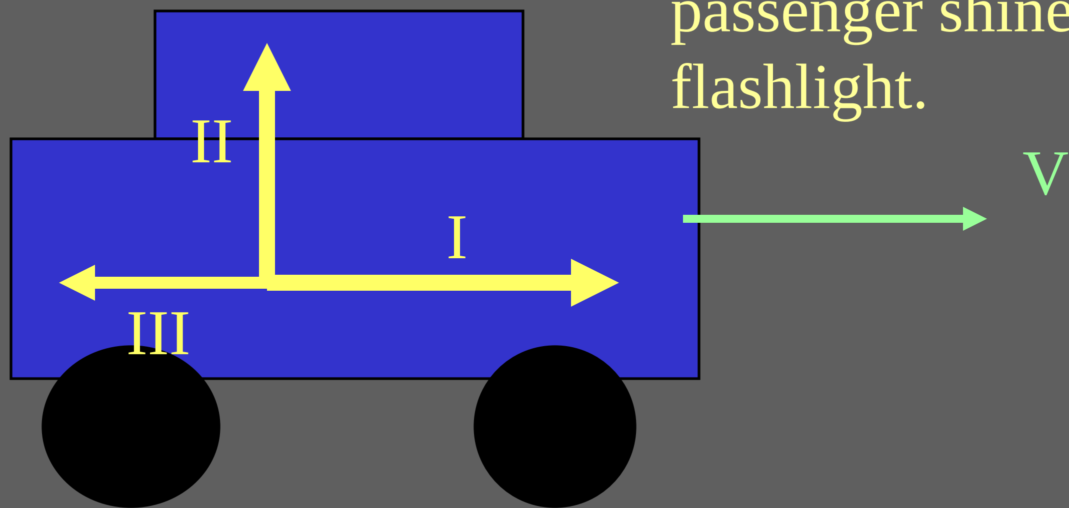
Speed with respect to you is 4 mi/hr



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!!

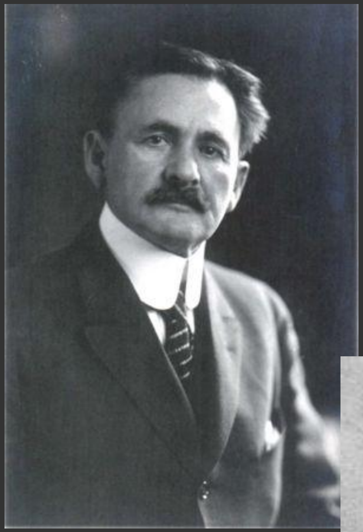
waves

Photo credit: Andrew Davidhazy

Michelson-Morley experiment

1881 – A.A. Michelson in Berlin

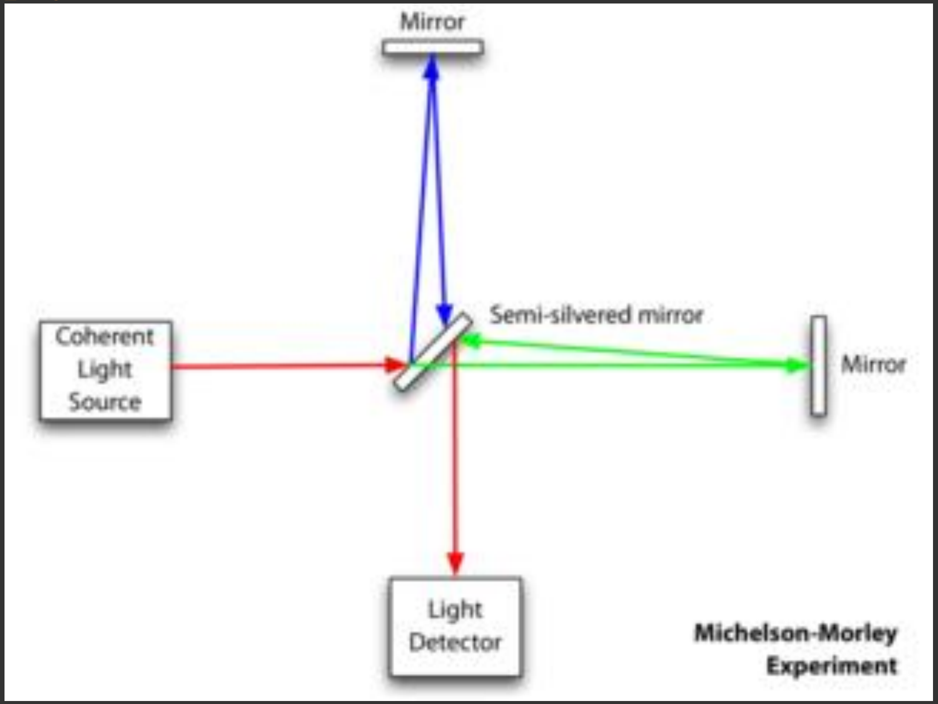
1887 - A.A. Michelson and E.W. Morley in US (Case Western)



1907 Nobel Prize in physics

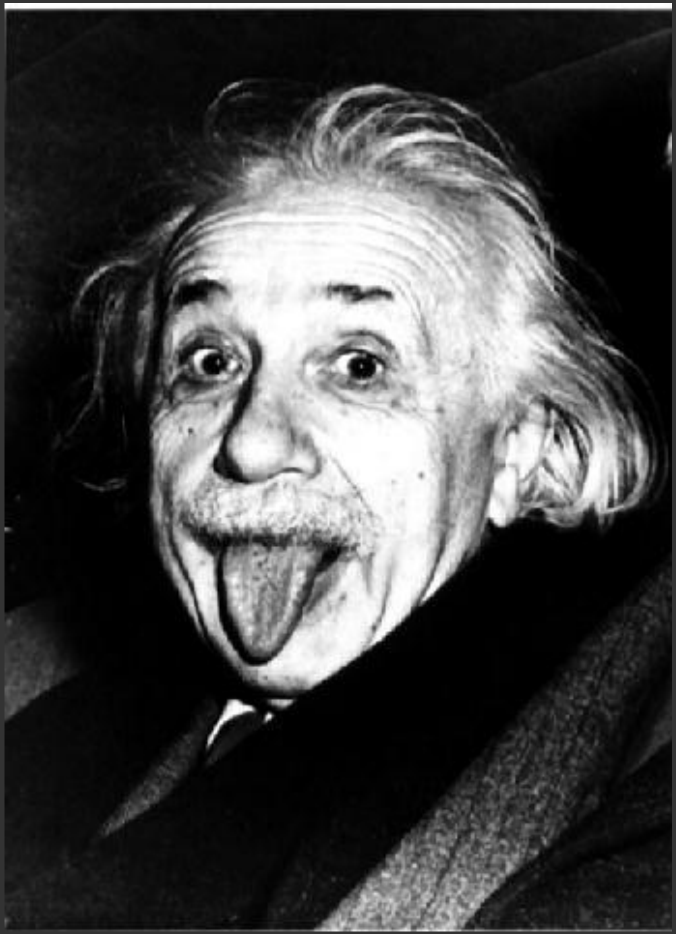
Michelson

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

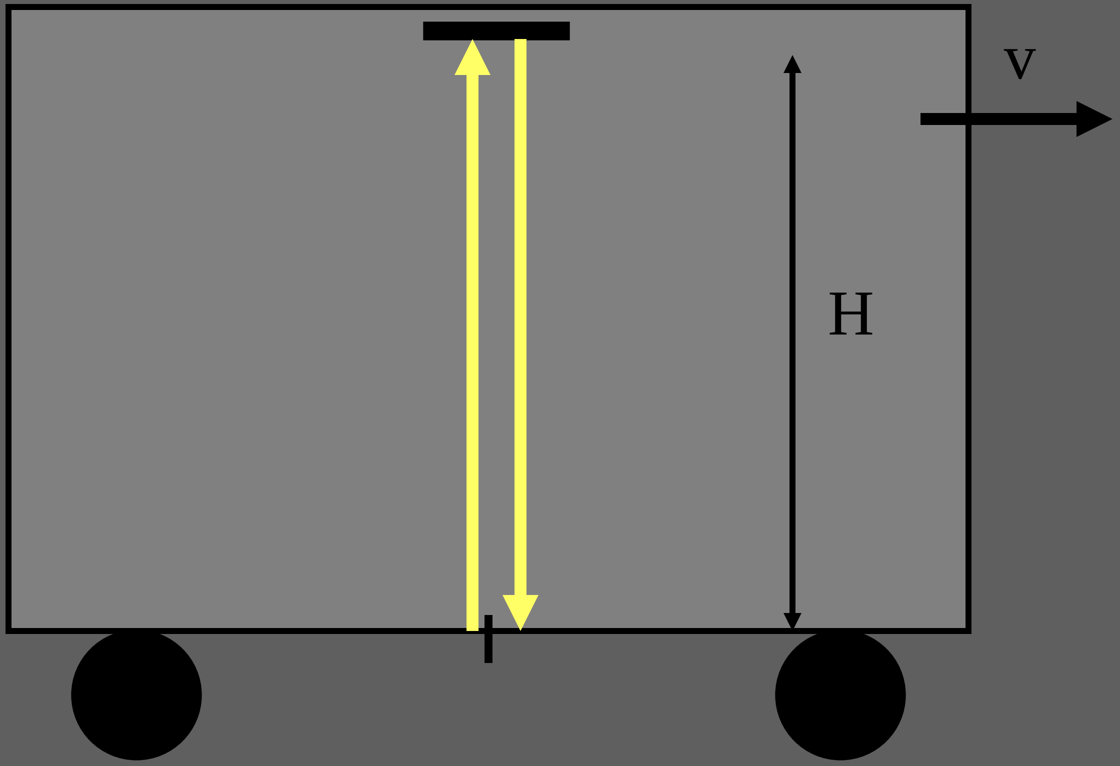
2) Physics is the same in all inertial reference frames

Point of view of observer

Moving at constant speed

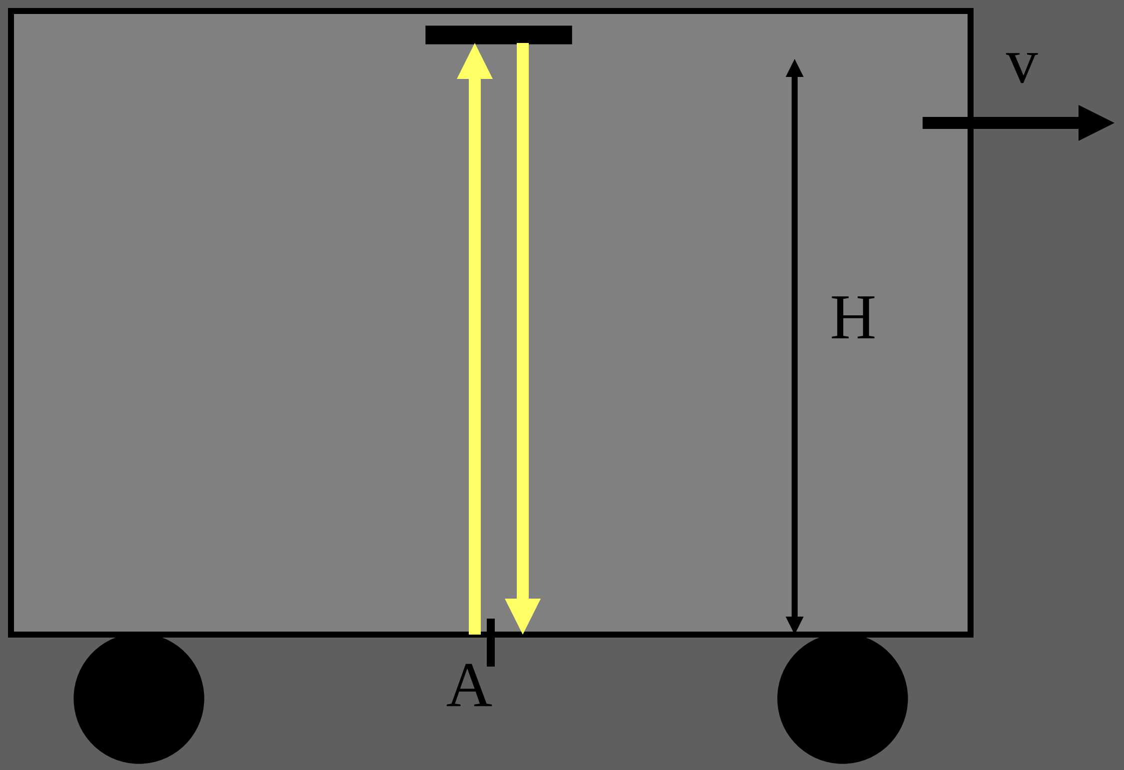
Einstein thought experiment:

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.

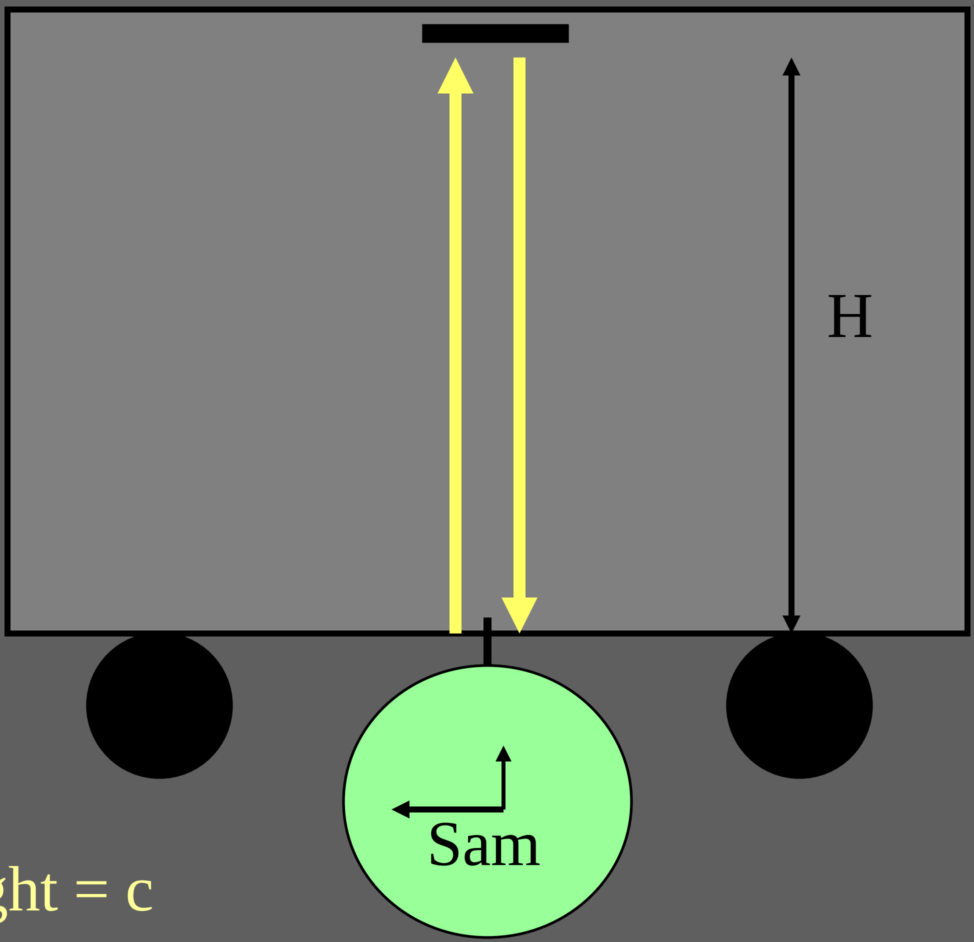


Fact: Light is emitted and detected at point A.

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



Sam is on the train



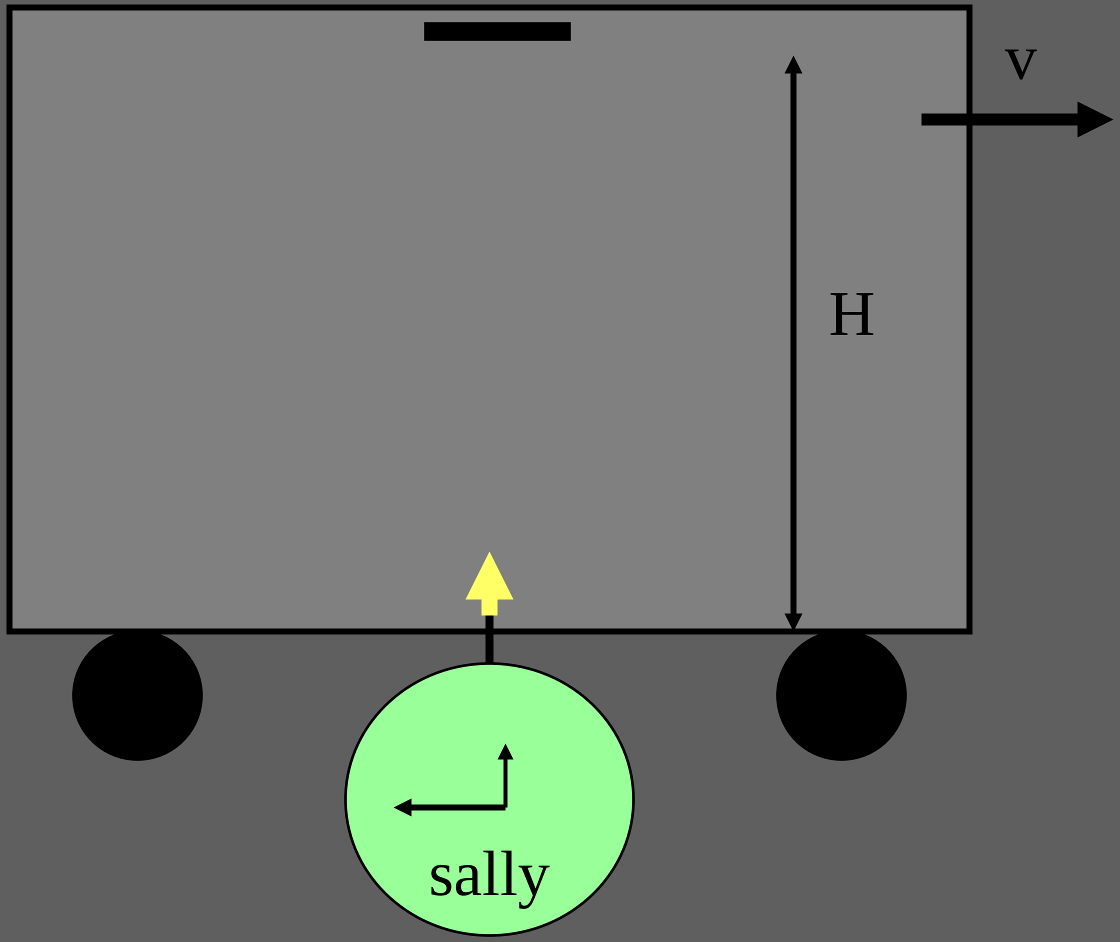
Velocity of light = c

c = distance/time

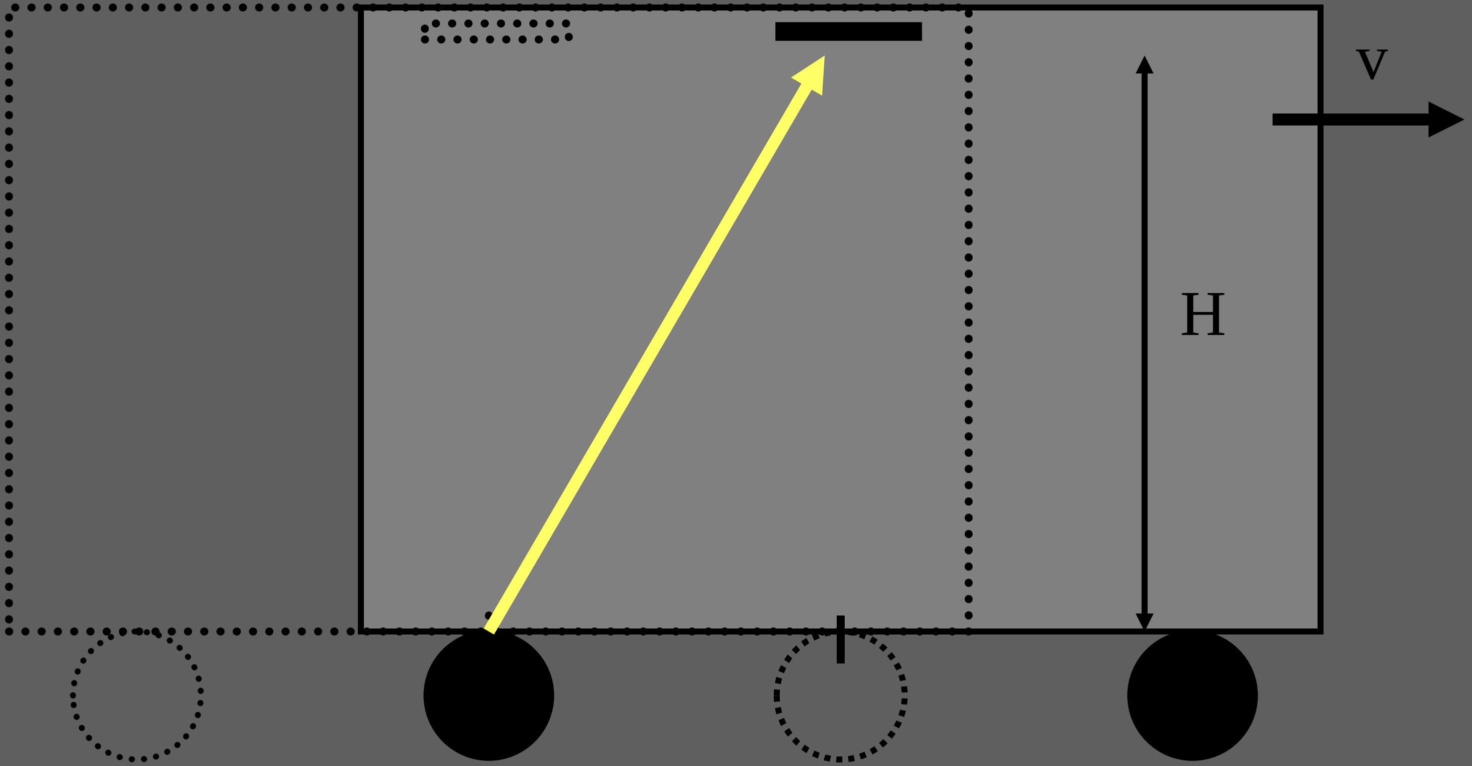
$c = 2H/T_{sam}$

$T_{sam} = 2H/c$

Sally watches the train pass and makes the same measurement.

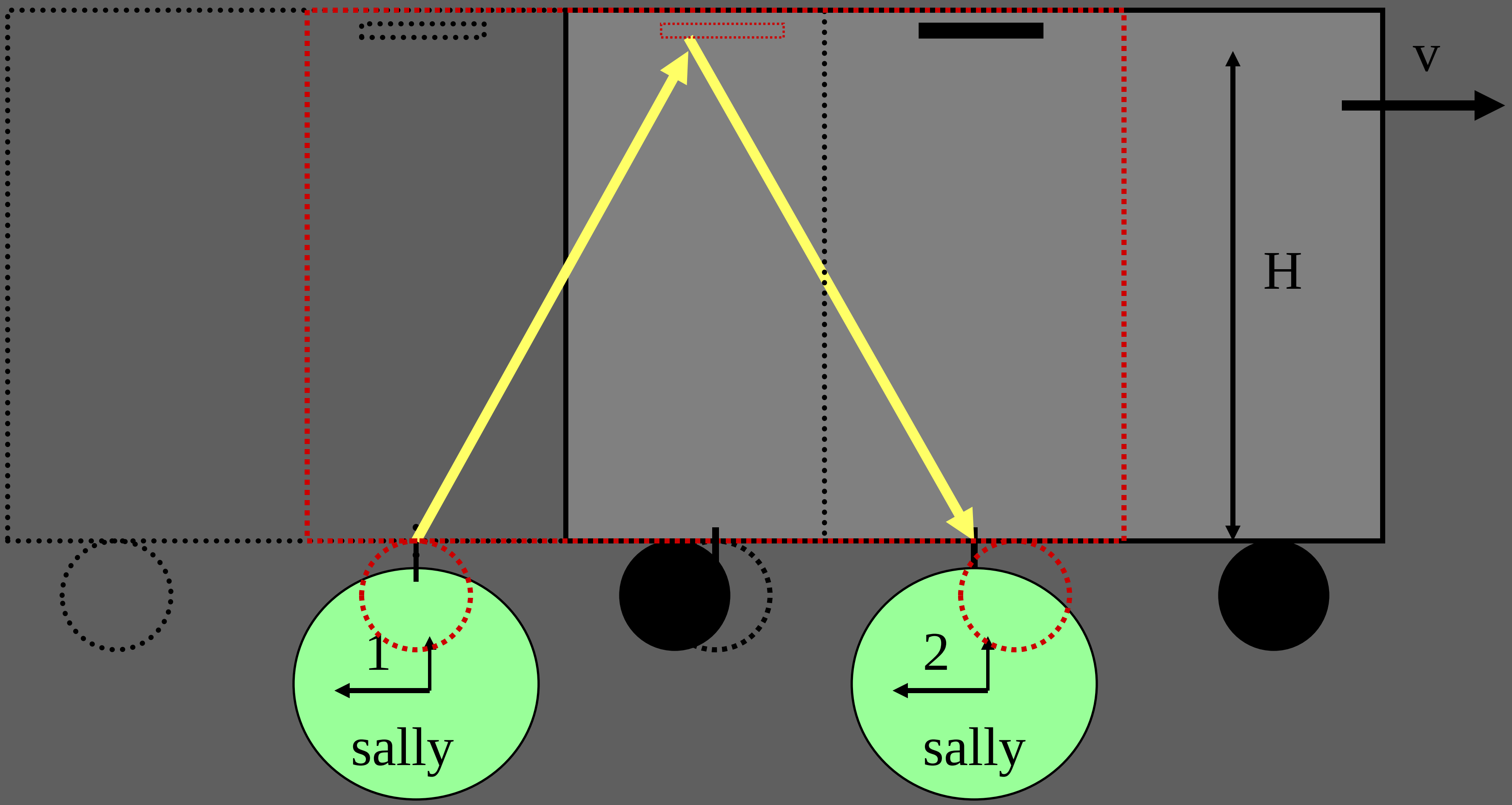


Light is emitted



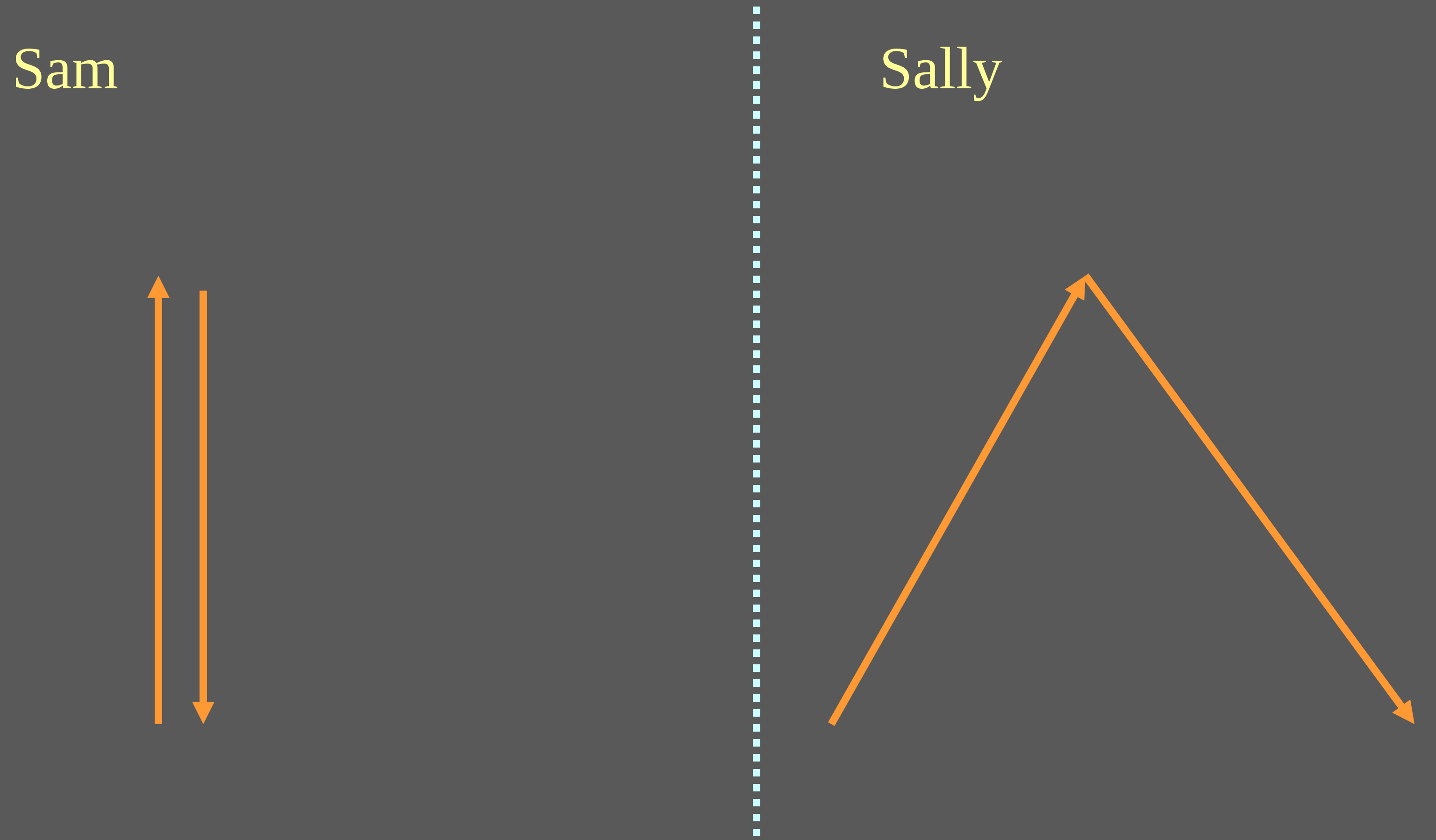
v
H

Sally is standing still, so it takes two clocks.



Light is emitted

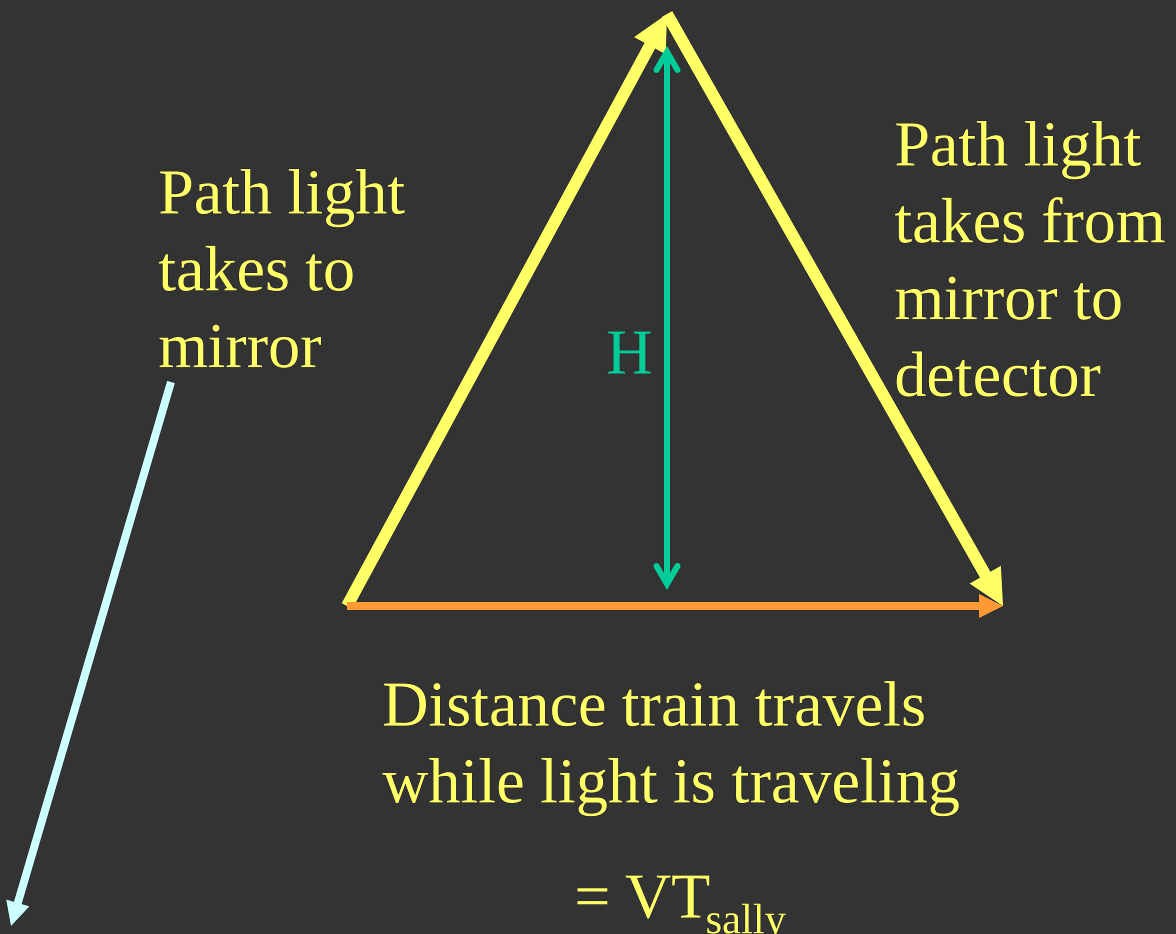
Light returns



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!!

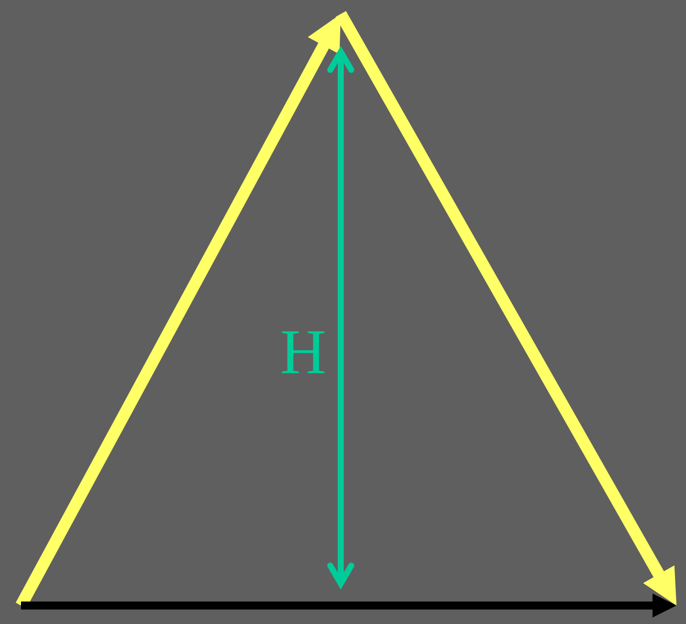
From Sally's point of view



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

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 $2H = cT_{sam}$

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

$$c^2 = \frac{c^2 T_{sam}^2}{T_{sally}^2} + \mathrm{v}^2 \quad \longrightarrow$$

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

Sam (on train)

Sally (on ground)

$2H/T_{sam} = c$

$c = 2D/T_{sally}$

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

A bit of algebra.

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

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.

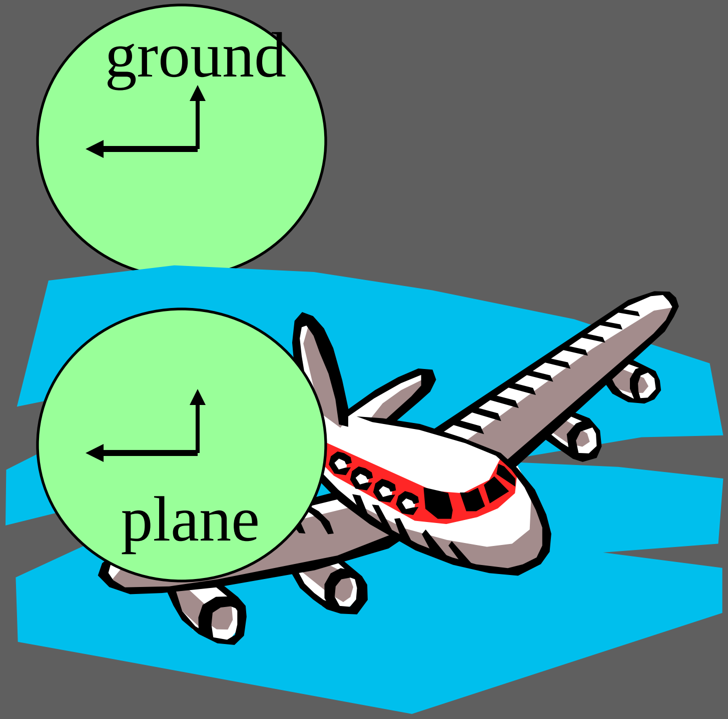
Yet, $T_{sally} > T_{sam}$

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

Time is not absolute! It is relative!

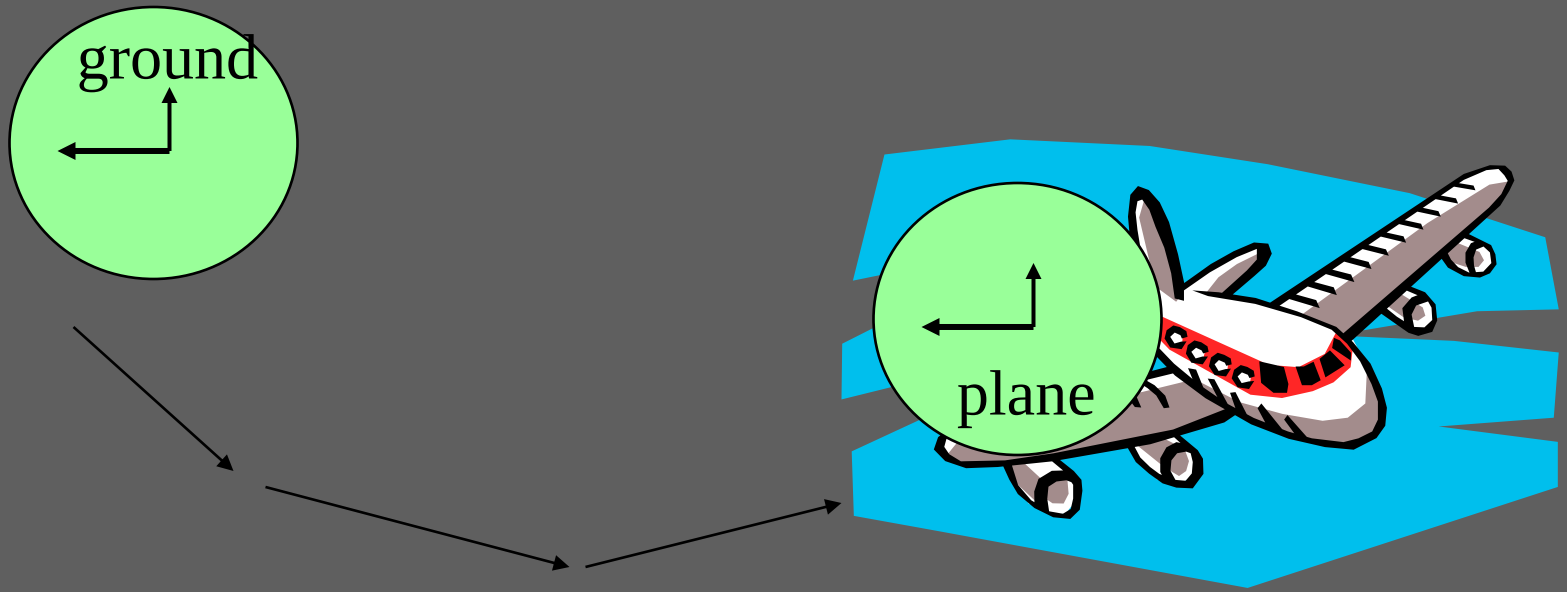
Can this be true??

Experiment says YES!

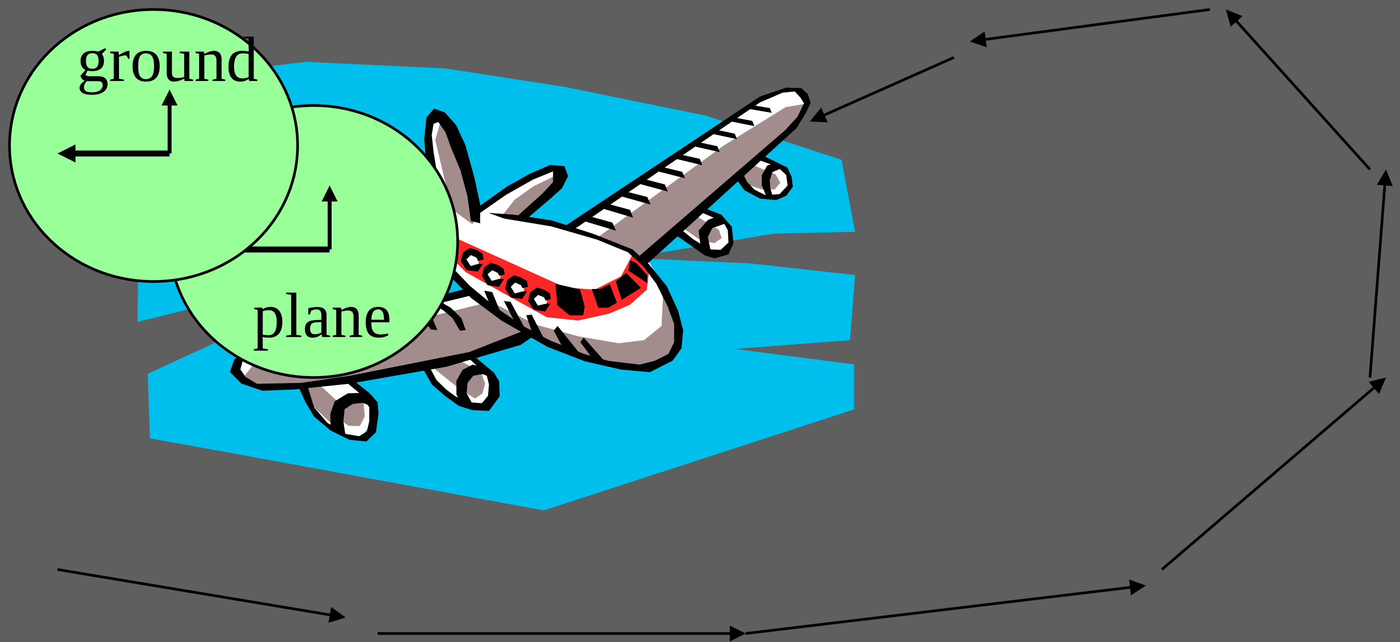


Can this be true??

Experiment says YES!



Less time elapsed on the clocks carried on the airplane



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

$\gamma > 1$

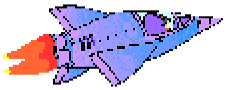
"Proper Time"

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

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

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

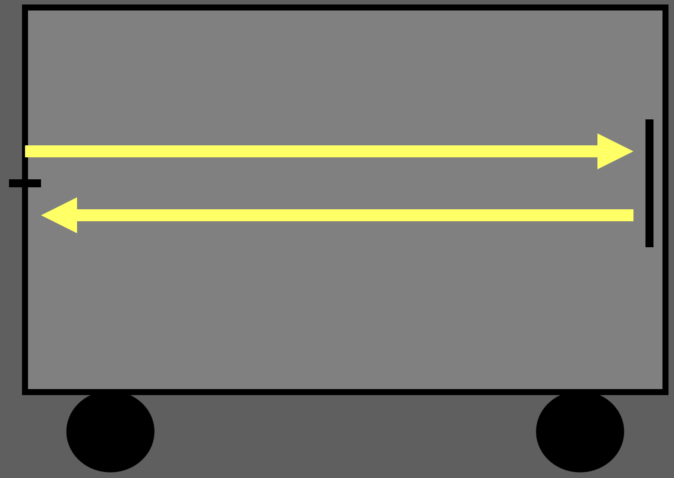
V=0.98c



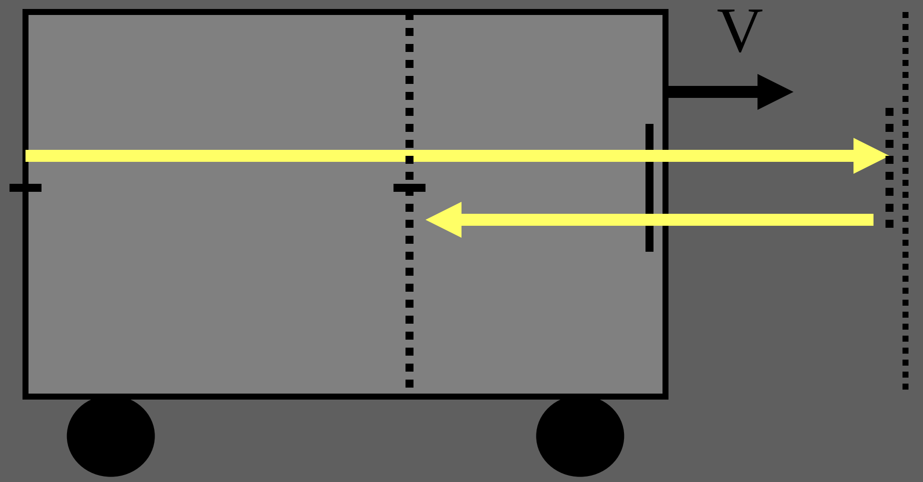
Lifetime=70 years on spaceship

Earth at rest

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



Measure the length of a boxcar where you are on the car.



Measure the length of a boxcar moving by you.

Length is relative, too!