Physics 102 - January 26, 2011

How did Mon. recitation go?

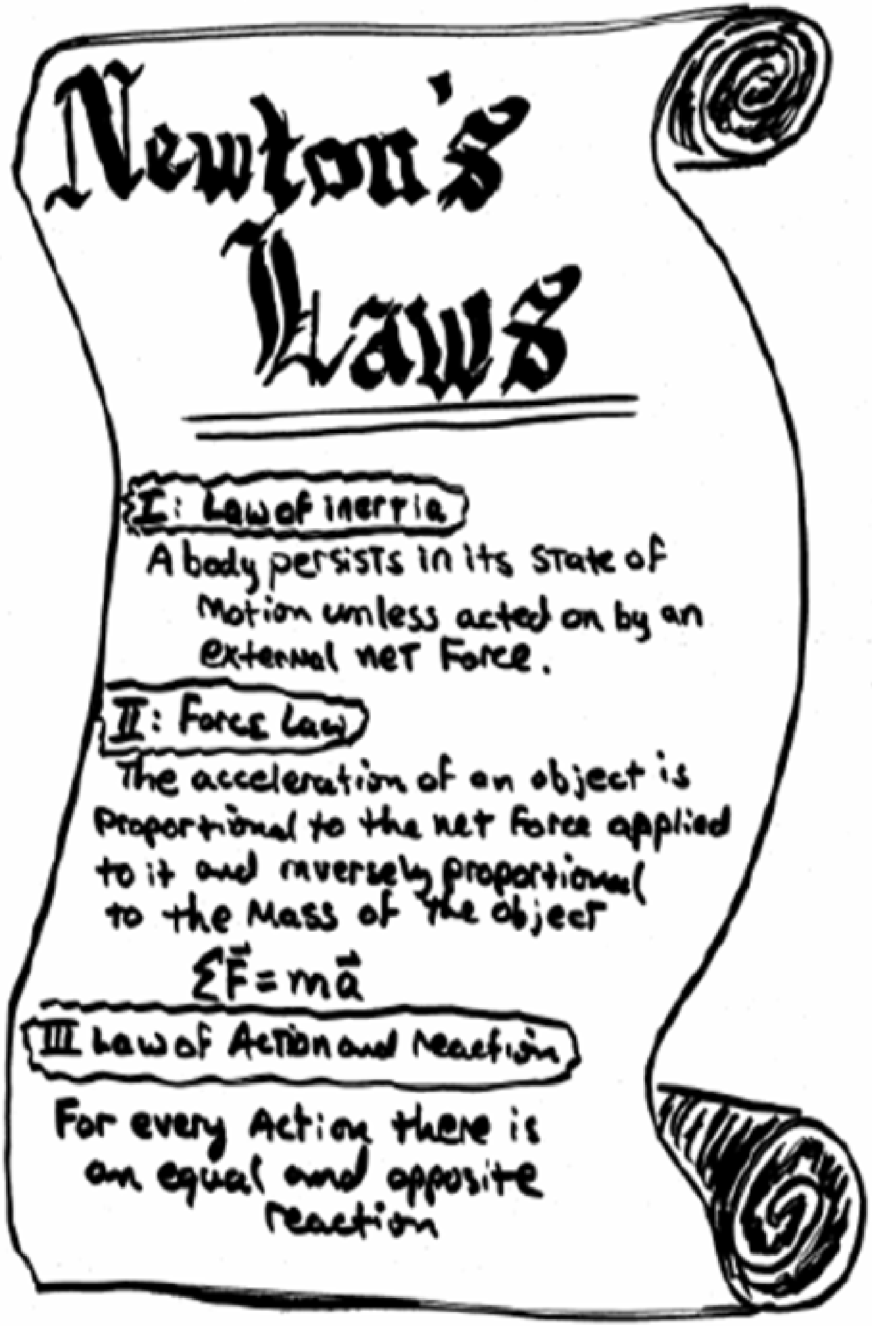
Reading is posted for this week

Last Time

Kinematic variables

$$x,\ v,\ a,\ t$$

$$\frac{\Delta x}{\Delta t} \qquad \frac{\Delta v}{\Delta t}$$



Newton's Laws

I: Law of inertia

A body persists in its state of Motion unless acted on by an external net Force.

II: Force Law

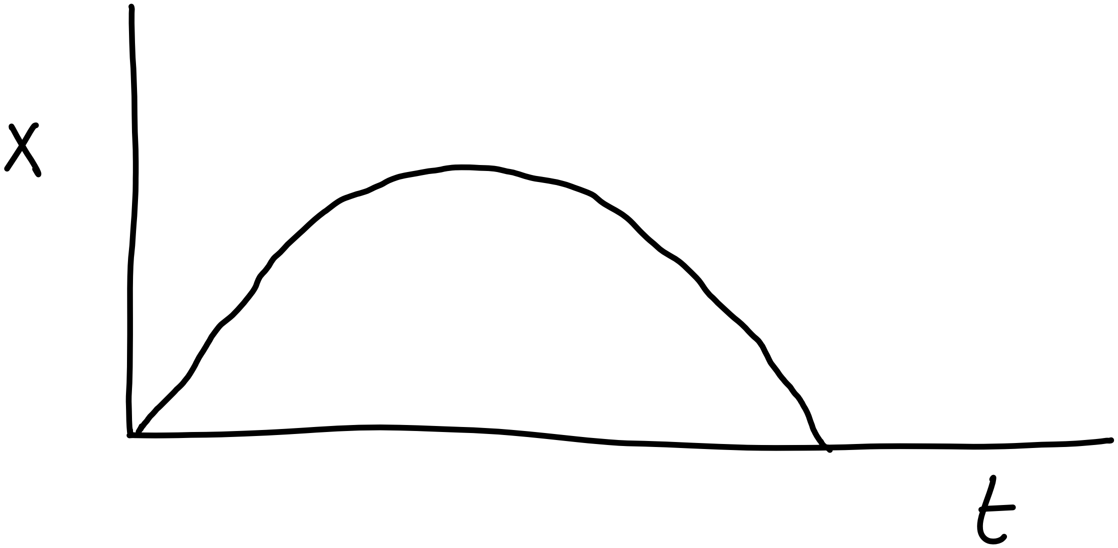
The acceleration of an object is Proportional to the net Force applied to it and inversely proportional to the Mass of the object

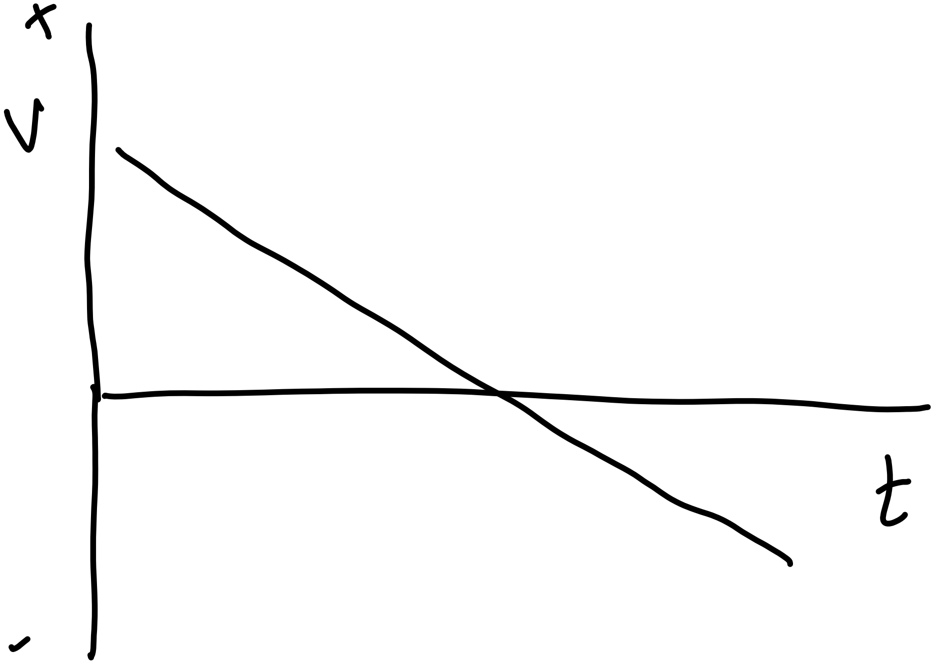
$$\sum \vec{F} = m\vec{a}$$

III Law of Action and Reaction

For every Action there is an equal and opposite reaction

What is a force?


x
t


+
v
-
t

Newton's Laws + Kinematical Defs

Inertia

F = ma

Action - reaction

x

$v = \Delta x / \Delta t$

$a = \Delta v / \Delta t$

Make calculations / predictions abt motion of objects under the influence of forces

$\boxed{\text{Deterministic Universe}}$

Relativity: the warping of space, time, and minds

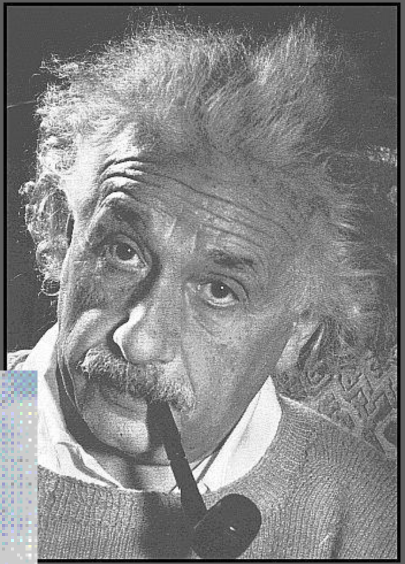
ANNALEN
DER
PHYSIK.

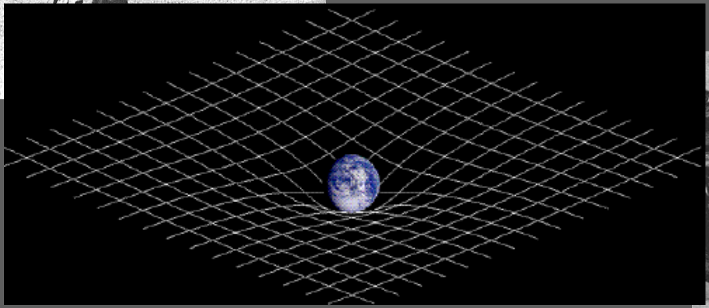
VIERTE FOLGE.

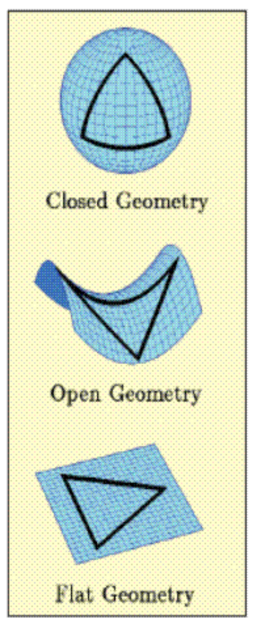
BAND 17.

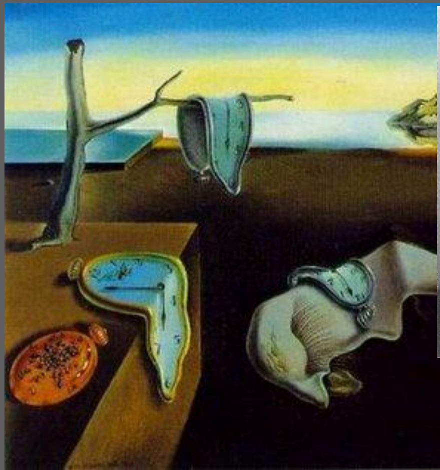
3. Zur Elektrodynamik bewegter Körper;
von A. Einstein.

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,

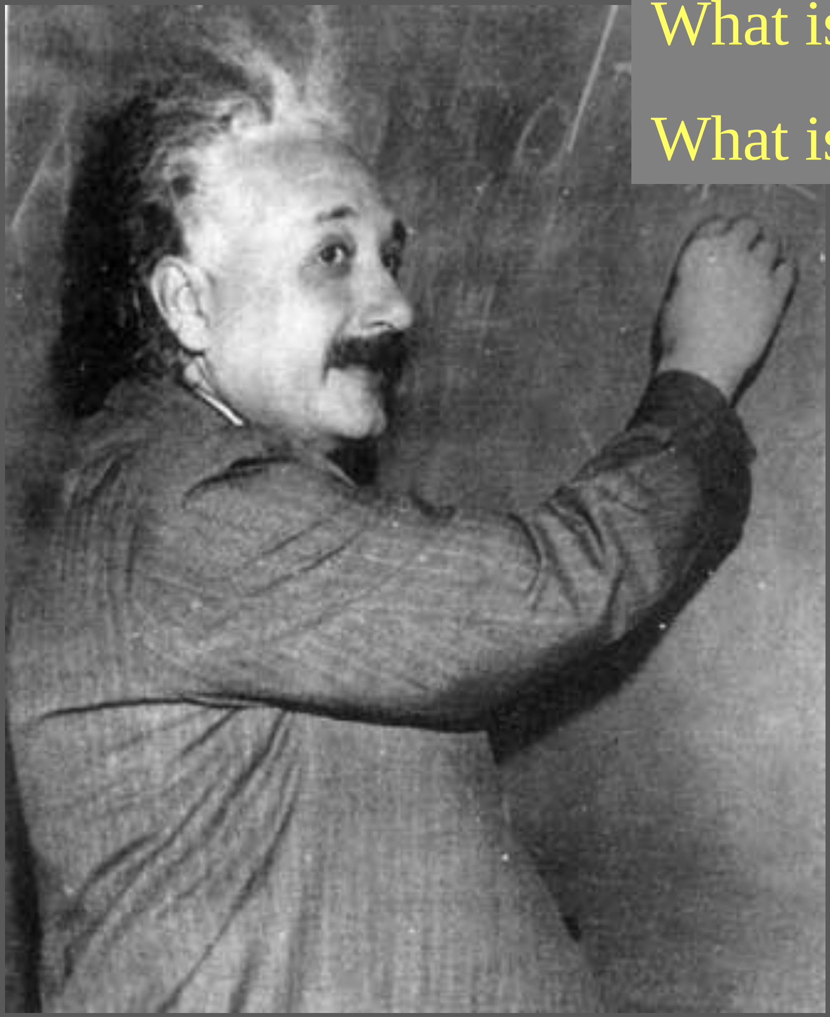








Steve Manly
Department of Physics and Astronomy
University of Rochester



What is time??

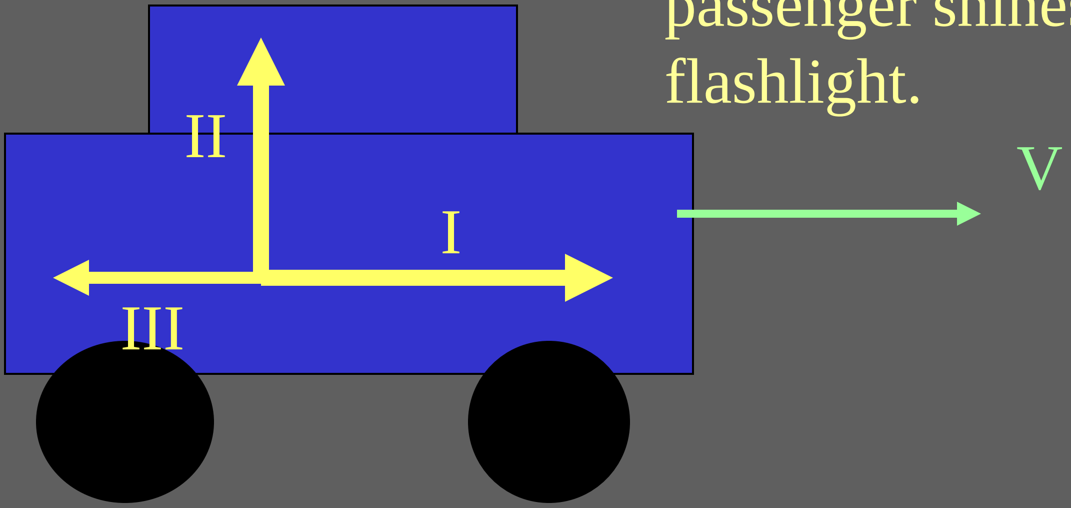
What is space??

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!!

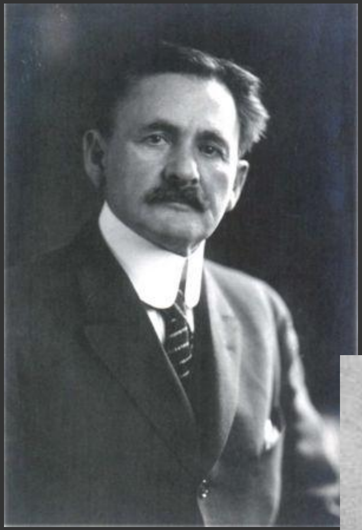
waves

Photo credit: Andrew Davidhazy

Michelson-Morley experiment

1881 – A.A. Michelson in Berlin

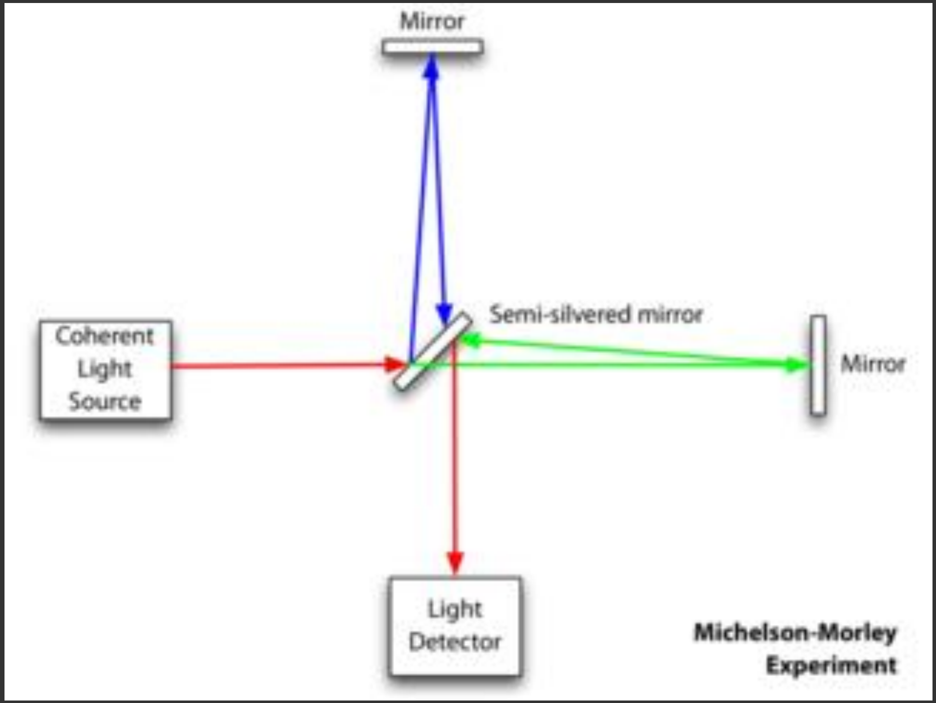
1887 - A.A. Michelson and E.W. Morley in US (Case Western)



1907 Nobel Prize in physics

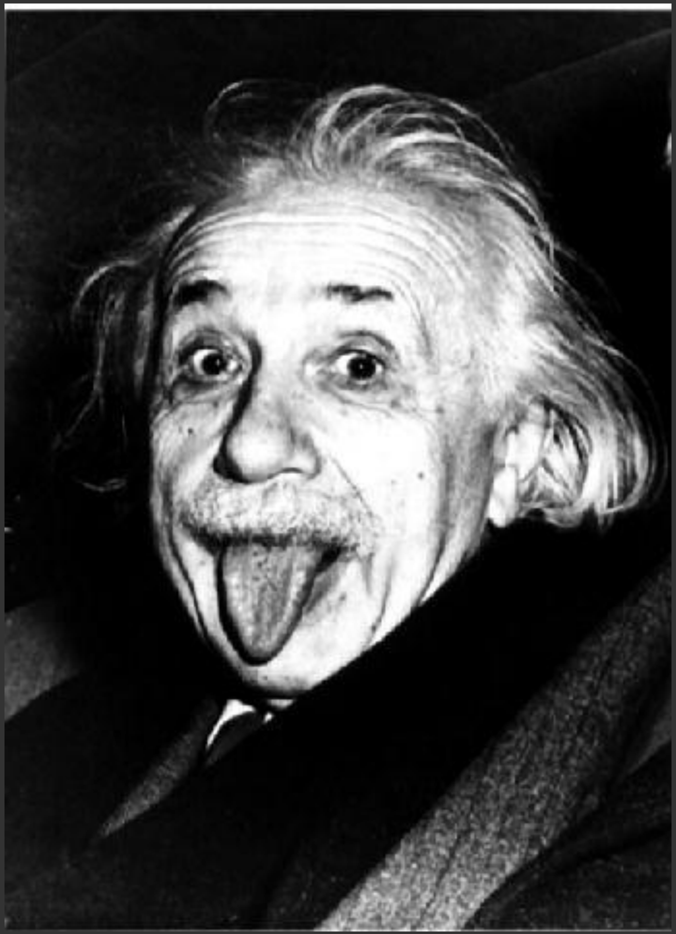
Michelson

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

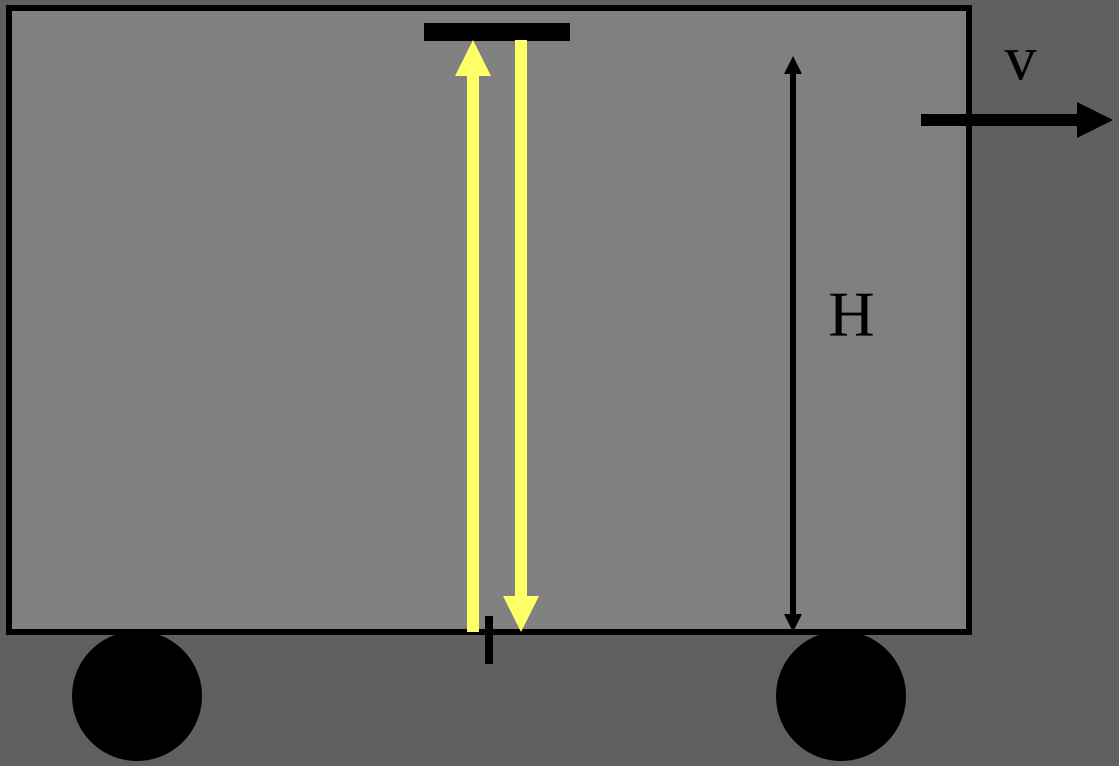
2) Physics is the same in all inertial reference frames

Point of view of observer

Moving at constant speed

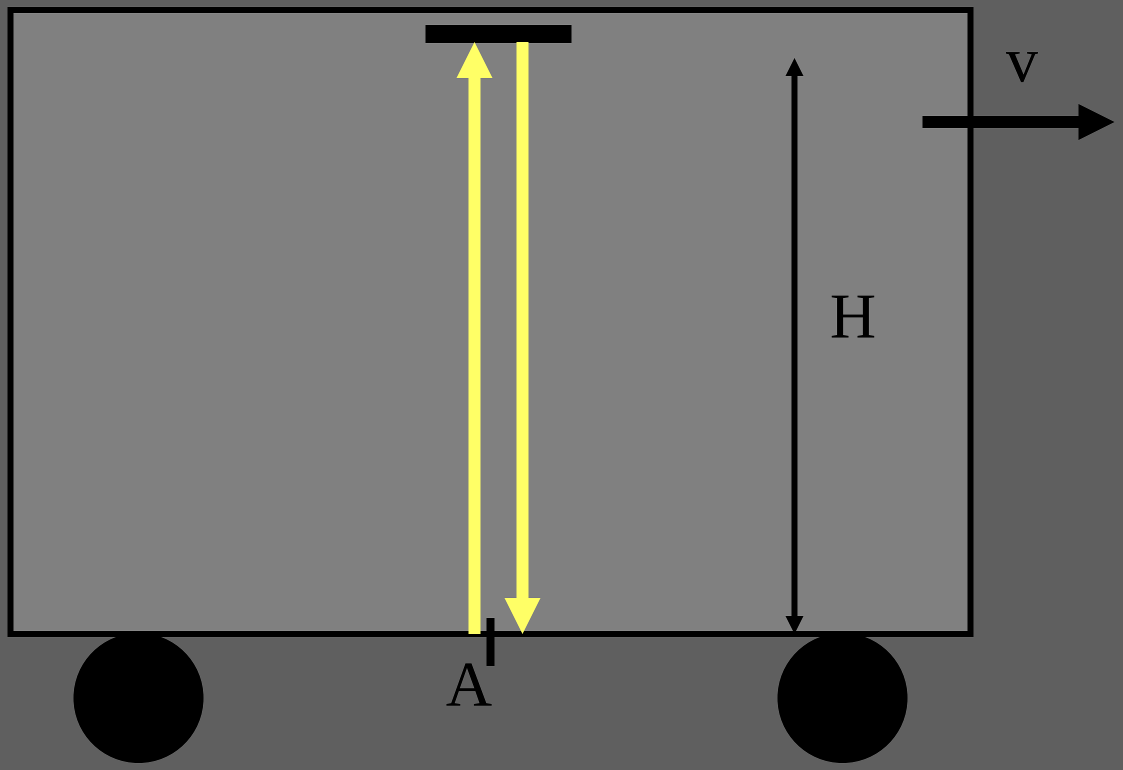
Einstein thought experiment:

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.

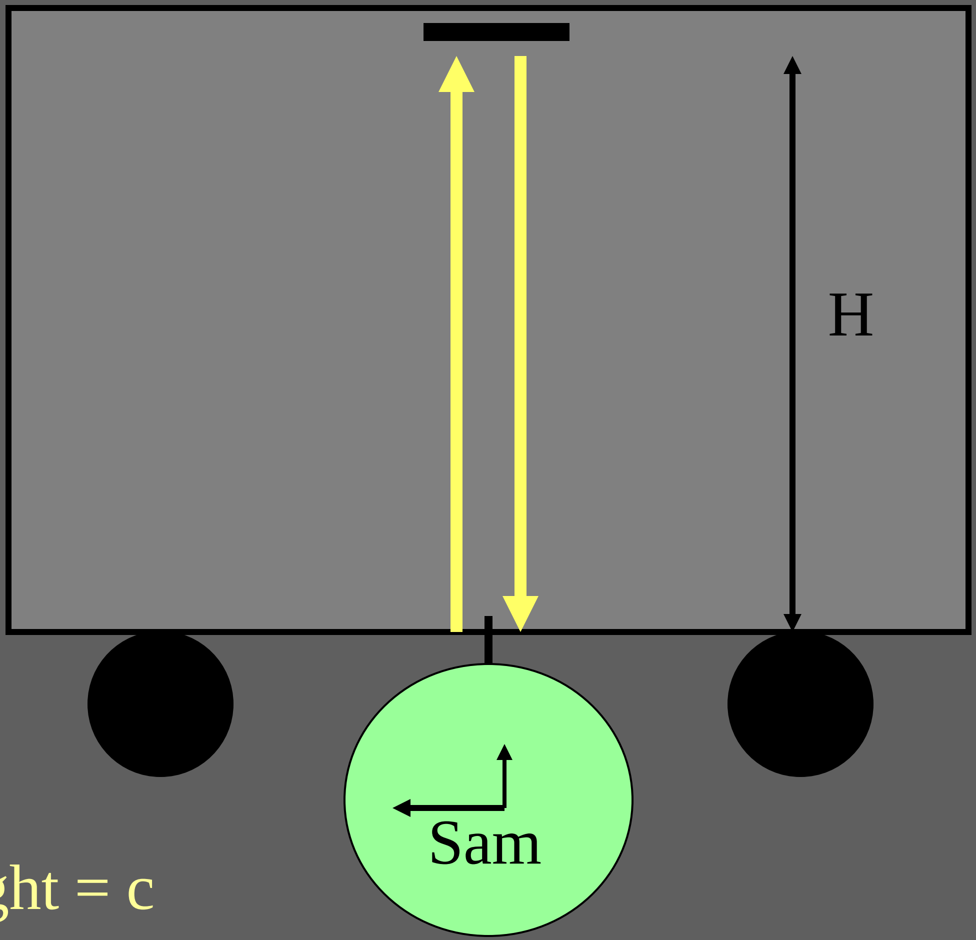


Fact: Light is emitted and detected at point A.

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



Sam is on the train



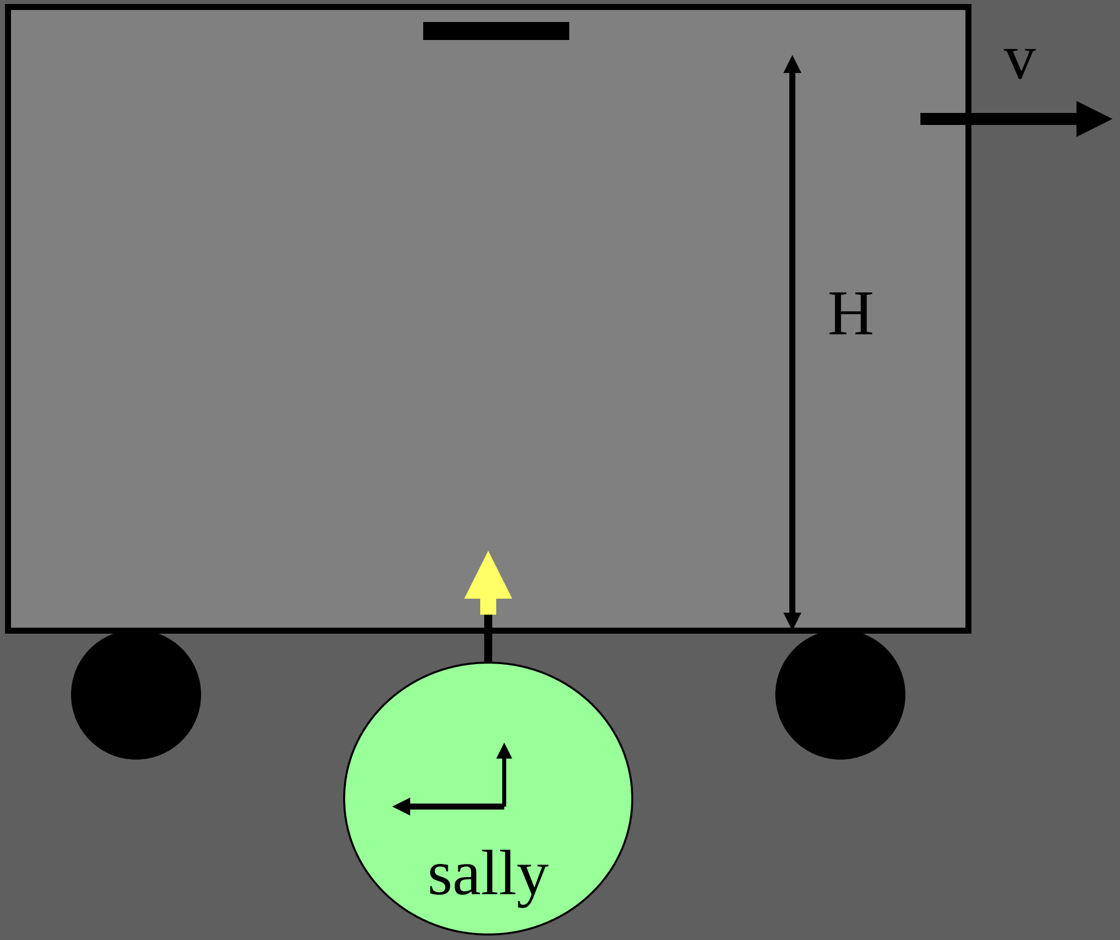
Velocity of light = c

c = distance/time

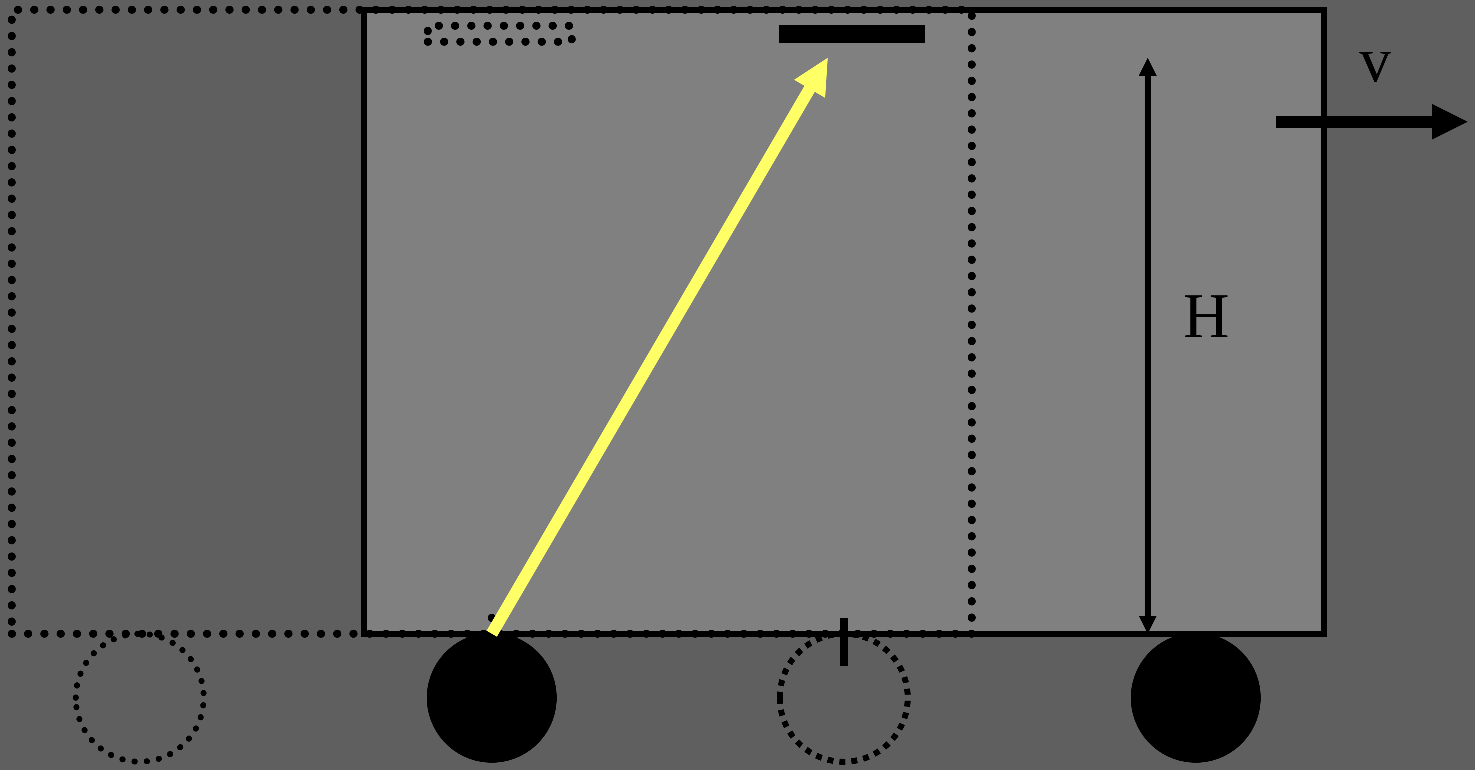
$c = 2H/T_{sam}$

$T_{sam} = 2H/c$

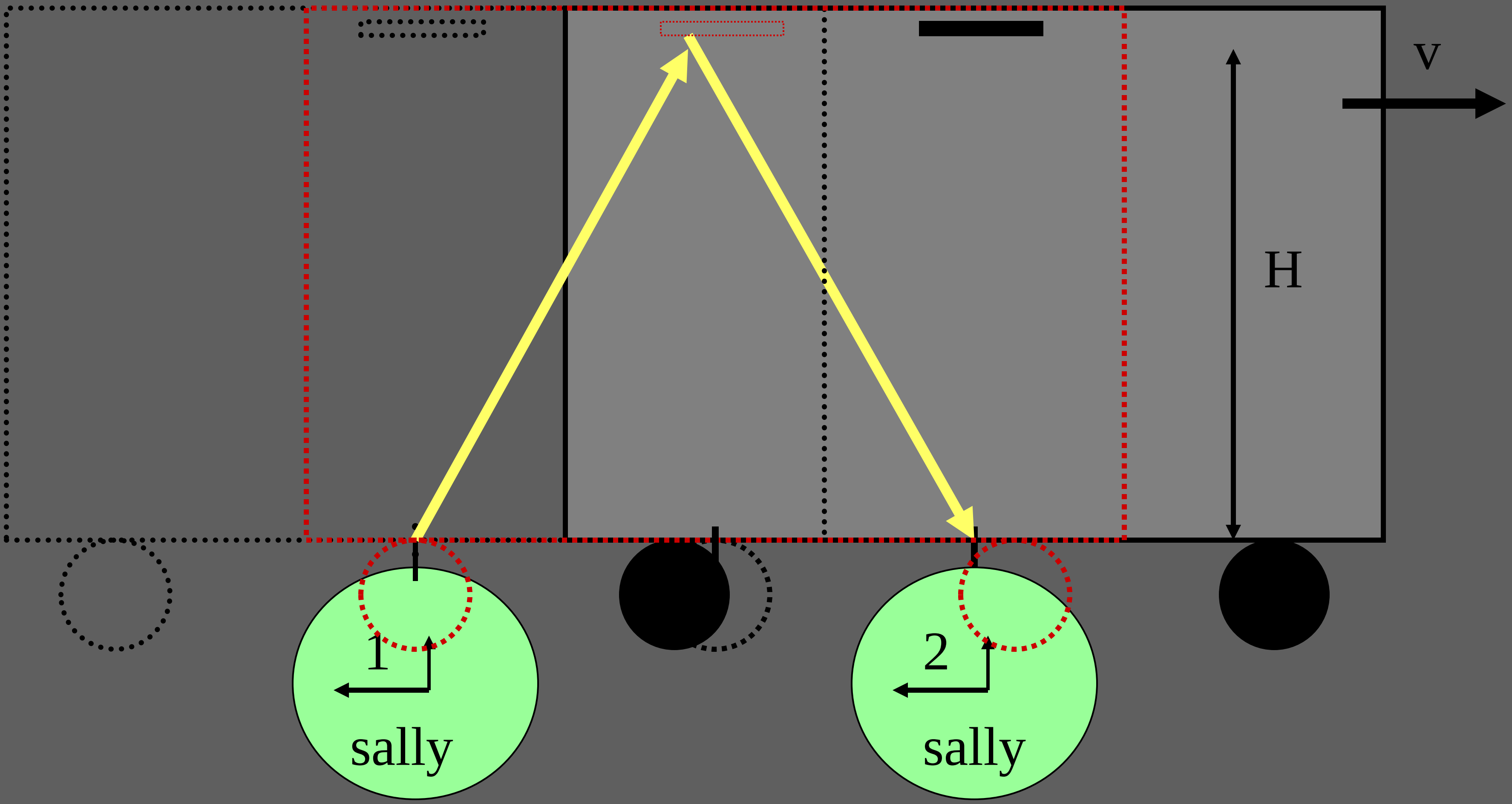
Sally watches the train pass and makes the same measurement.



Light is emitted

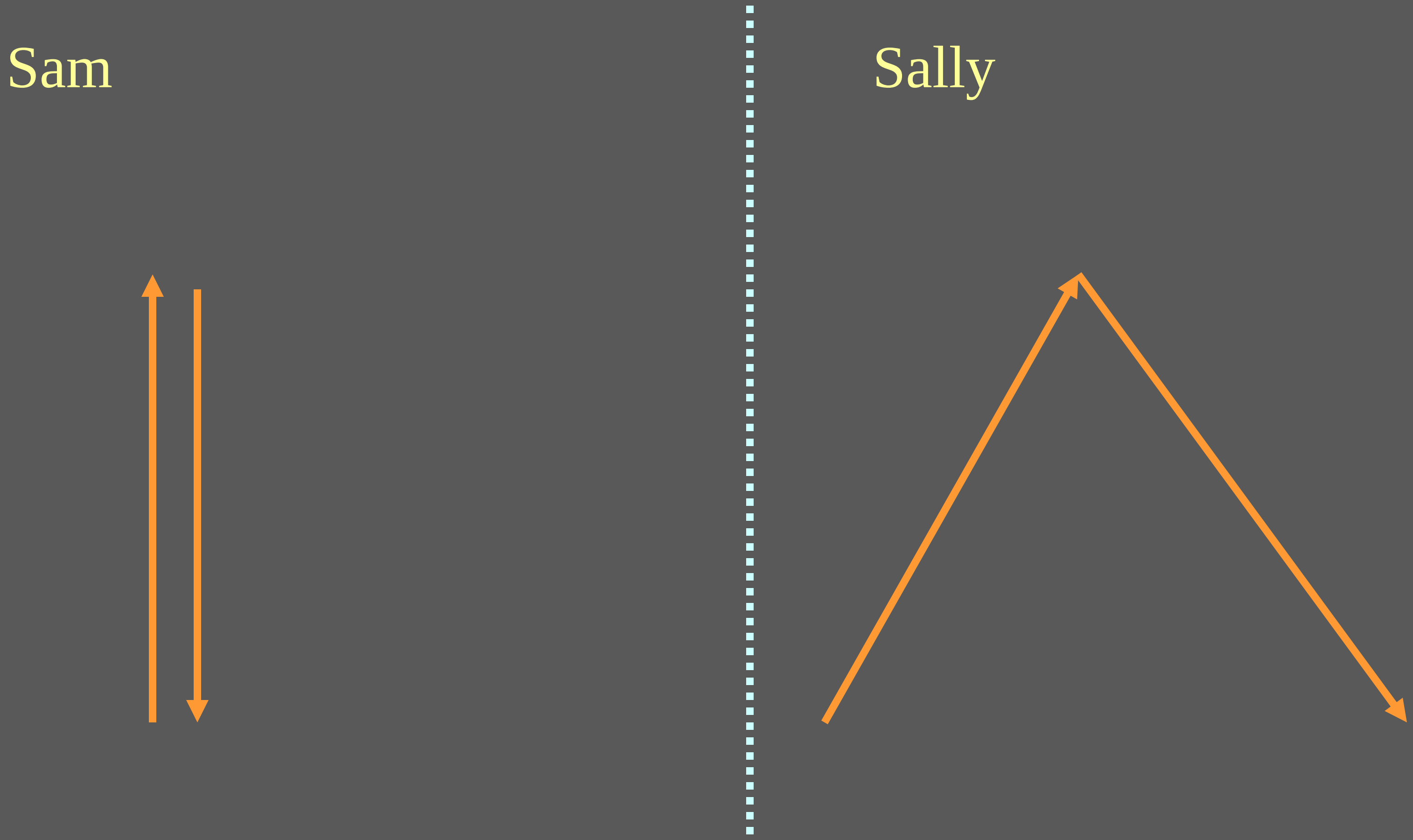

v
H

Sally is standing still, so it takes two clocks.



Light is emitted

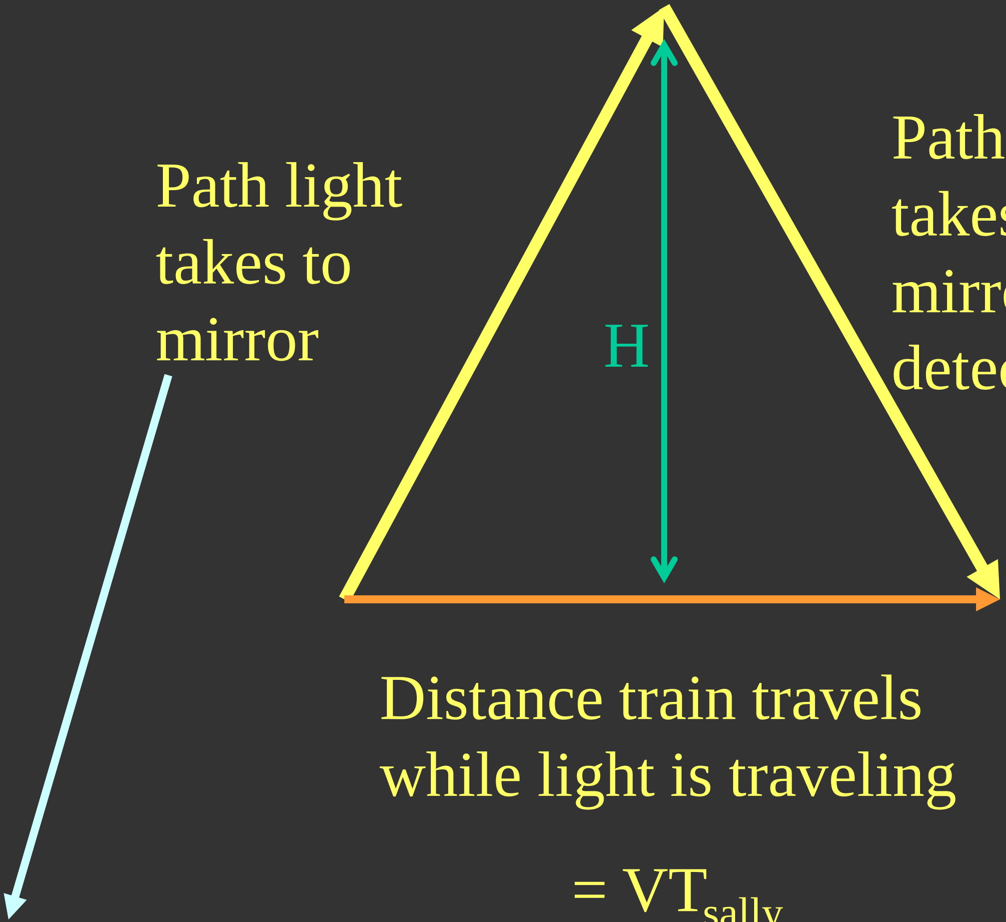
Light returns



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



Path light takes to mirror

Path light takes from mirror to detector

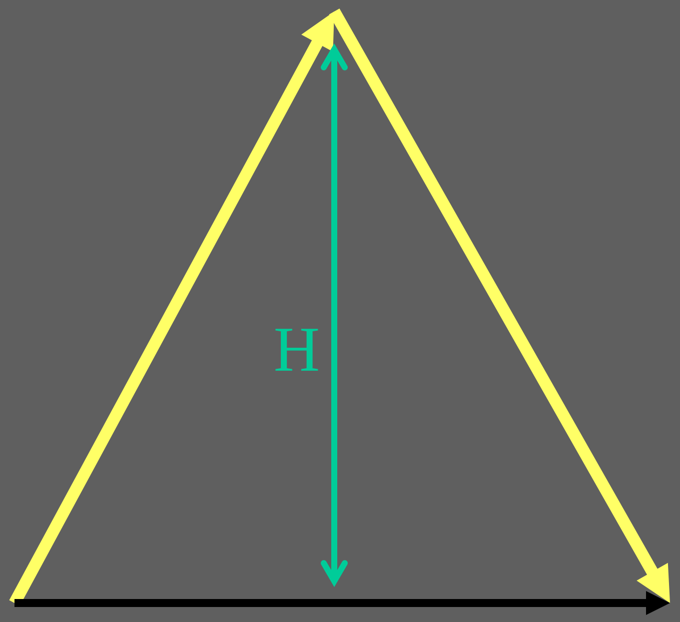
Distance train travels while light is traveling

$= VT_{sally}$

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

Makes use of Pythagorian theorem

From Sally’s point of view



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

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

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$_{\text{sam}}$ = c or 2H=cT$_{\text{sam}}$

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

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

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.

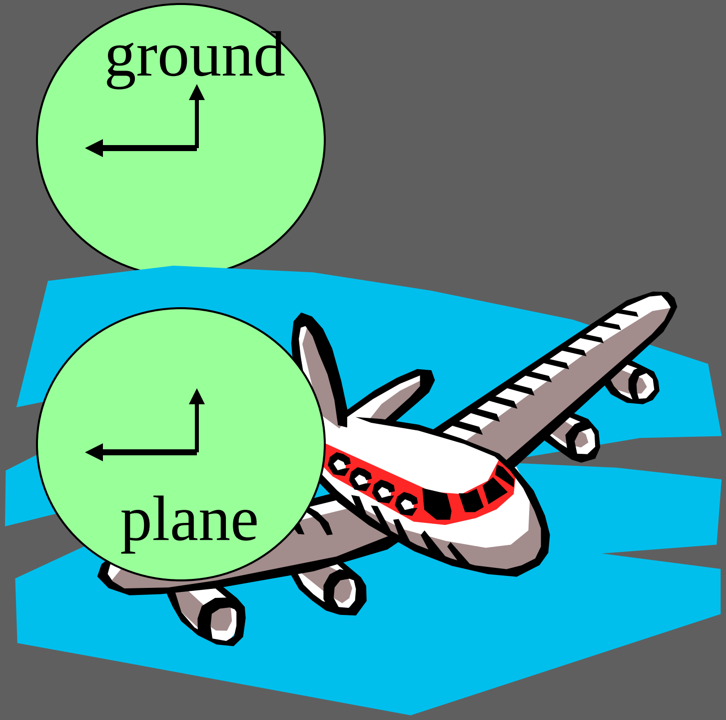
Yet, $T_{sally} > T_{sam}$

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

Time is not absolute! It is relative!

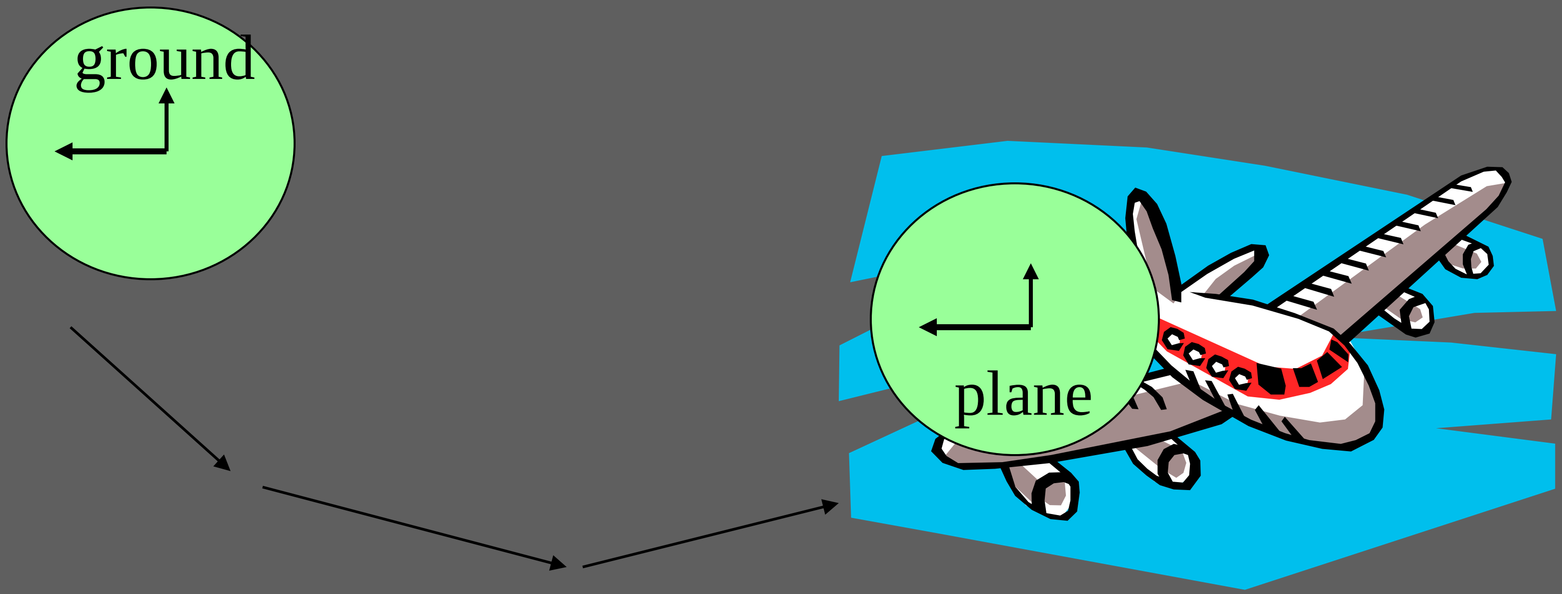
Can this be true??

Experiment says YES!

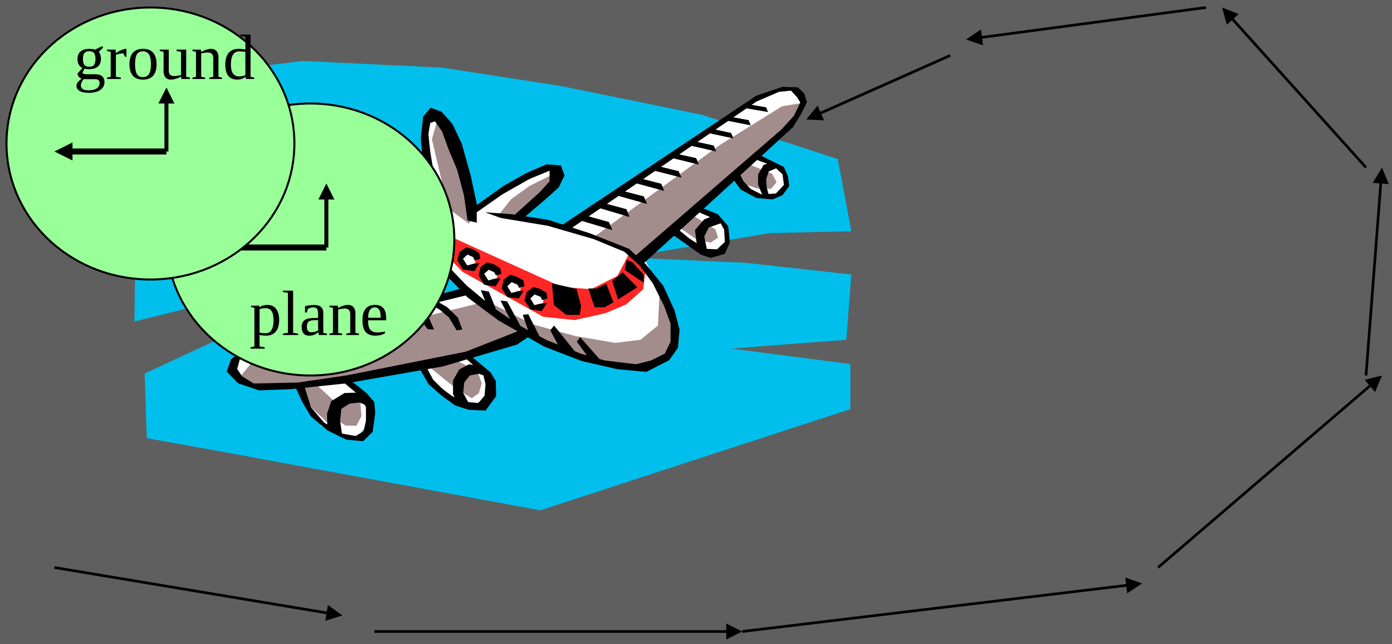


Can this be true??

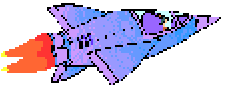
Experiment says YES!



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?

$$t_{earth} = \overbrace{\frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}}}^{\gamma > 1} \underbrace{t_{spaceship}}_{\text{"Proper Time"}}$$

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

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

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