Physics 100 - Sept. 17, 2007

- Recitations begin this week
  probably useful to bring calculator

Last Time —

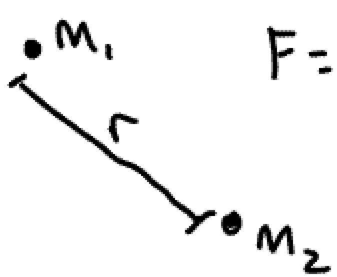
Play Newton song

Force → Think $F = ma$

Forces of Nature

Talk about later

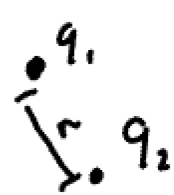
Gravitation (Newton)



$$F = \frac{G m_1 m_2}{r^2}$$

Electromagnetism

→ Coulomb's Law



$$F = \frac{k q_1 q_2}{r^2}$$

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

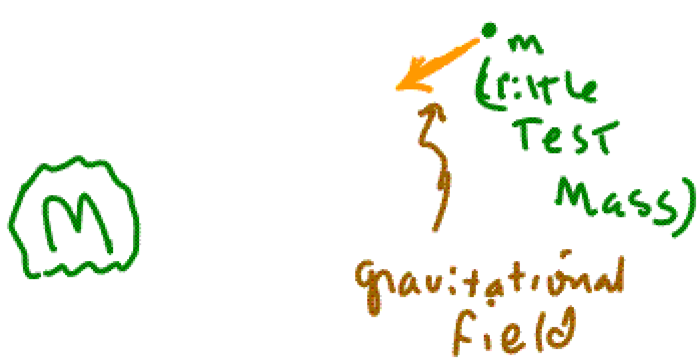
gravitational Field

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



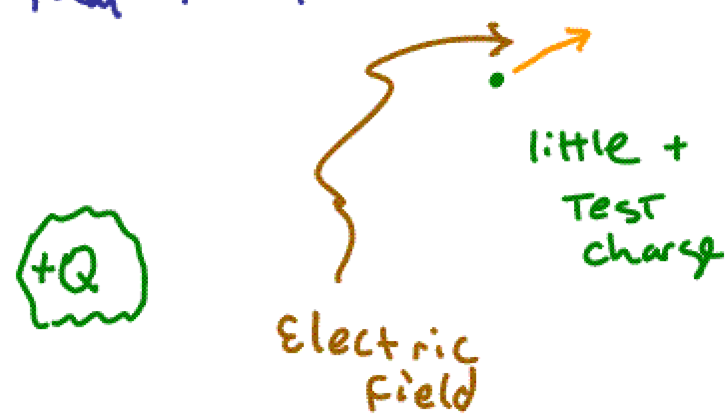
Electric field

At each point in space

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

(Magnitude + direction)

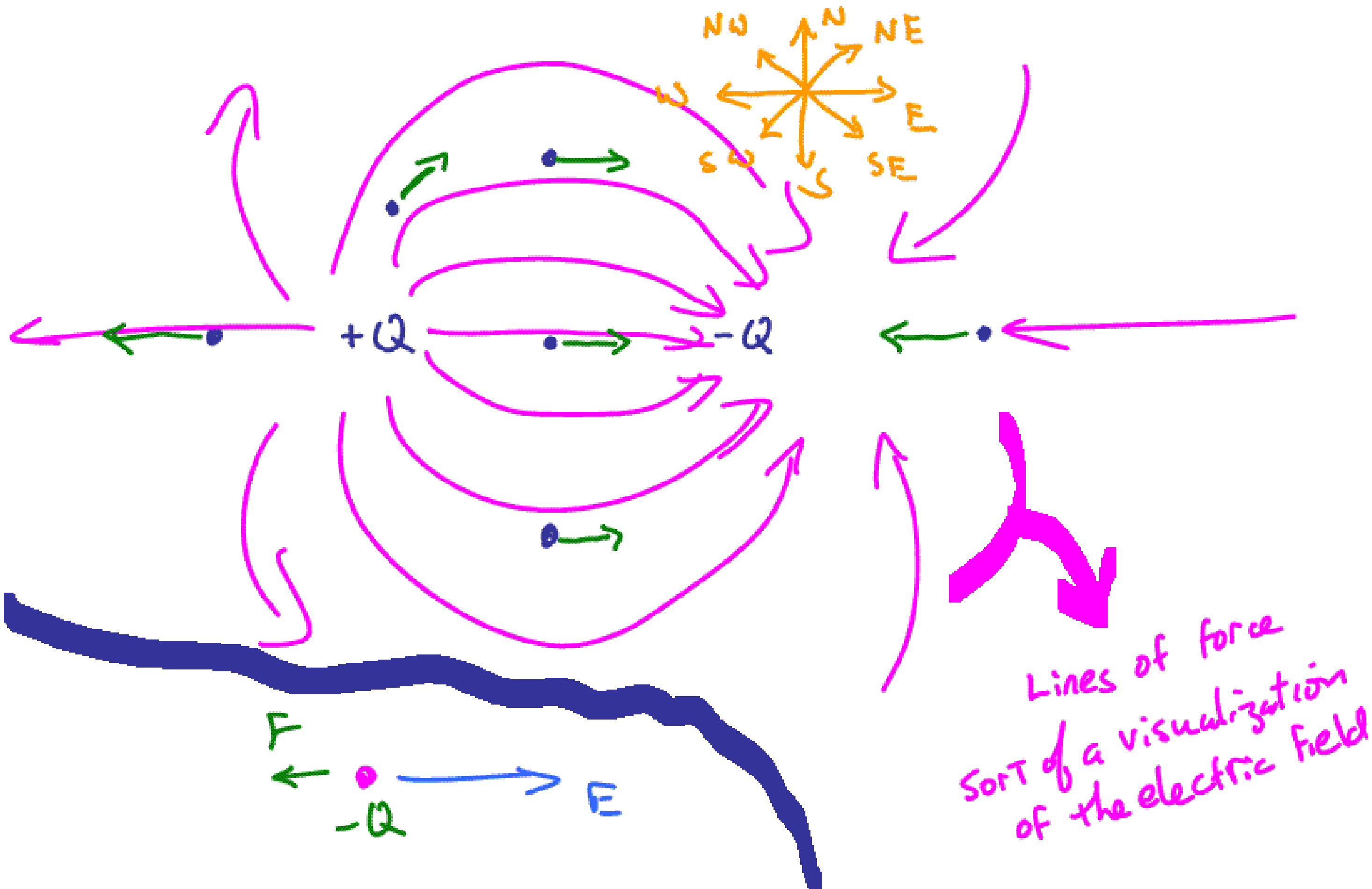
that would be felt by a little + test charge at that Point



Think of "Temperature Field" or "Wind field"

Greece 69	Roch 70	webster 68
		FairporT 72

Greece ↘	Roch ↘	webster →
		FairporT ↘

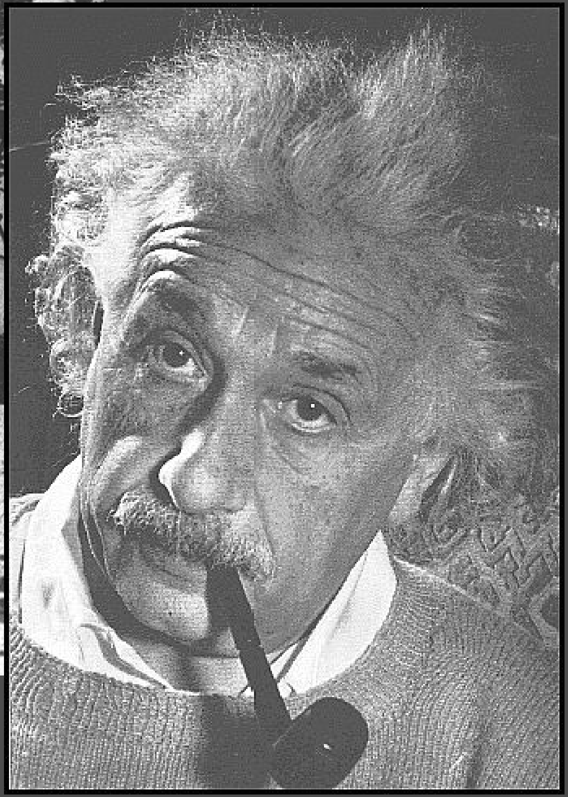


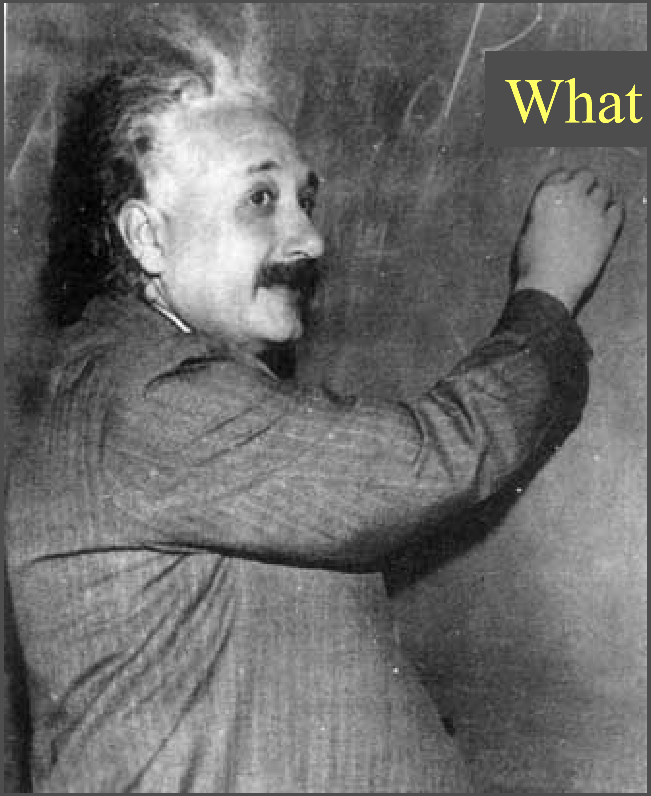
The Essence of Special Relativity

Steve Manly

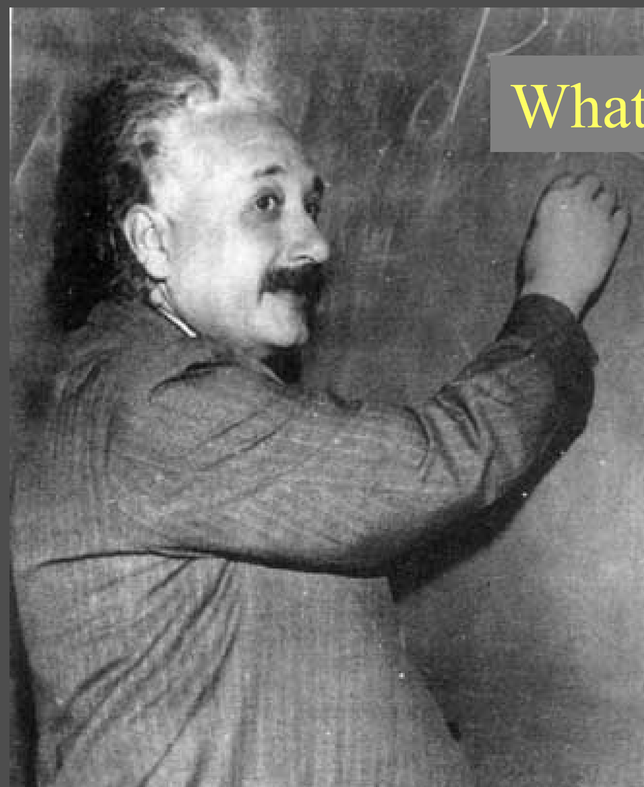
Department of Physics and Astronomy

University of Rochester





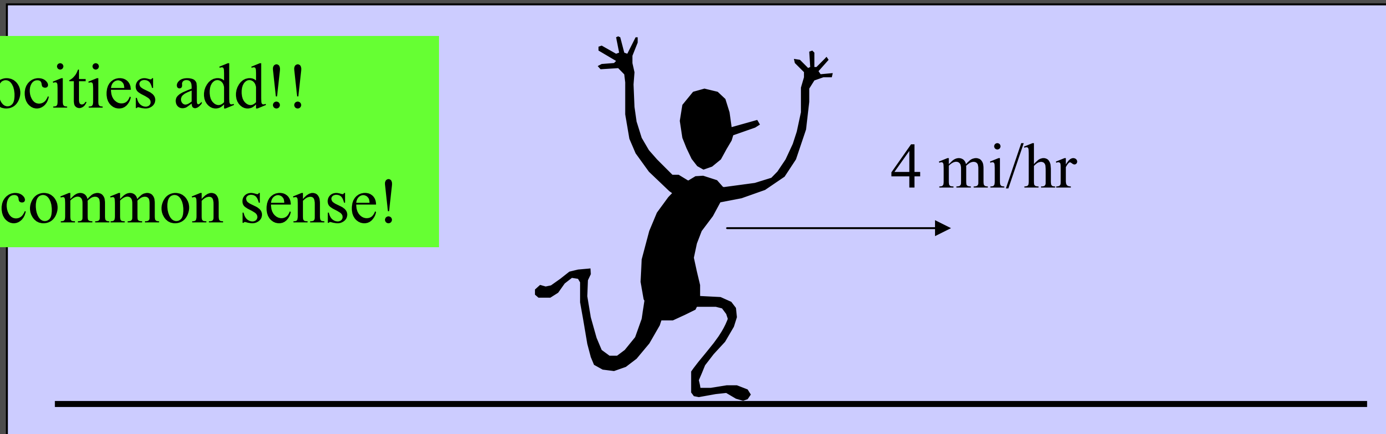
What is time??



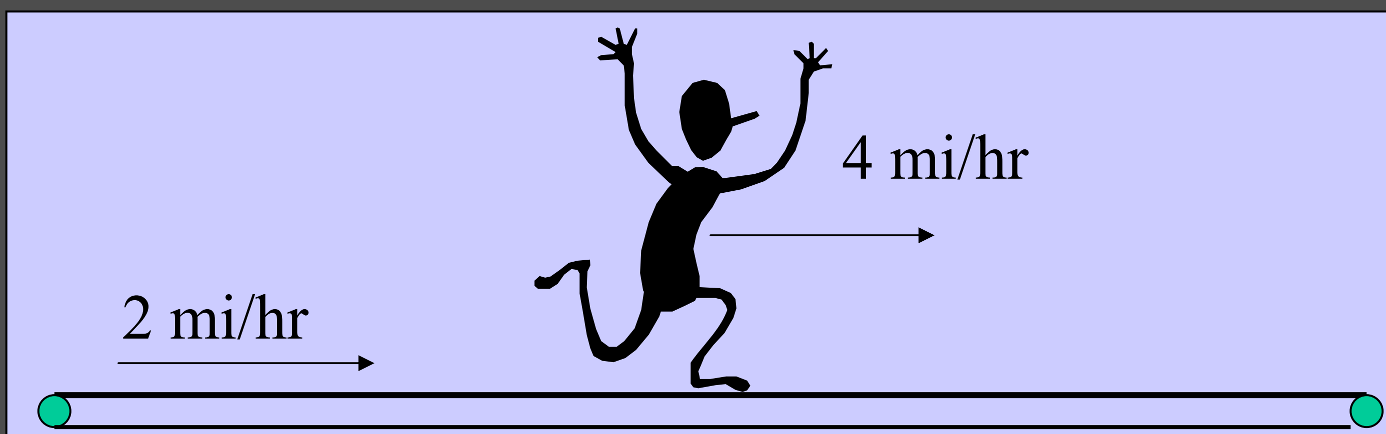
What is space??

Velocities add!!

It's common sense!



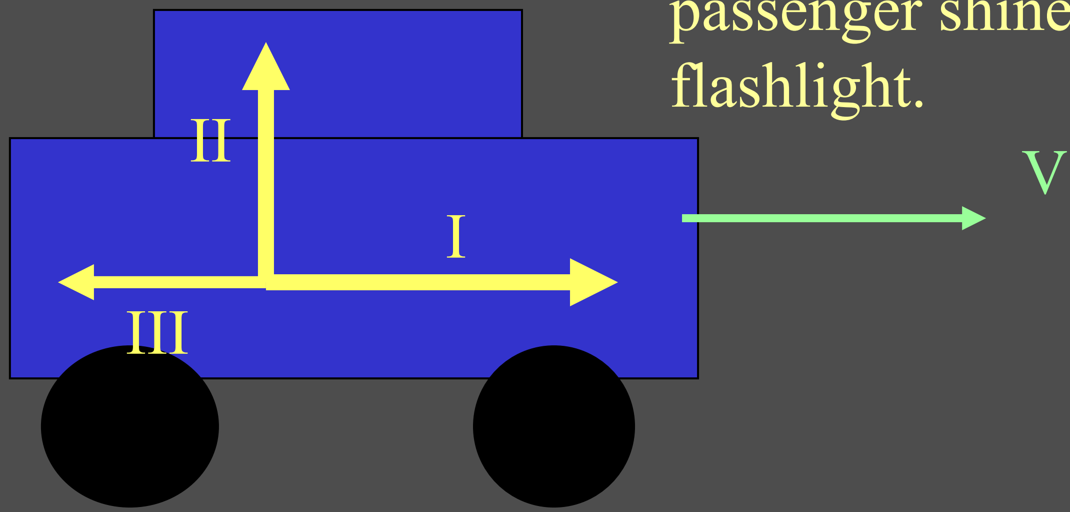
Speed with respect to you is 4 mi/hr



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?

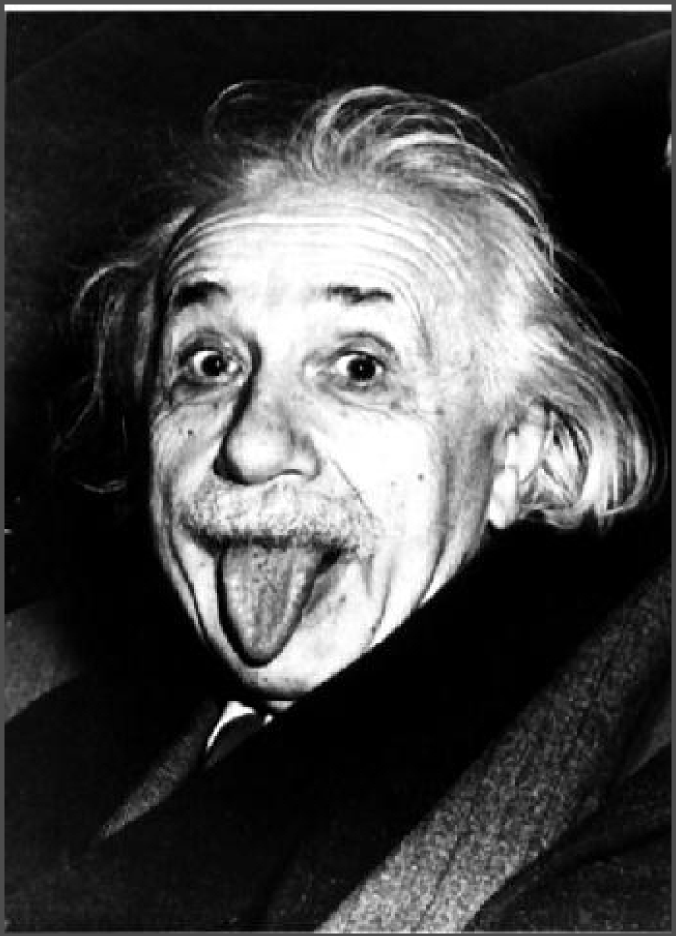
Car moves while passenger shines a flashlight.



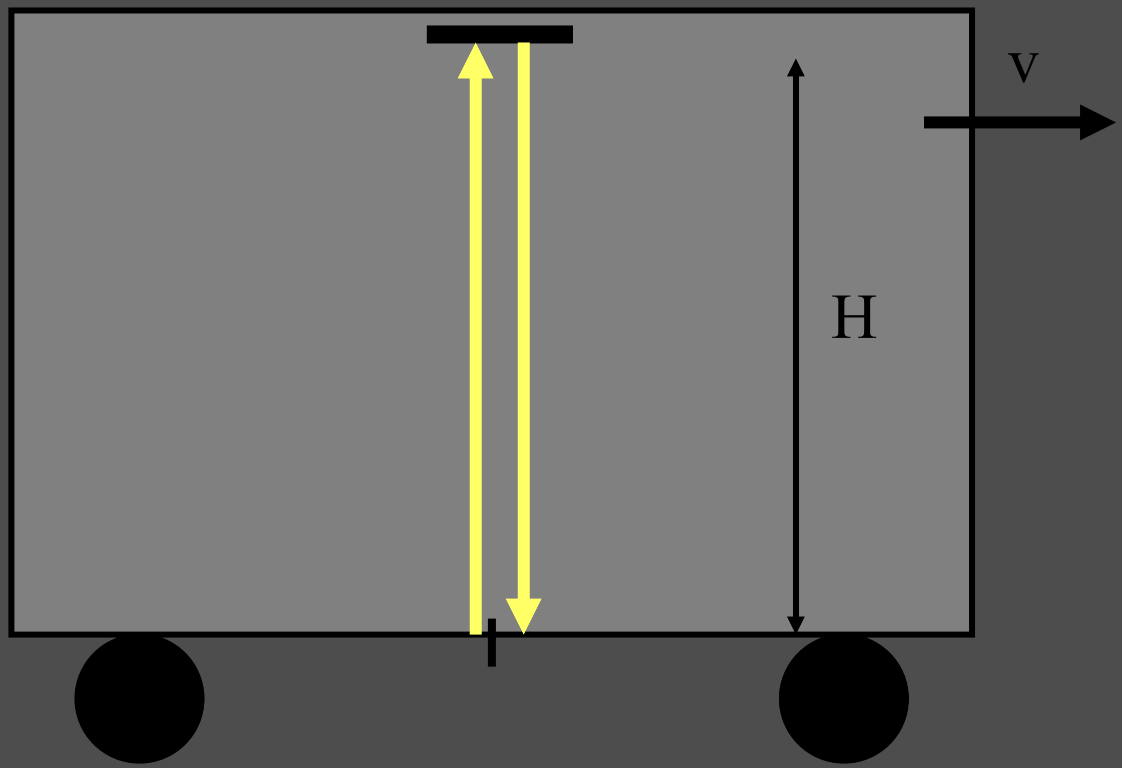
Experiment says the speed of light is the same in all directions!!

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

Enter our man Einstein!

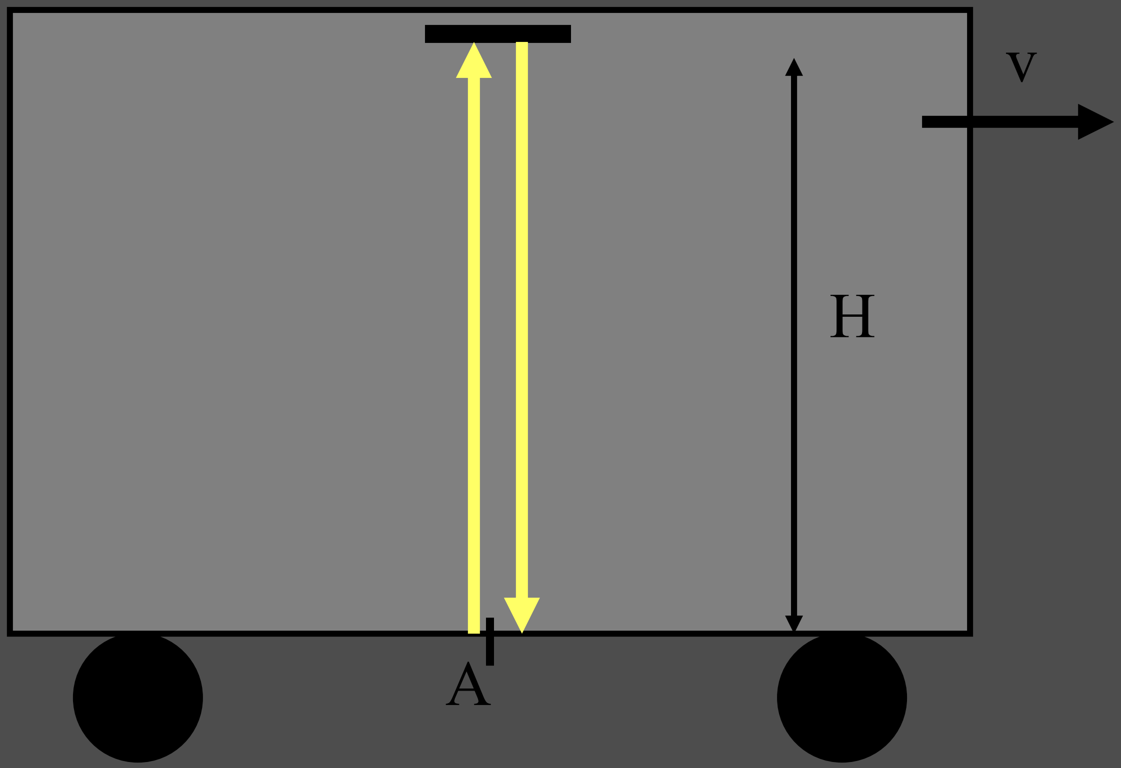


Einstein thought experiment:
Consider a beam of light that is emitted from the floor of a train that bounces off a mirror on the ceiling and returns to the point on the floor where it was emitted.

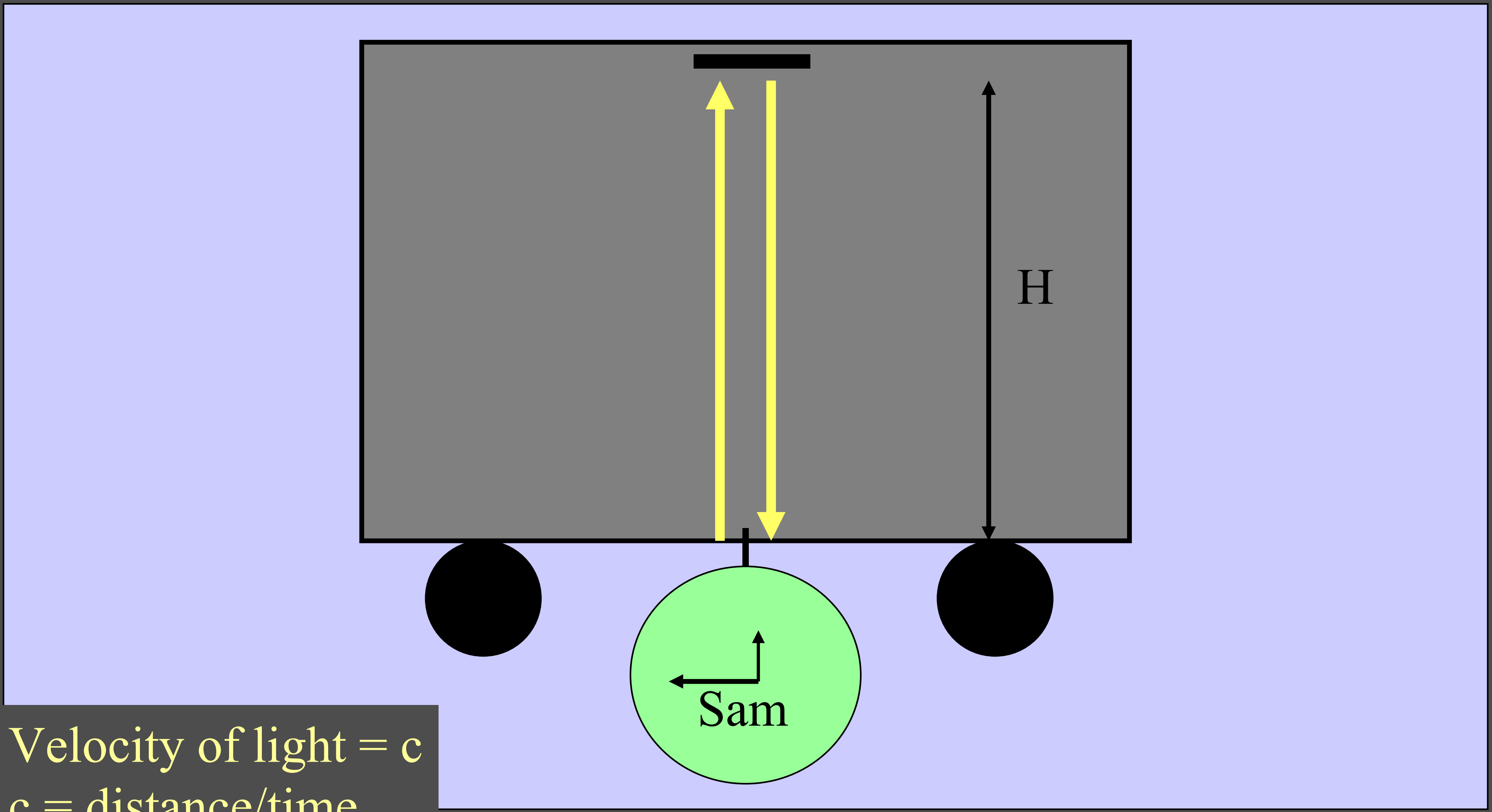


Fact: Light is emitted and detected at point A.

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



Sam is on the train



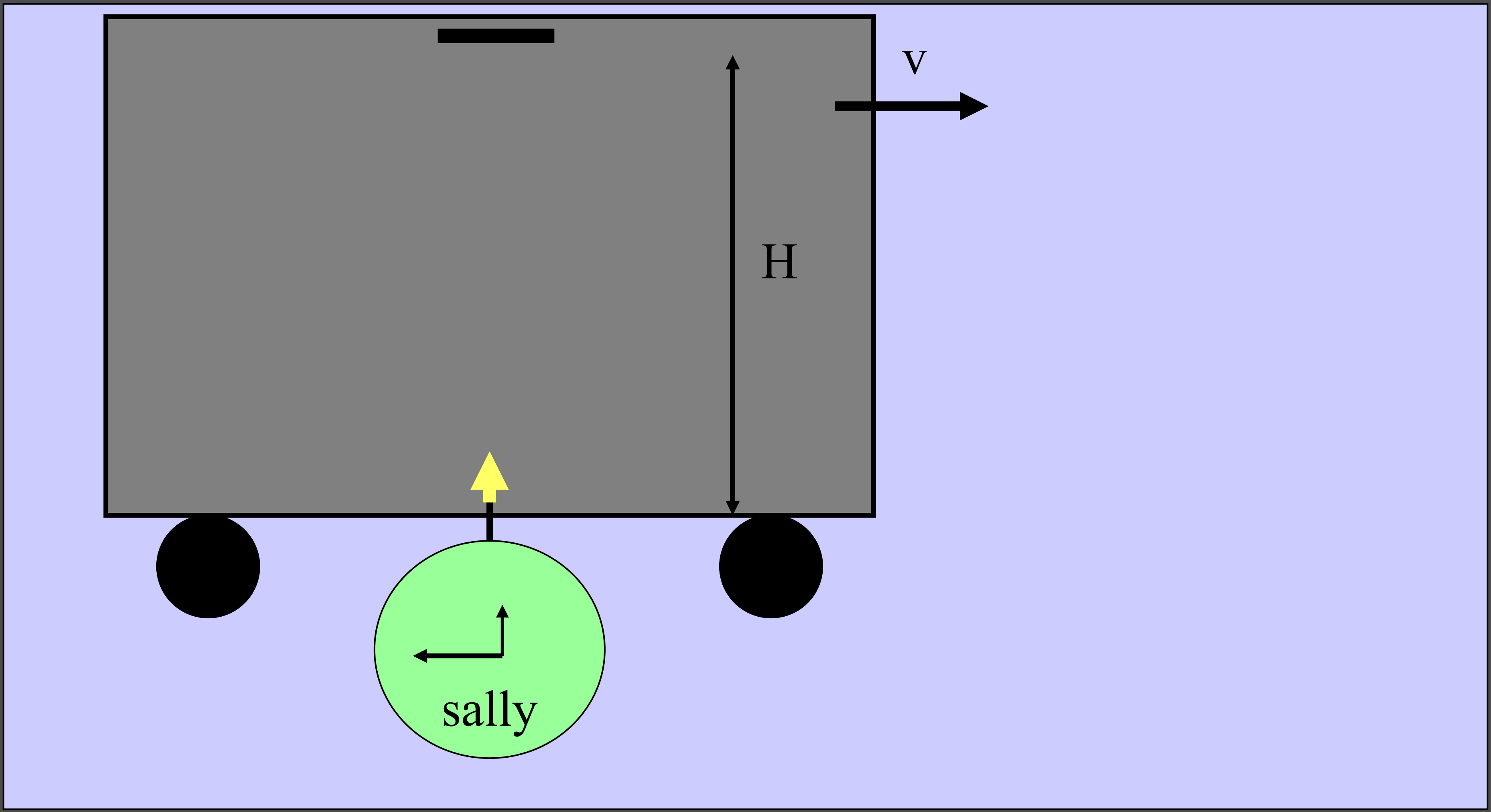
Velocity of light = c

c = distance/time

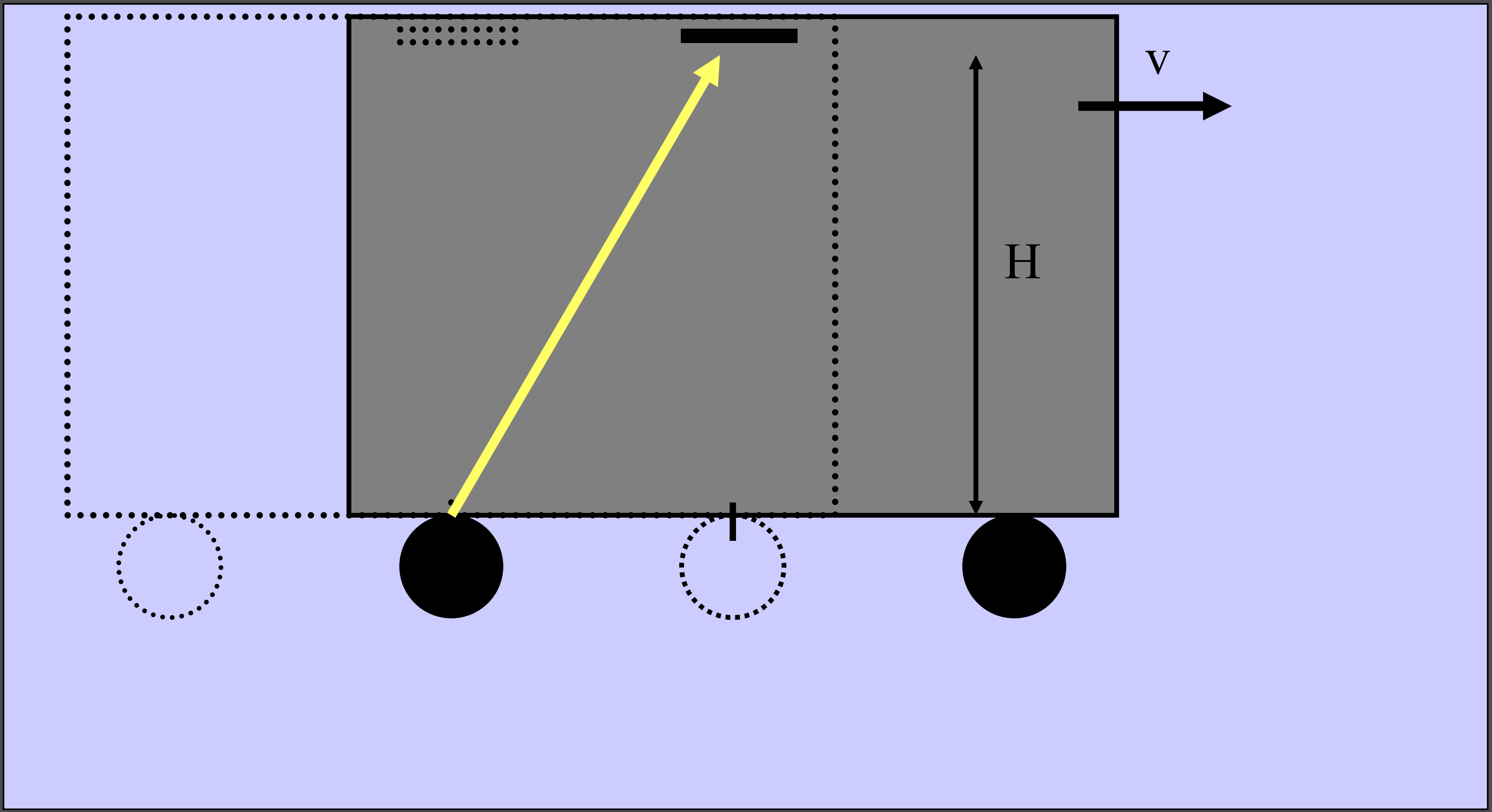
$c = 2H/T_{sam}$

$T_{sam} = 2H/c$

Sally watches the train pass and makes the same measurement.

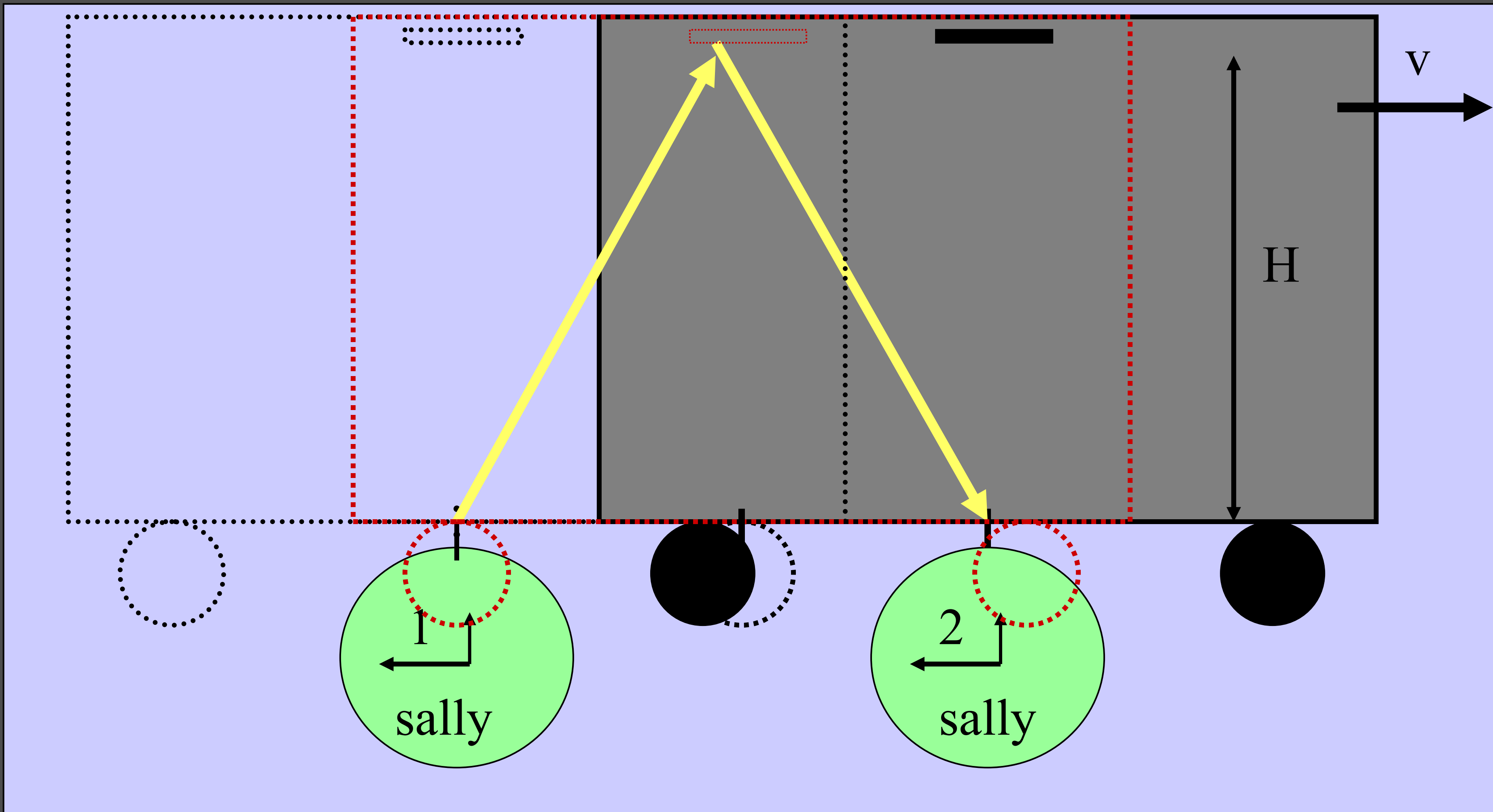


Light is emitted



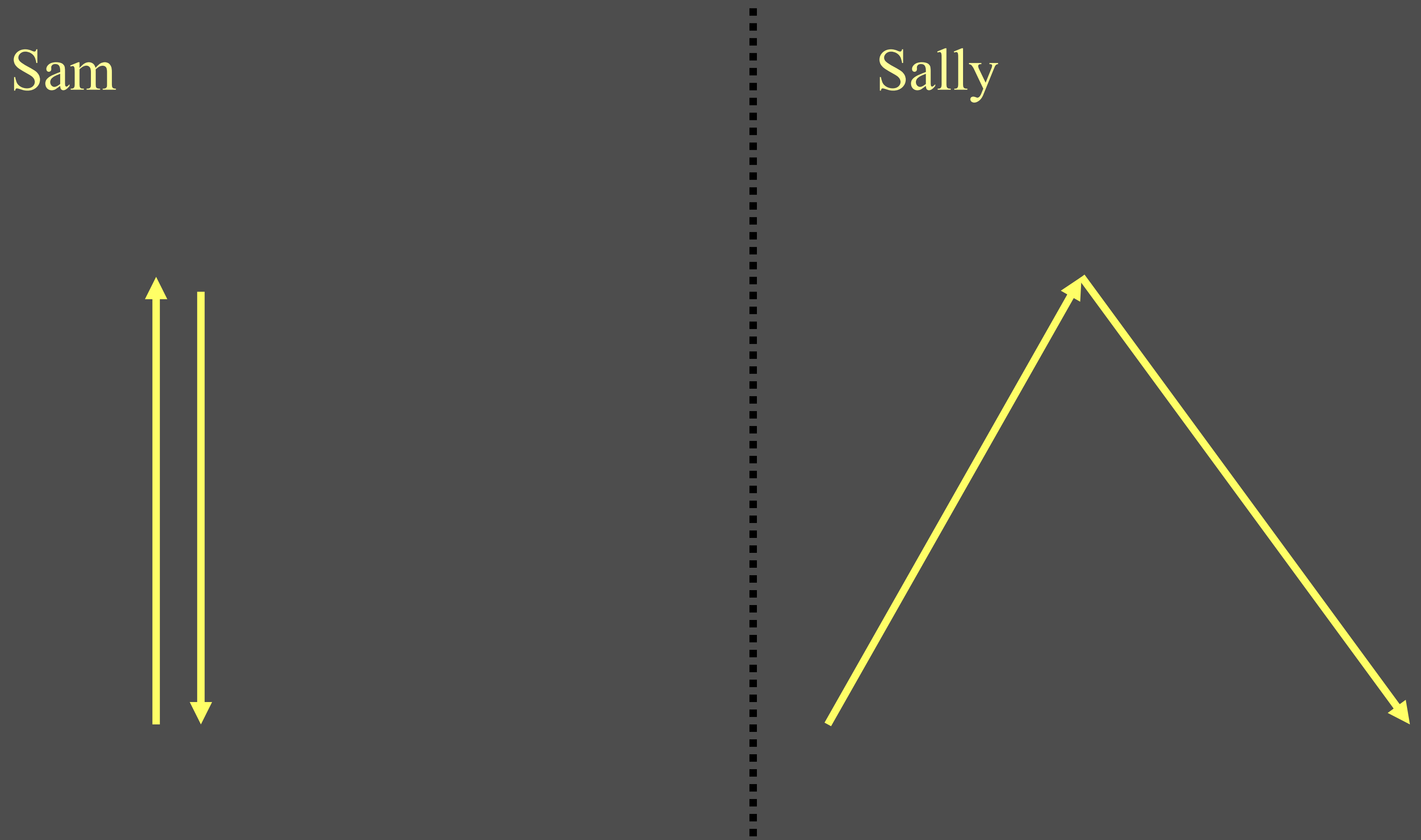
v
H

Sally is standing still, so it takes two clocks.



Light is emitted

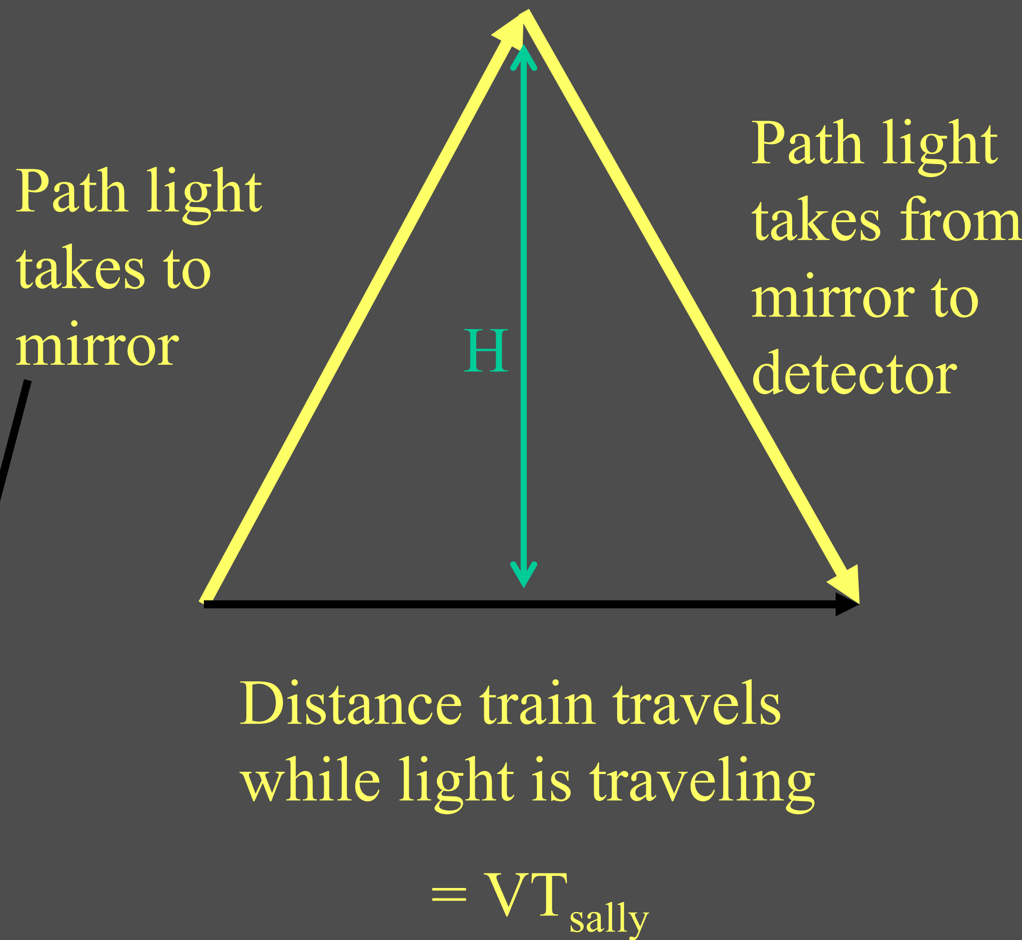
Light returns



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!!

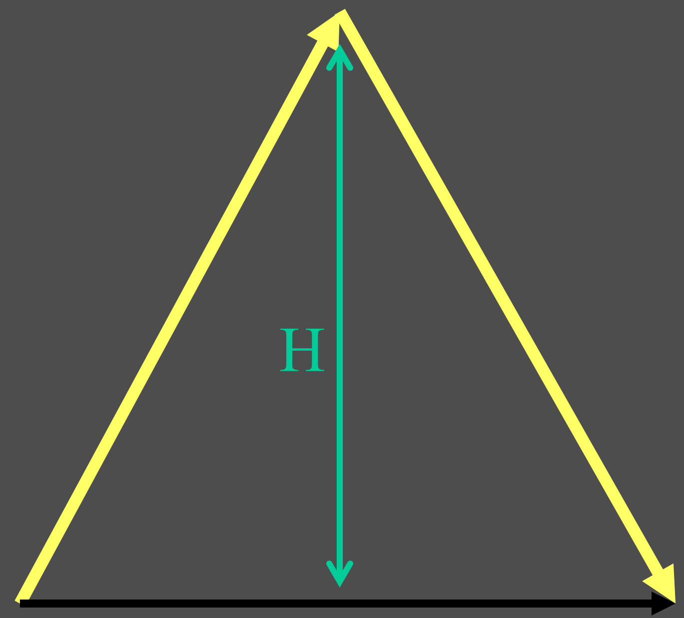
From Sally's point of view



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

Makes use of Pythagorian theorem

From Sally's point of view



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

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

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

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

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

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.

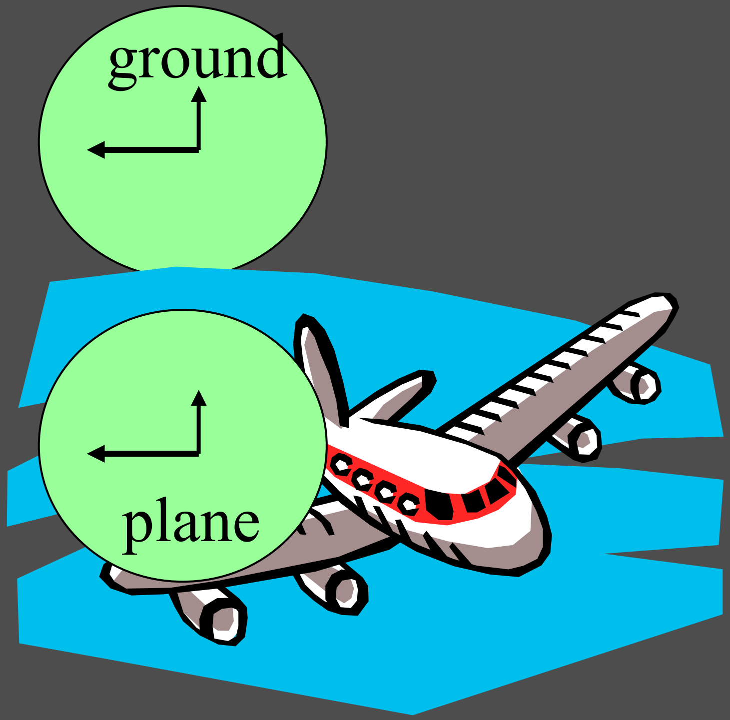
Yet, $T_{sally} > T_{sam}$

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??

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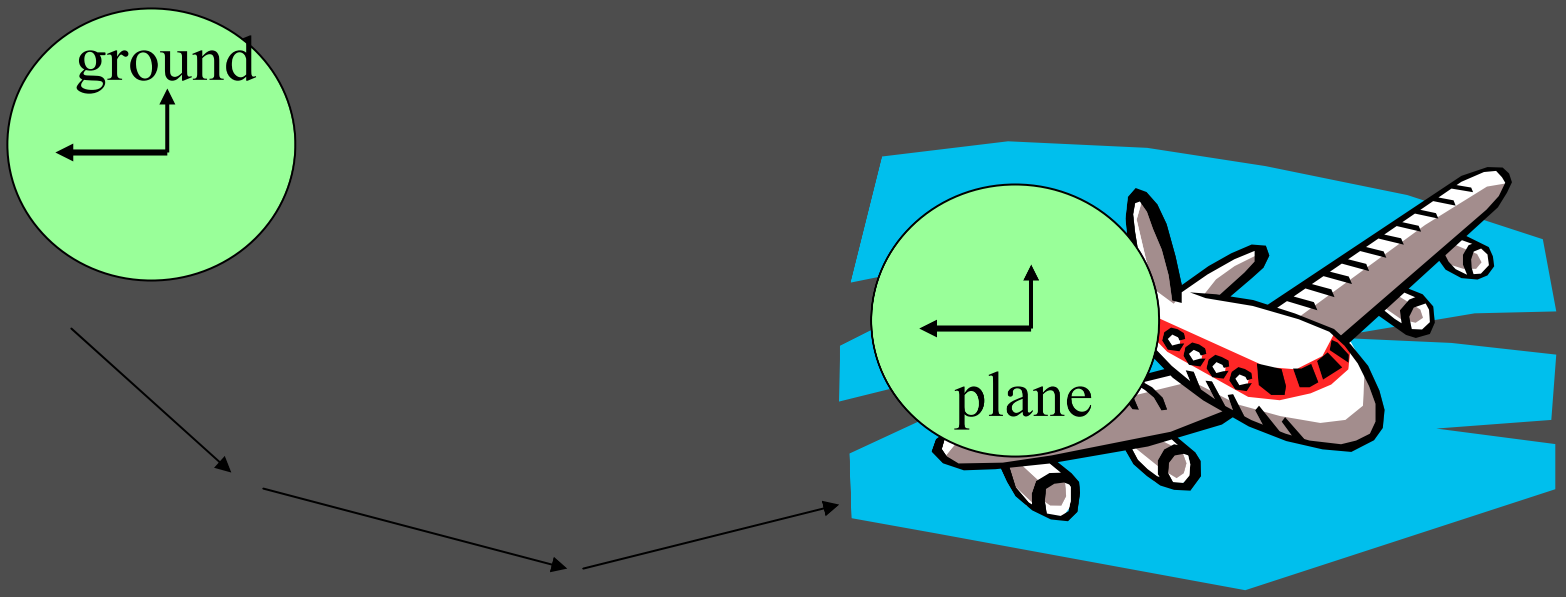
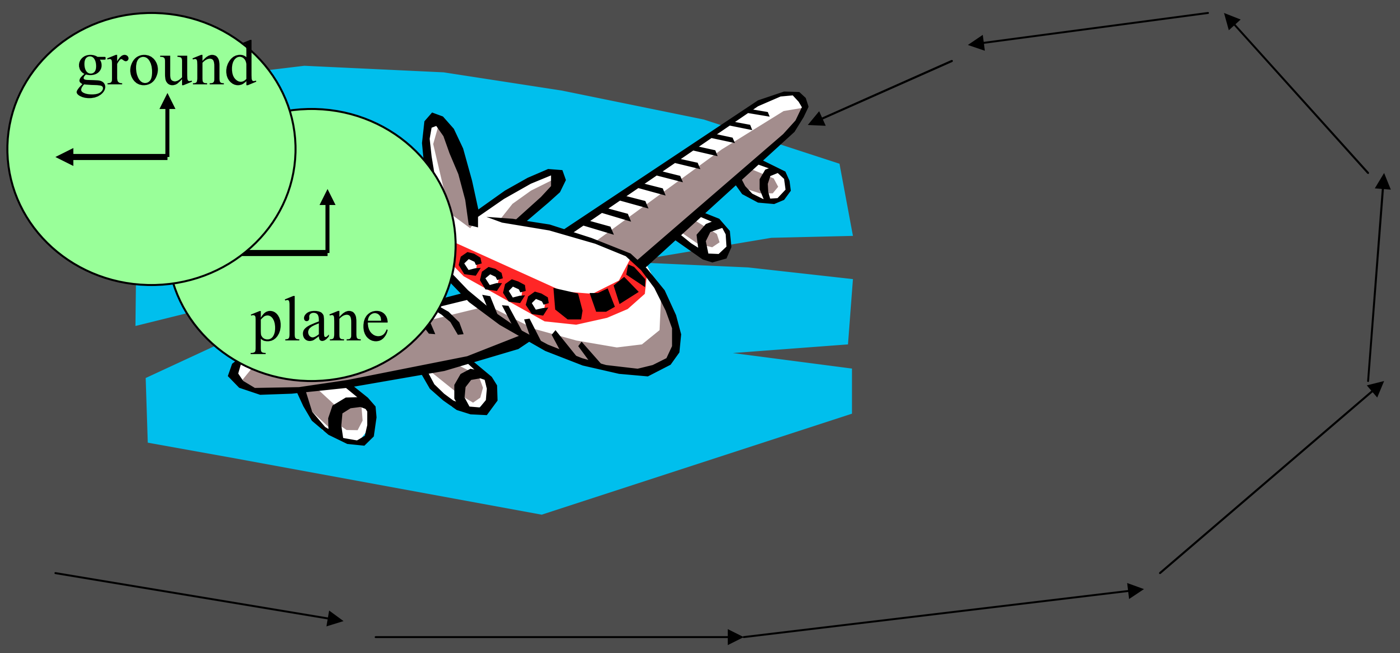
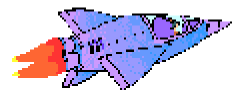


Less time elapsed on the clocks carried on the airplane



V=0.98c



Lifetime=70 years on spaceship

Earth at rest

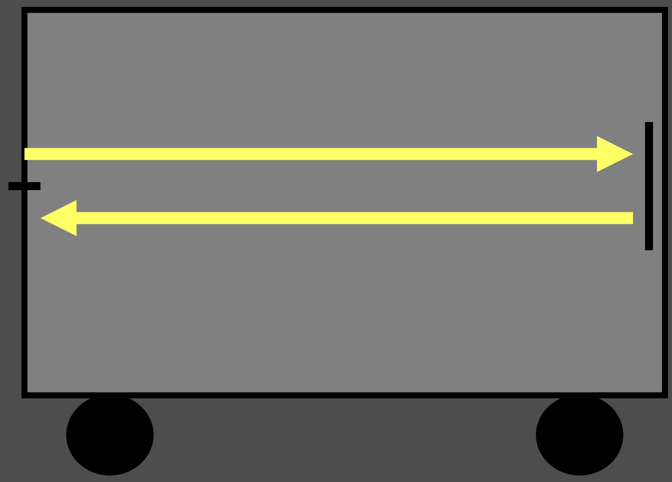
How long does person appear to live to astronomers on earth?

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

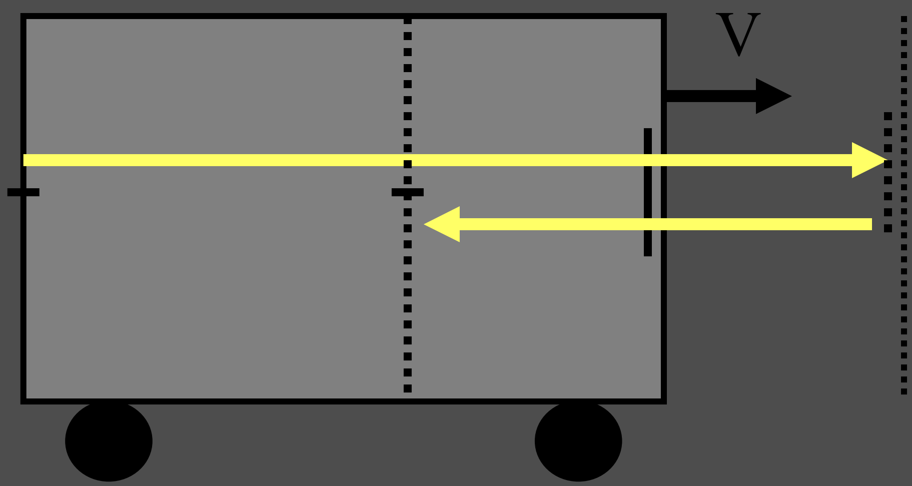
$$t_{earth} = \frac{1}{\sqrt{1-\left(\frac{.98c}{c}\right)^2}} (70 \text{ years})$$

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

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



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!