

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 Proton

gravitational field

At each point in space

gravitational Force
mass

(Magnitude + direction)

that would be felt by
a little test mass at
that point



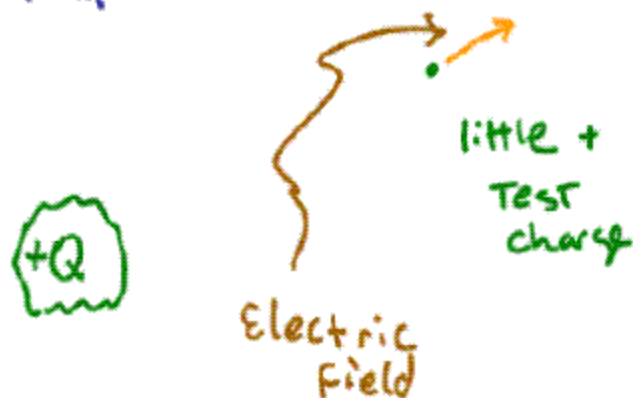
Electric field

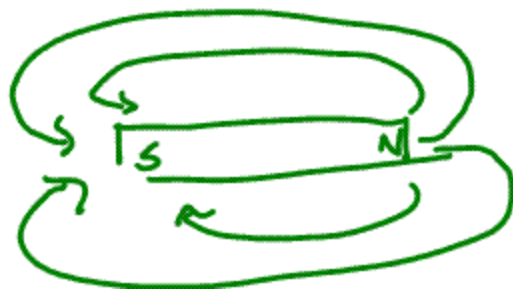
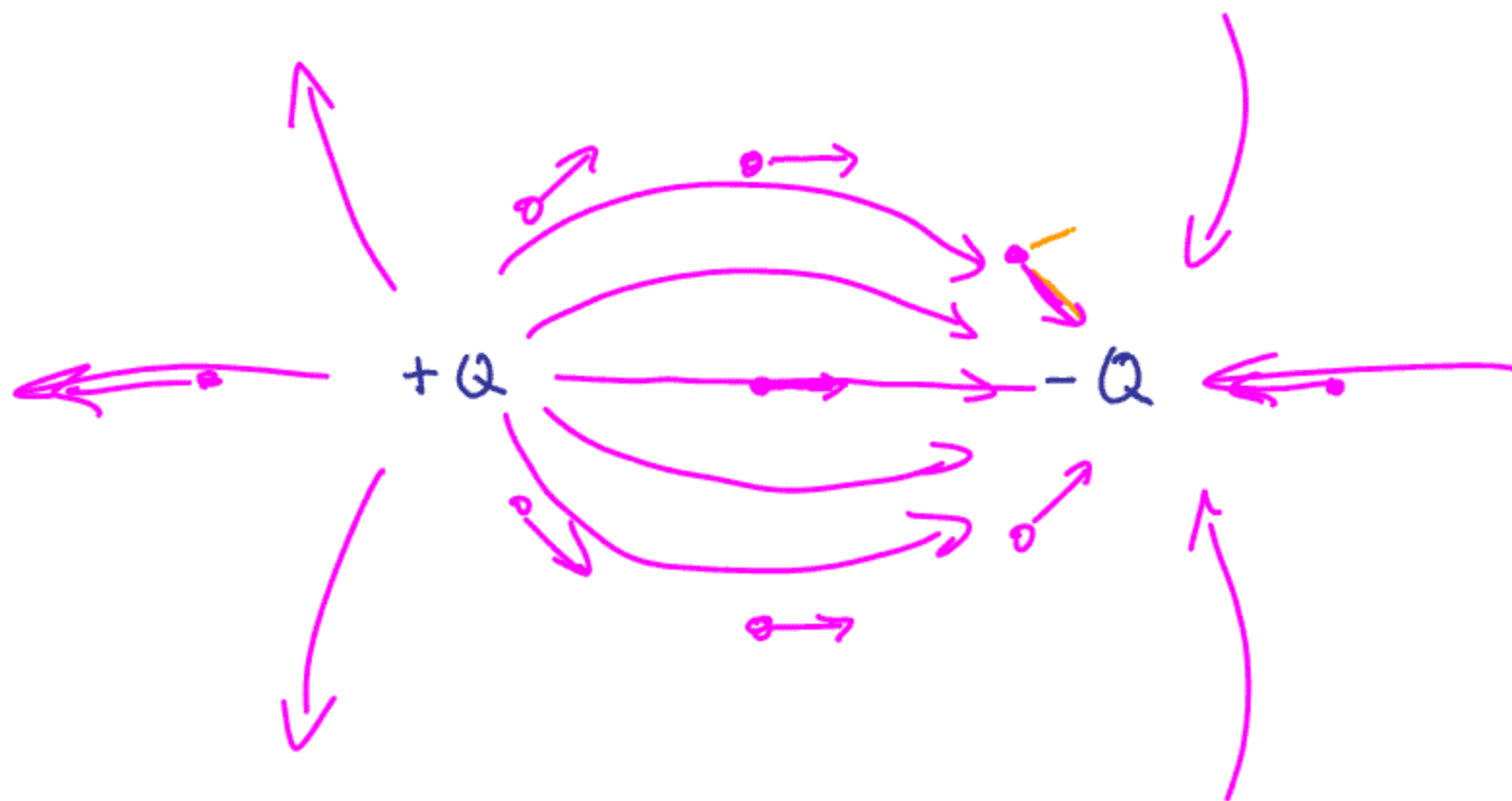
At each point in space

Electric Force
charge

(Magnitude + direction)

that would be felt by
a little + test charge at
that point





ANNALEN
DER
PHYSIK.

Handbook for International Users

VIERTHE FOLGE.

BAND 17.

BAND 10

WILSON THOMAS

MEMBERS:
F. KOHLRAUSCH, M. PLANCK, G. QUINCKE,
W. C. HÖNIGSMANN, E. WARBURG.

OTHER NETWORKS

VEREINIGTE DEUTSCHE
DER DEUTSCHEN PHYSIKALISCHEN GESELLSCHAFT

THE UNIVERSITY OF CHICAGO

MR. PLATON

1994-1995

PAUL DEUDE.

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED



LEITING, 1991

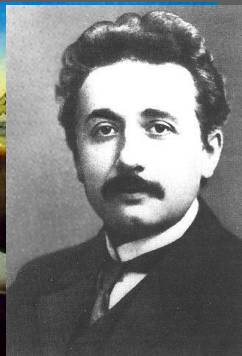
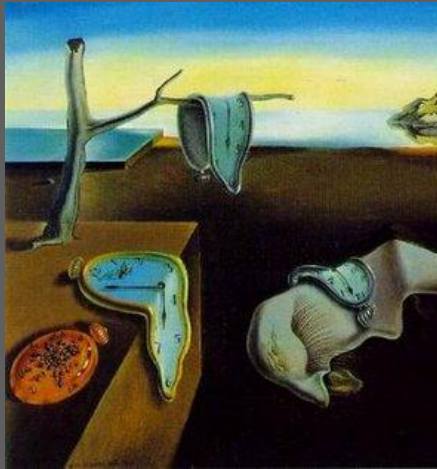
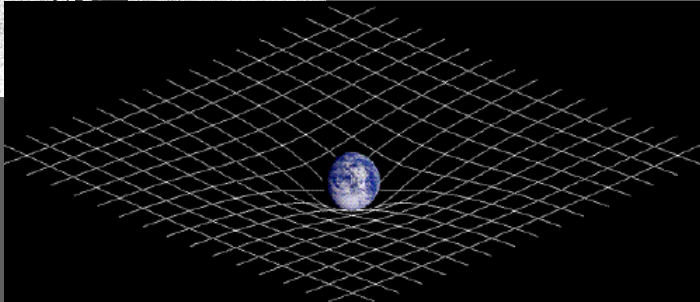
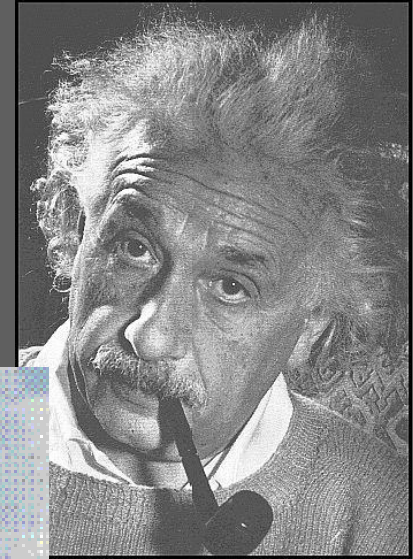
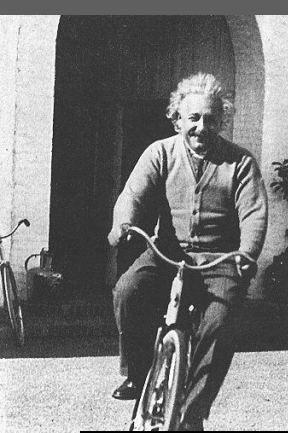
LEIPZIG, 1970.
VERLAG VON JOHANN AMERONGUS FARTH.

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

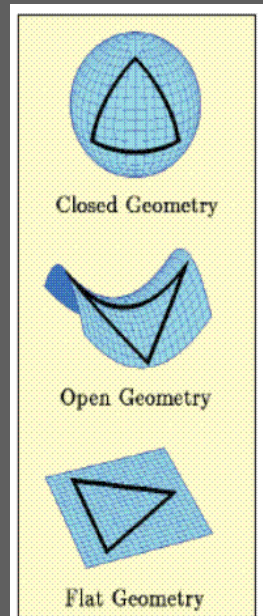
Daß die Elektrodynamik Maxwells — wie dieselbe gegenwärtig aufgestellt zu werden pflegt — in ihrer Anwendung auf bewegte Körper zu Asymmetrien führt, welche den Platonismus nicht anerkennen scheinen, ist bekannt. Mit demselben z. B. an der elektrodynamischen Wechselwirkung zwischen einem Magneten und 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 umgibt der Leiter, so entsteht in der Umgebung des Magneten ein elektrisches Feld von gewissem Energiewerte, welches an dem Orte, wo sich Teile des Leitens befindet, einen Strom erzeugt. Ruht aber der Magnet und bewegt sich der Leiter, so entsteht in der Umgebung des Magneten kein elektrisches Feld, bewegen sich Leiter und Magnet zusammen, so entsteht auch keine Energie ausgetauscht, die aber — Gleichwohl der Relativbewegung bei den beiden ins Auge gefaßten Betrachtungen — zu elektrischen Strömen von derselben Maß der elektrischen Verspannung gibt, wie im ersten Fall. Solches ist die erste.

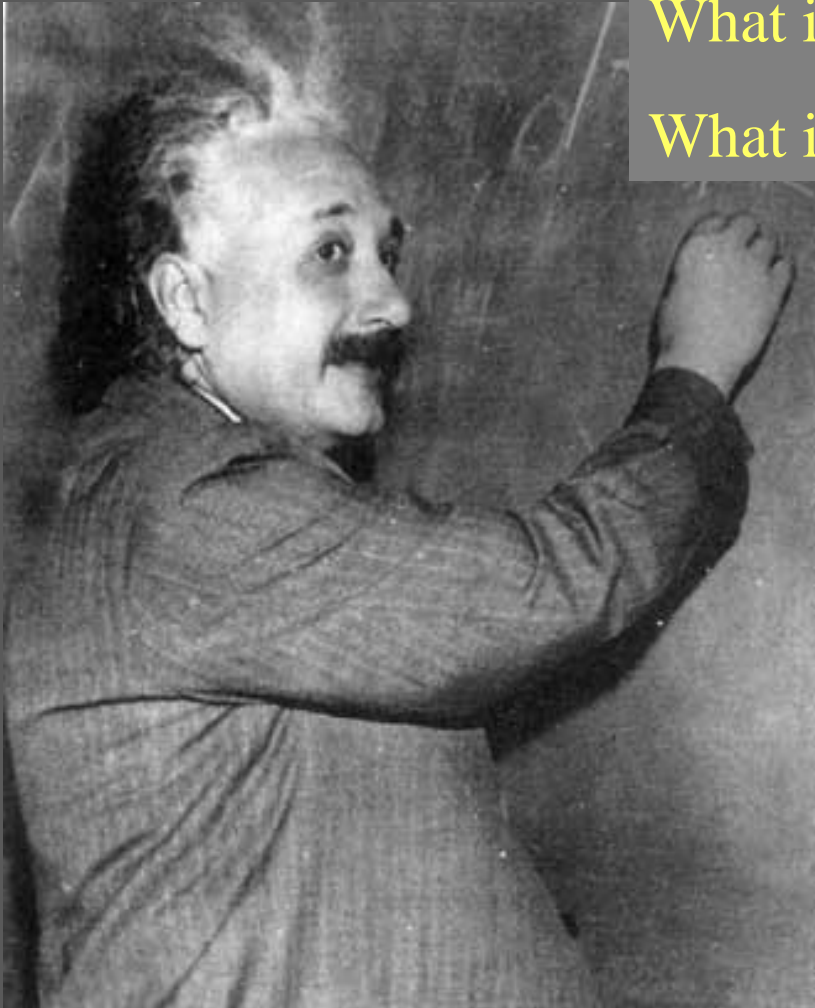
Die mechanische Art, sowie die massigenen Verhältnisse der Bewegung der Erde relativ zum „Lichtmedium“ zu betrachten, führen zu der Vermutung, daß das Begriffe der Dynamik nicht nur in der Mechanik, sondern auch in der Elektrodynamik keine Eigenschaften der Erscheinungen enthalten, sondern daß vielmehr für alle Koordinatensysteme, welche die mechanischen Gleichungen gelten, auch die elektrodynamischen und optischen Gesetze gelten, wie es die ersten ersten Ordnung bereits erweisen ist. Wir können diese Vermutung (deren Inhalt im folgenden „Prinzip der Relativität“ genannt werden wird) zur Voraussetzung annehmen, indem die Zeit dann nur scheinbar unterschiedlich

Relativity: the warping of space, time, and minds



Steve Manly
Department of Physics and Astronomy
University of Rochester





What is time??

What is space??

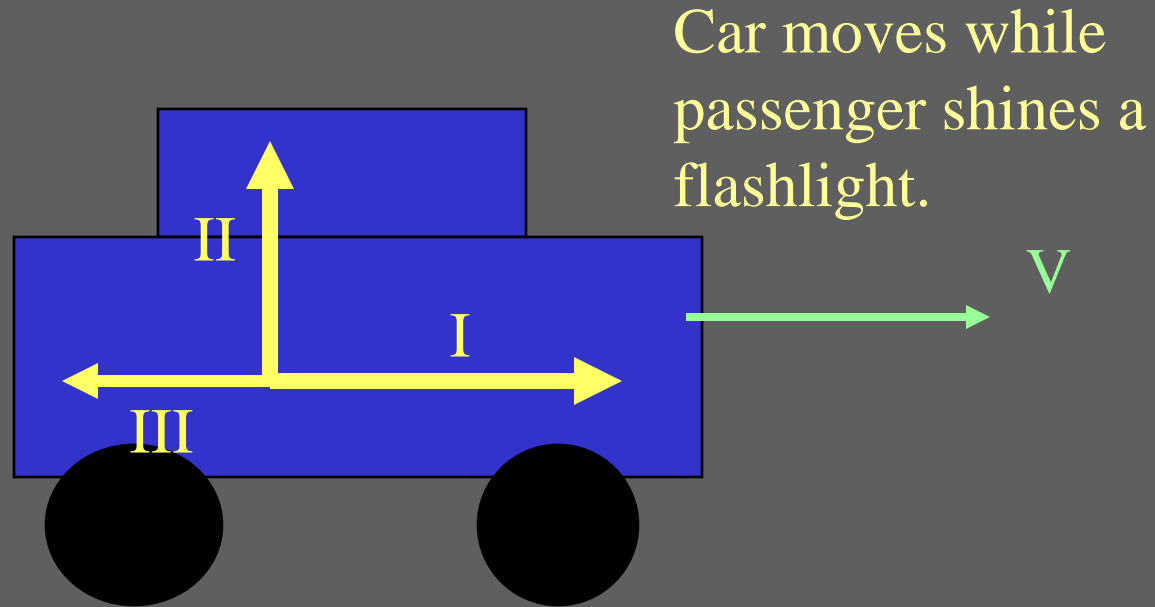


Speed with respect to you is 4 mi/hr



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?



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)

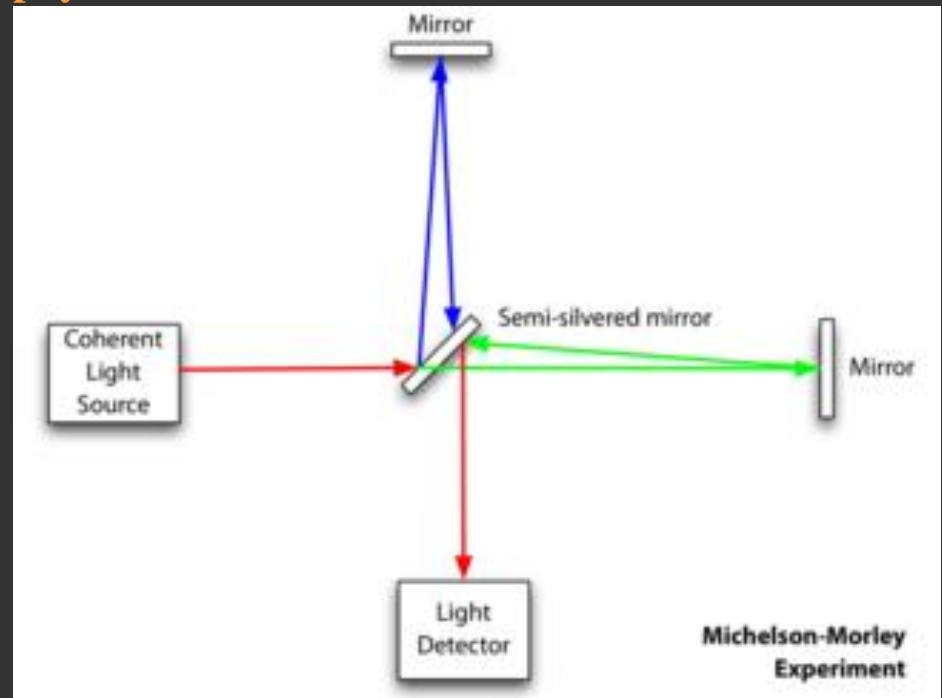


1907 Nobel Prize in physics

Michelson

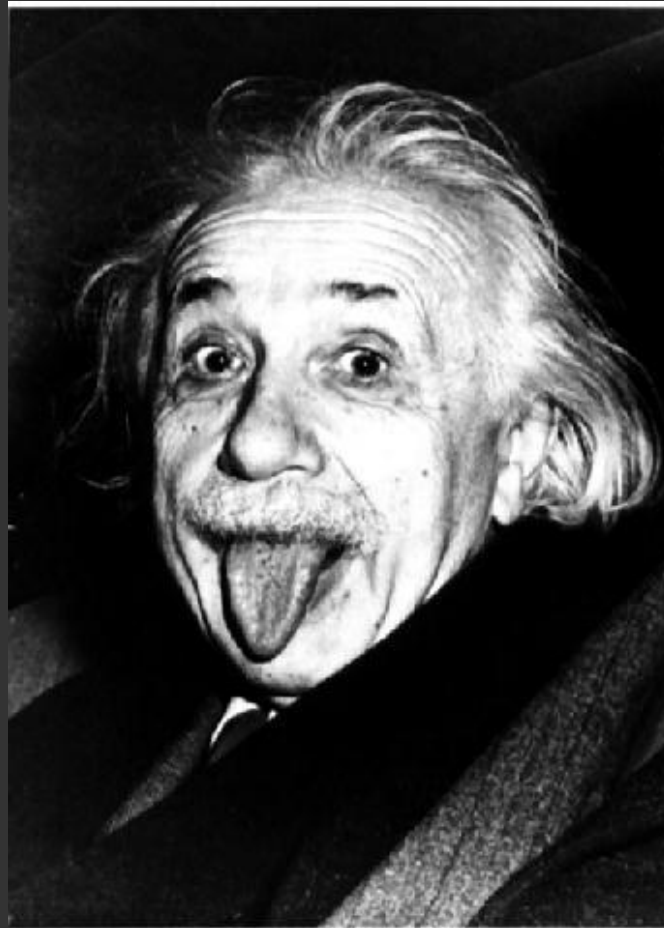


Morley



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

Moving at constant speed

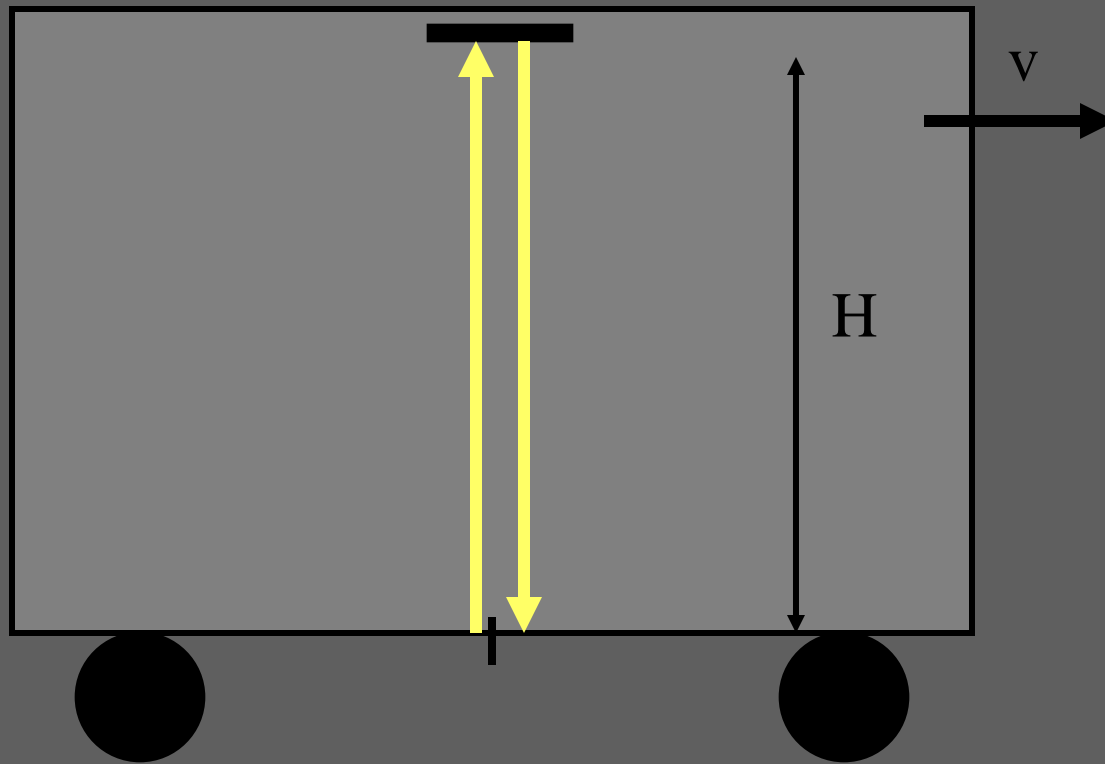


Point of view of observer



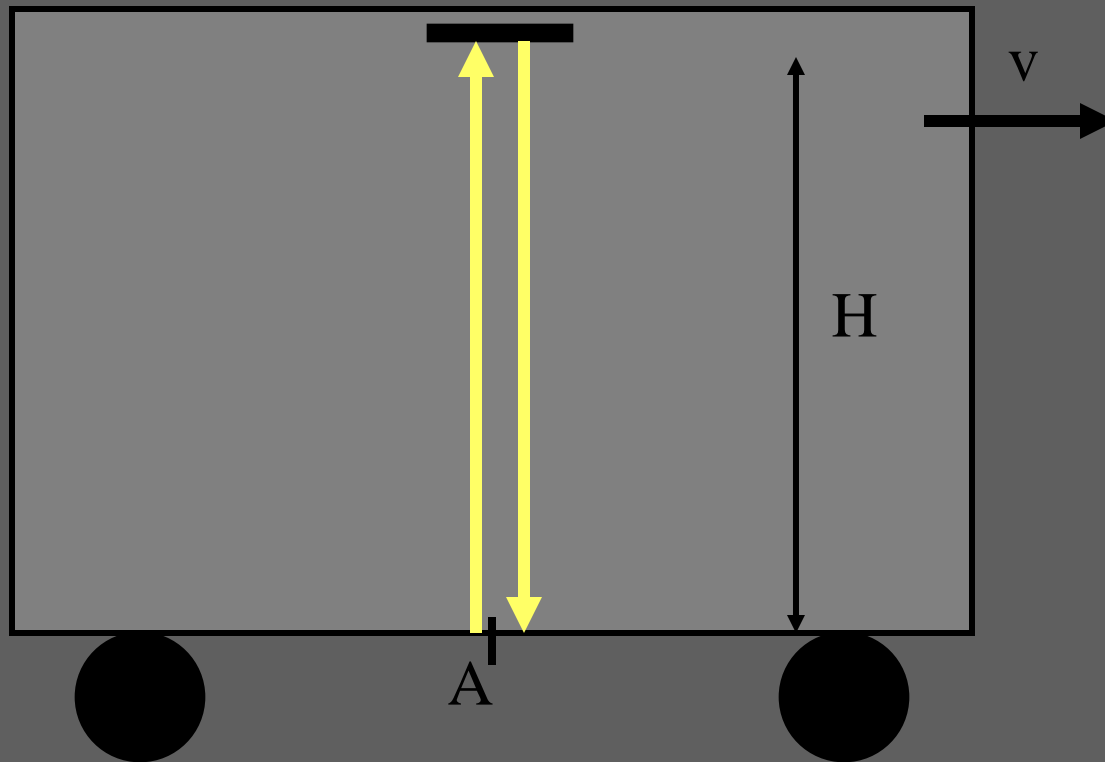
Einstein thought experiment:

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.

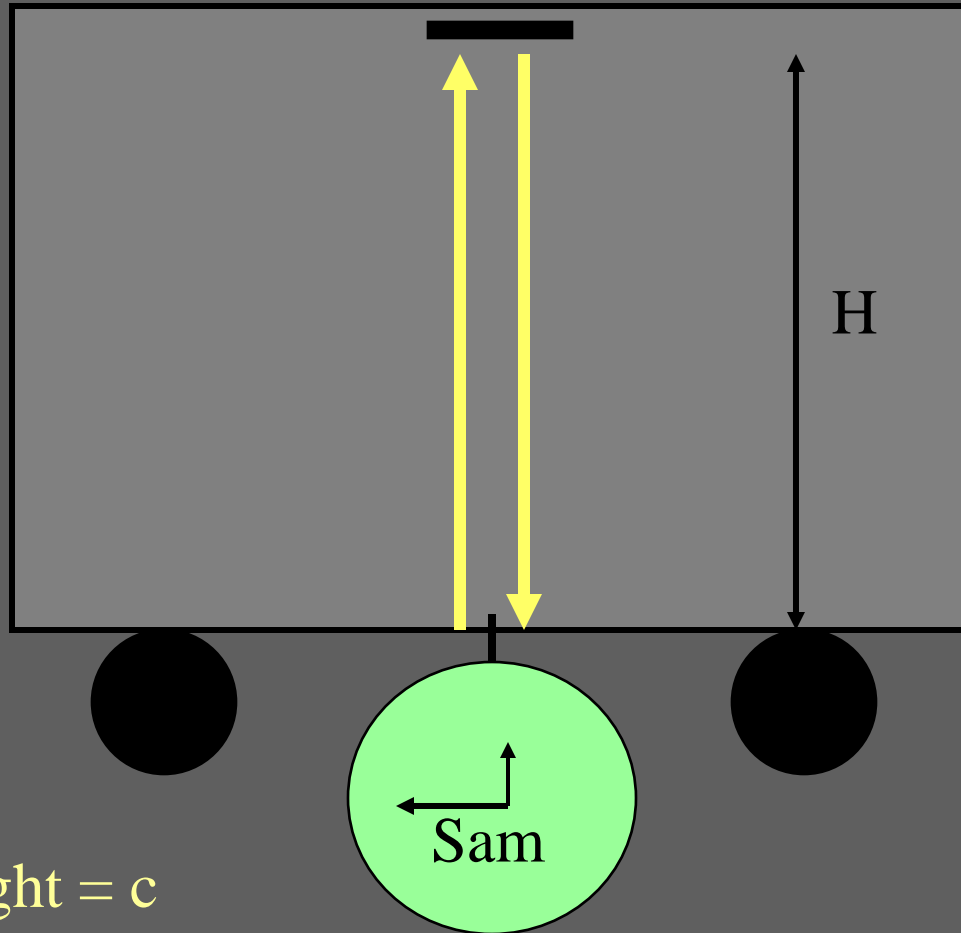


Fact: Light is emitted and detected at point A.

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



Sam is on the train



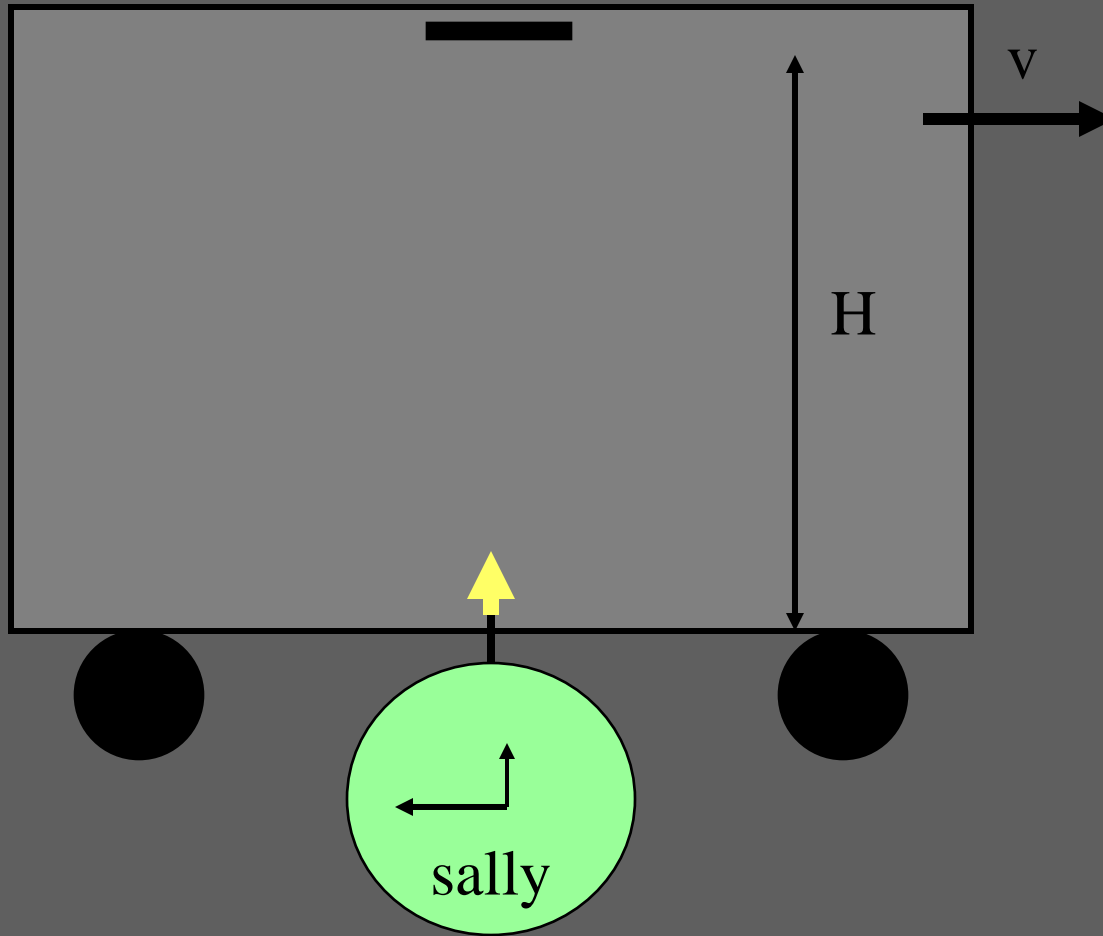
Velocity of light = c

$c = \text{distance}/\text{time}$

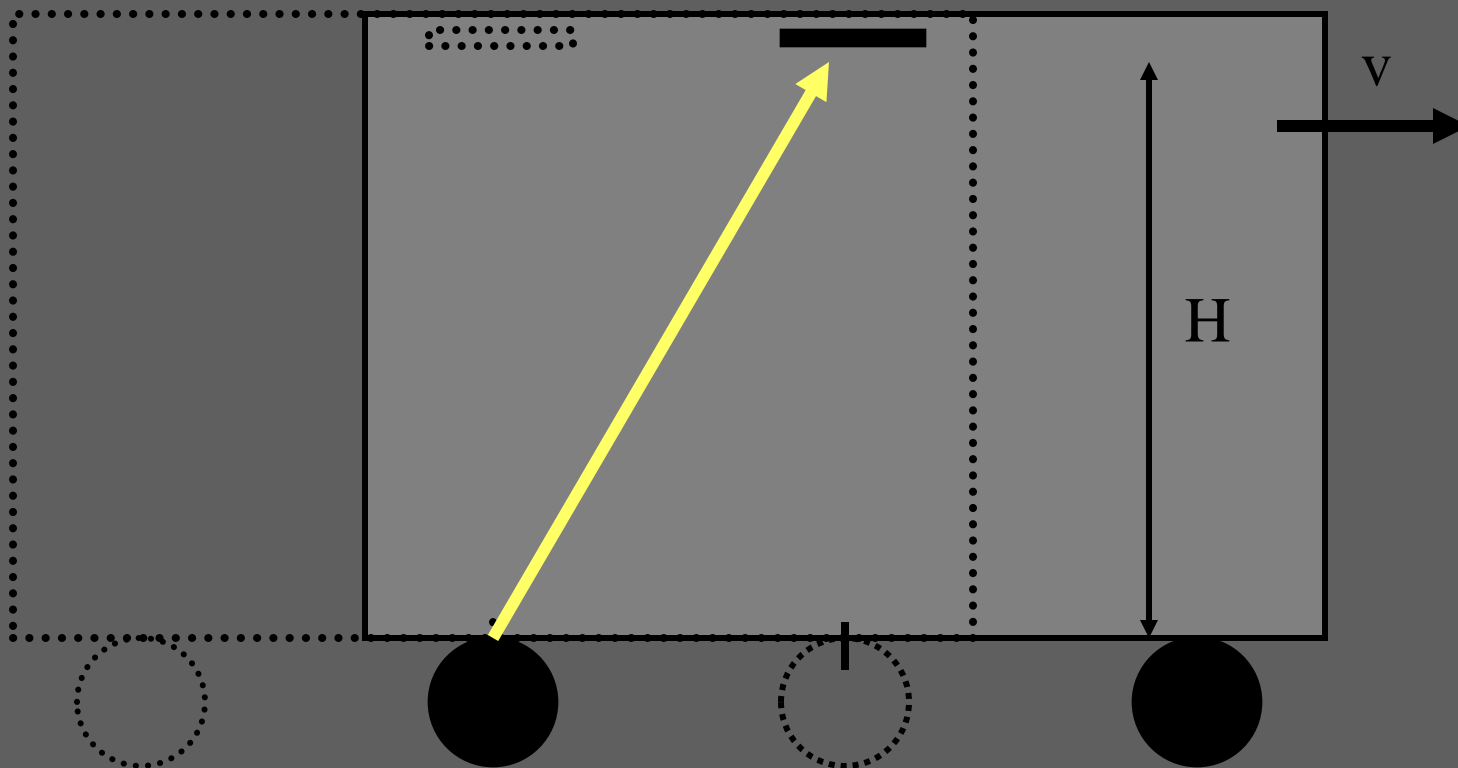
$c = 2H/T_{\text{sam}}$

$T_{\text{sam}} = 2H/c$

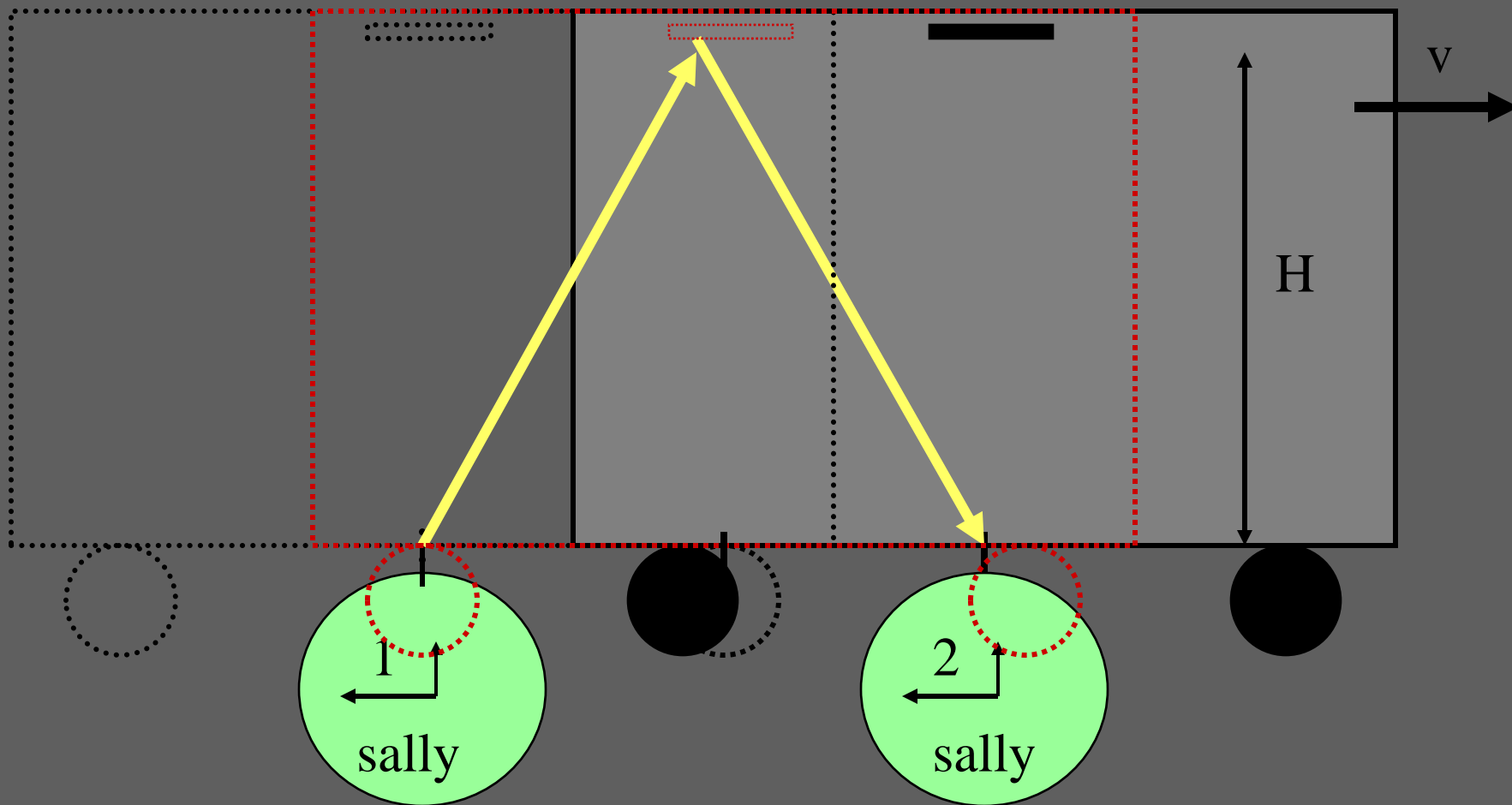
Sally watches the train pass and makes the same measurement.



Light is emitted



Sally is standing still, so it takes two clocks.



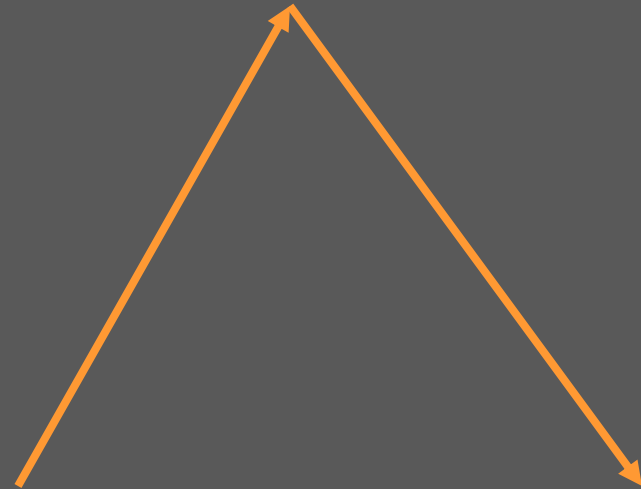
Light is emitted

Light returns

Sam



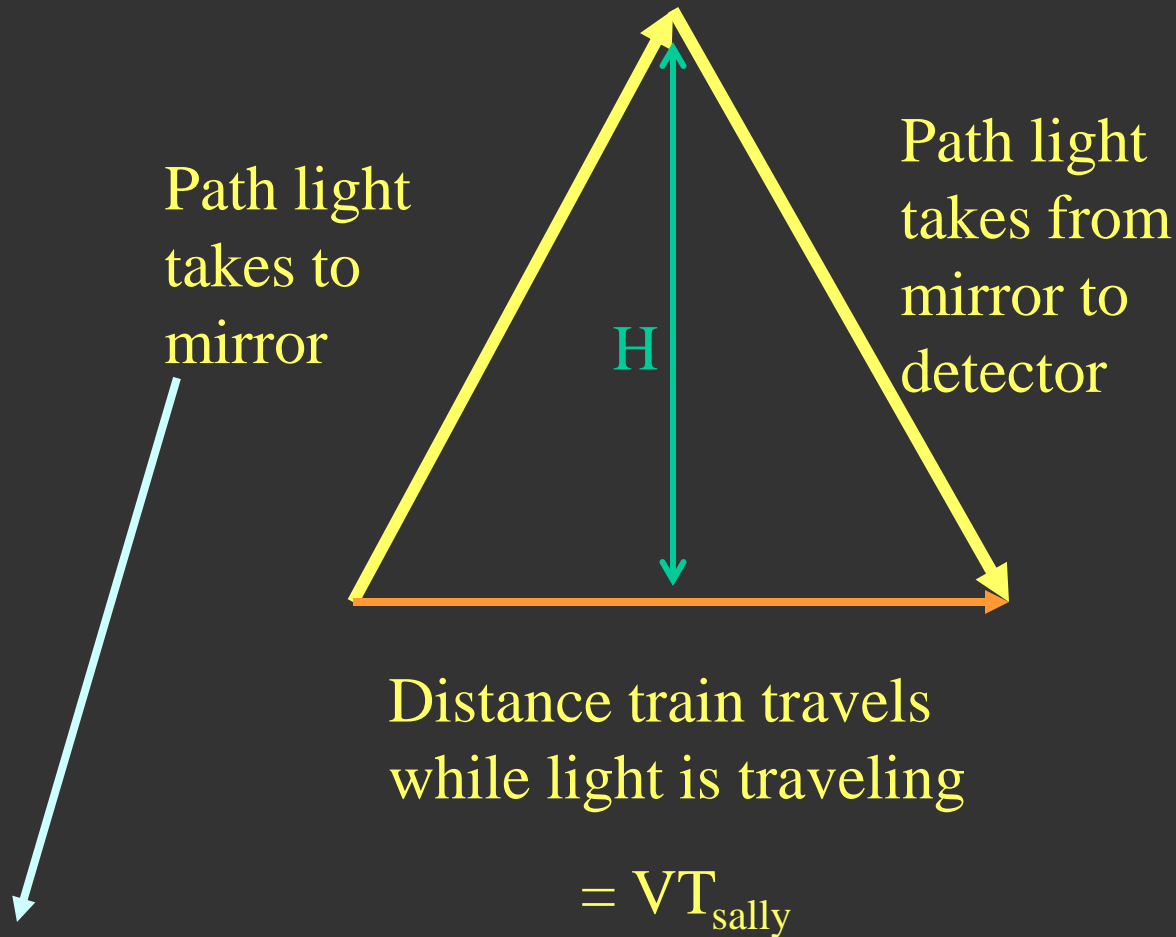
Sally



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!!

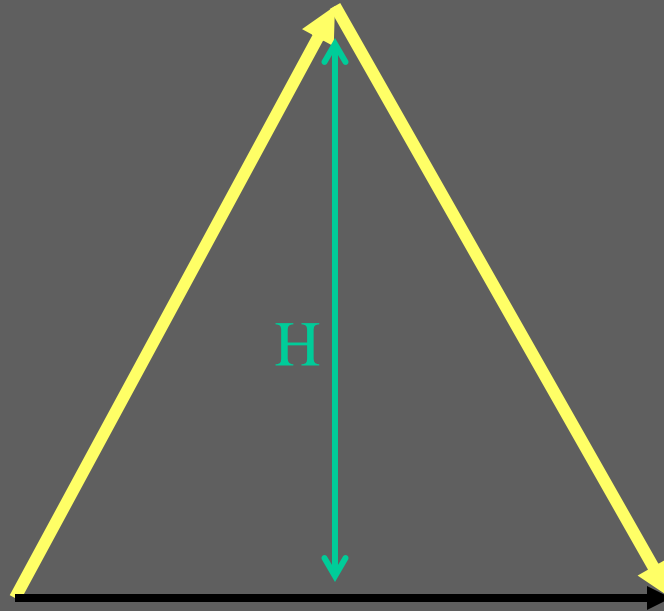
From Sally's point of view



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

Makes use of Pythagorean theorem

From Sally's point of view



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

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

Sam (on train)

Sally (on ground)

$$2H/T_{\text{sam}} = c$$

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

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

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

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

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

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

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

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

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

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

Sam (on train)

Sally (on ground)

$$2H/T_{\text{sam}} = c$$

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

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

A bit of algebra.

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

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.

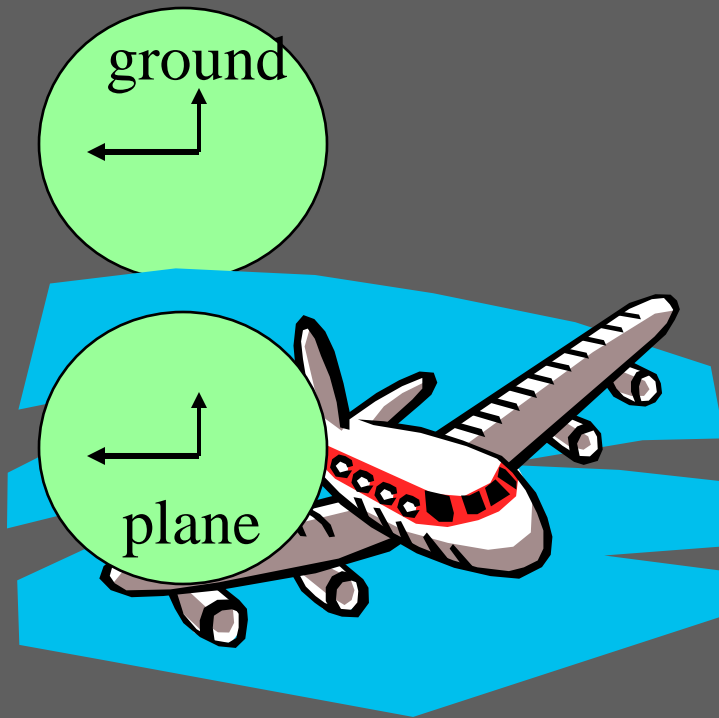
$$\text{Yet, } T_{\text{sally}} > T_{\text{sam}}$$

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

Time is not absolute! It is relative!

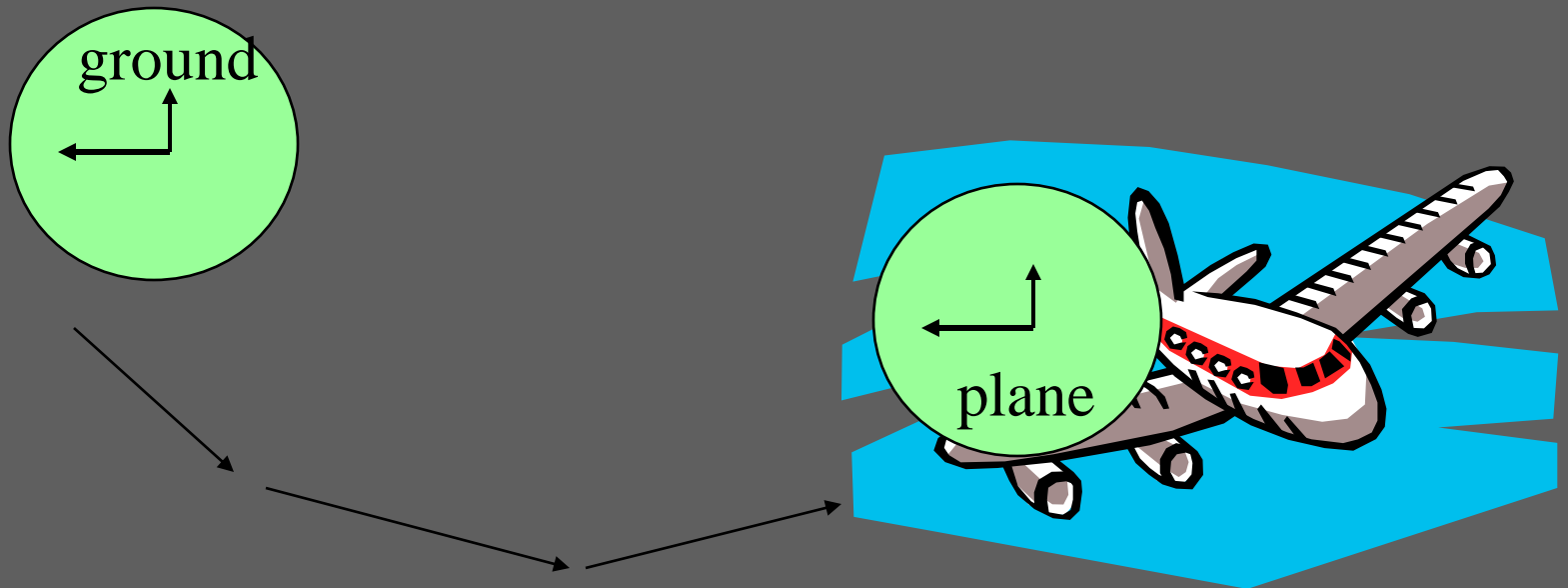
Can this be true??

Experiment says YES!

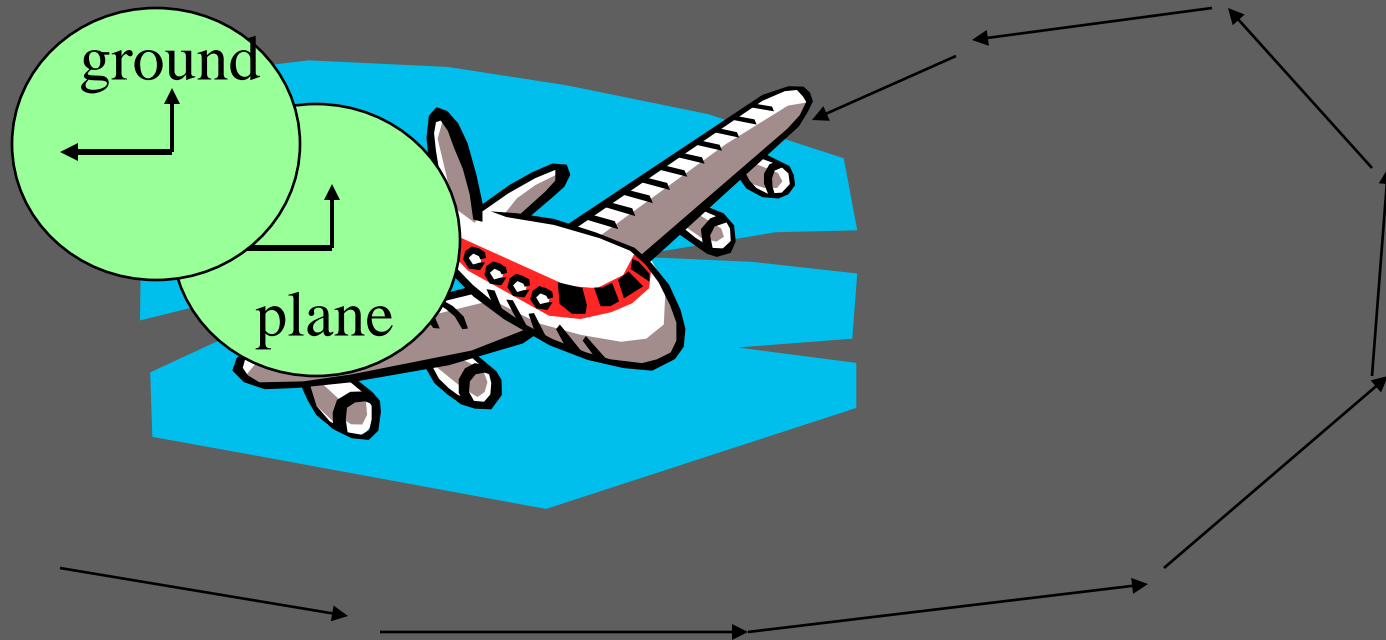


Can this be true??

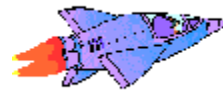
Experiment says YES!



Less time elapsed on the clocks carried on the airplane



$$V=0.98c$$



**Lifetime=70 years
on spaceship**

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

$\gamma > 1$

"Proper Time"

$$t_{\text{earth}} = \frac{1}{\sqrt{1 - \left(\frac{0.98c}{c}\right)^2}} (70 \text{ years})$$

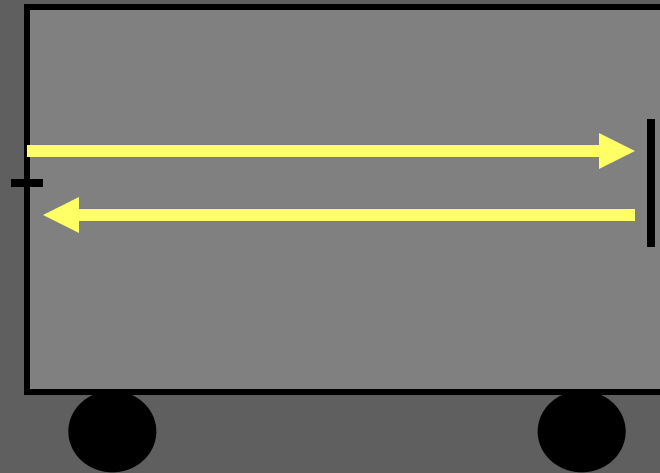
$$t_{\text{earth}} = (5) (70 \text{ years})$$

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

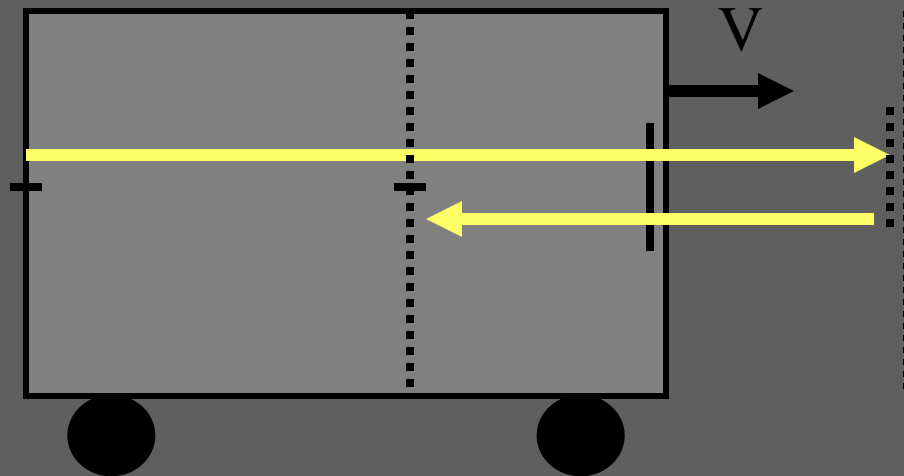
Earth at rest



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

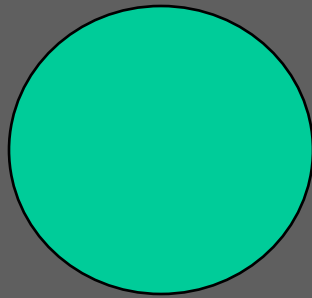


Measure the length of a boxcar where you are on the car.



Measure the length of a boxcar moving by you.

Length is relative, too!



$V=0$



Large V