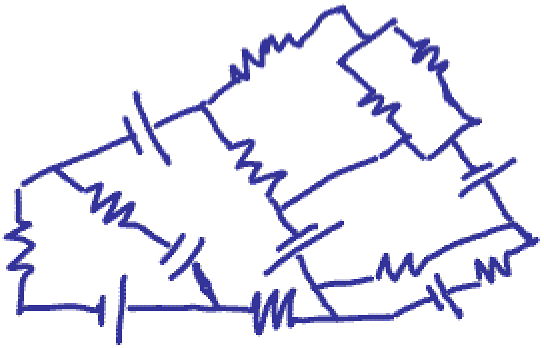
Physics 142 - October 16, 2007

- Exam graded
- Solns + Distribution Posted
  Will hand back + discuss at end of class
- Hand in Presentation Topic preference list
  Today / Tomorrow

Troubleshooting guide
regrade policy
→ on web

Look over exam + Solutions carefully !

Last Time



suppose you meet a circuit in a dark Alley one night ...

... And the electrons Are NOT looking for love ...

Kirchoff's Rules:

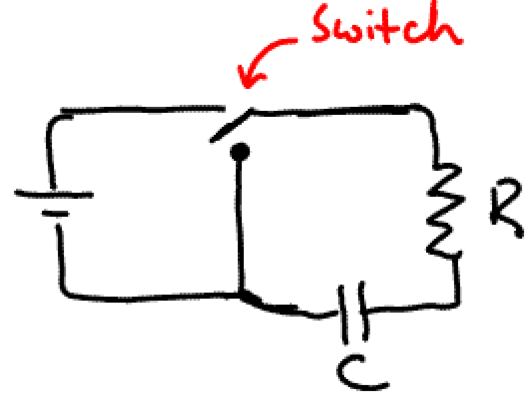
① $\Sigma V = 0$ around closed Loop in circuit

② current is conserved at any Branch point in circuit

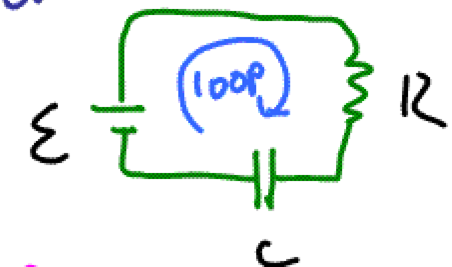
- use these rules to create N independent equations to solve for N unknowns

- Choose independent loops
- Use sign conventions consistently + with care

DC - RC circuits



Switch in up position
→ capacitor charging



$$\sum V = 0$$

$$\mathcal{E} - iR - \frac{q}{C} = 0$$

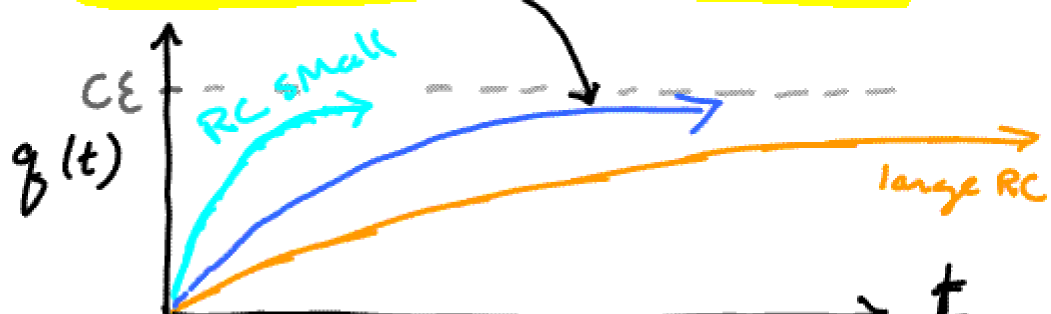
differential Eqn

$$\mathcal{E} = \frac{dq}{dt} R + \frac{q}{C}$$

Sub in to check this as solution

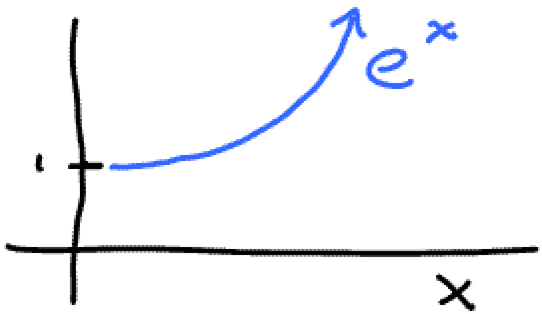
charging capacitor

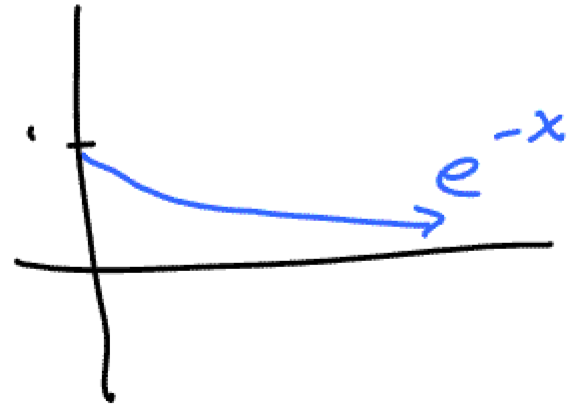
$$q(t) = C\mathcal{E}\left(1 - e^{-t/RC}\right)$$

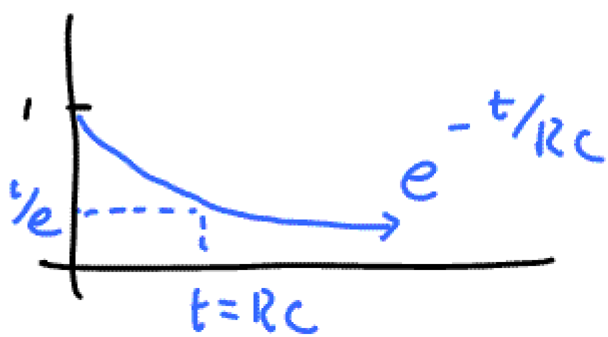


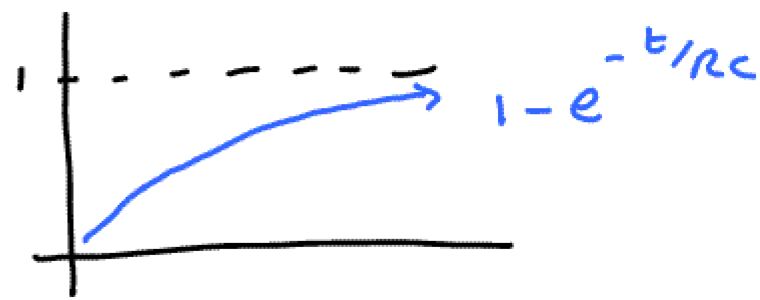
RC ≡ time constant (units of seconds)
of circuit

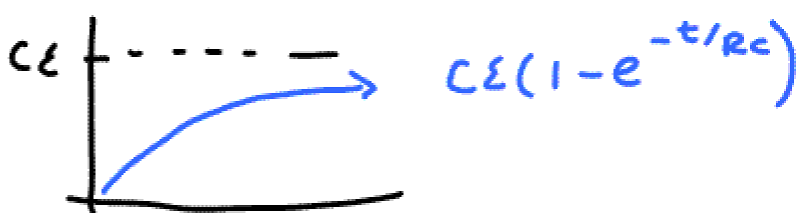
Dictates "Rise time" for q on capacitor



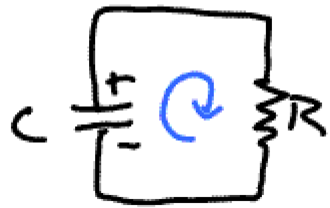








Throw switch down → discharge capacitor



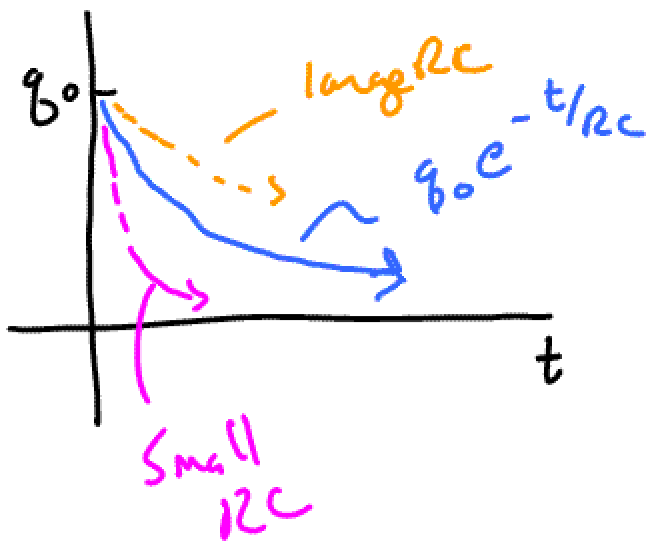
$$\Sigma V = 0$$

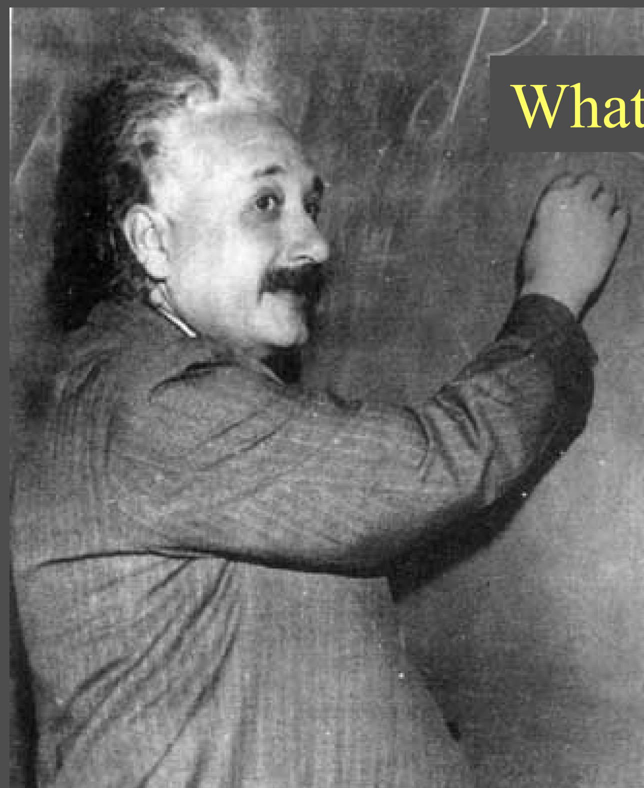
$$-\frac{dq(t)}{dt}R = \frac{q(t)}{C}$$

$$\int_0^t \frac{dt}{RC} = -\int_{q_0}^{q} \frac{dq}{q}$$

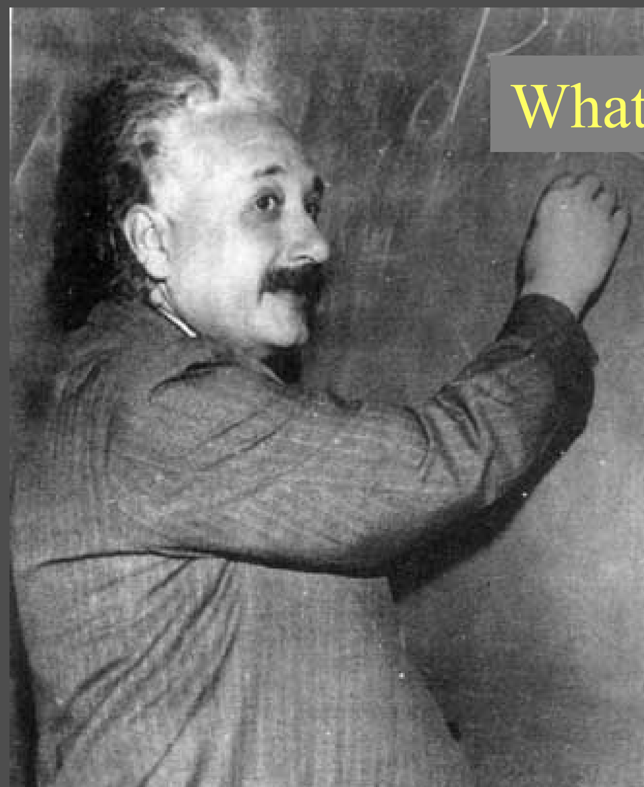
$$\frac{t}{RC} = -\ln\frac{q}{q_0}$$

$$q = q_0 e^{-t/RC}$$





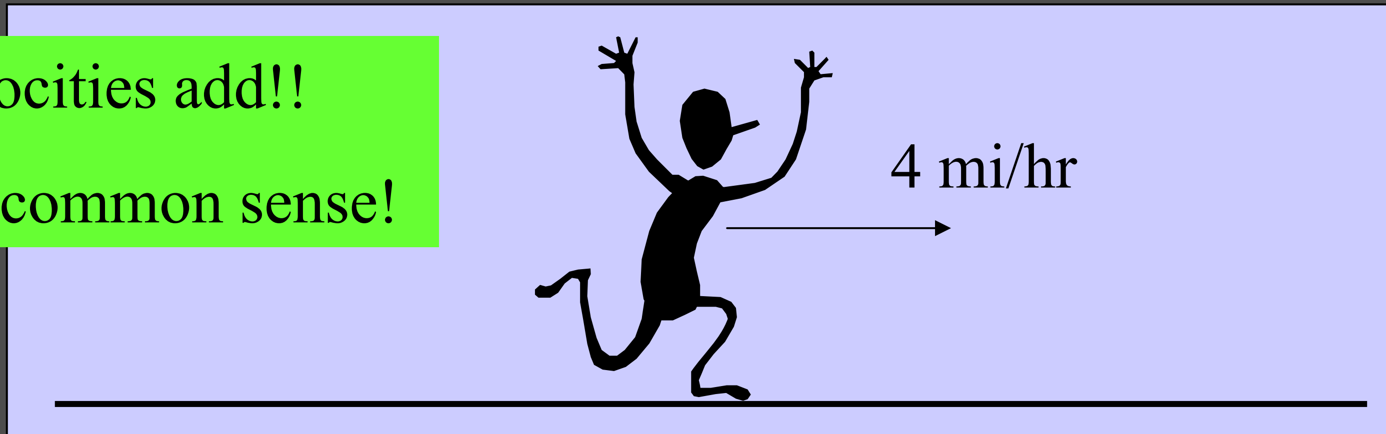
What is time??



What is space??

Velocities add!!

It’s common sense!

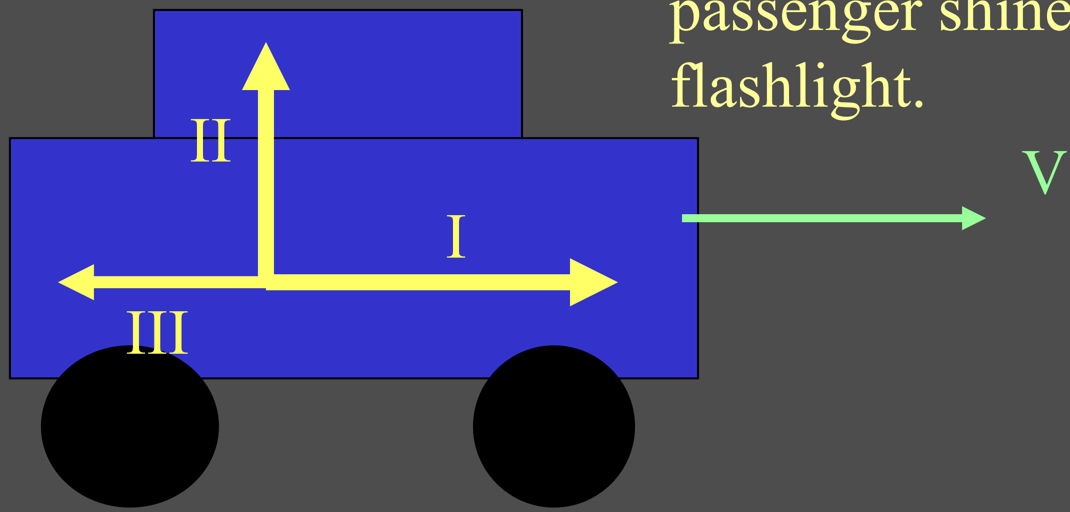


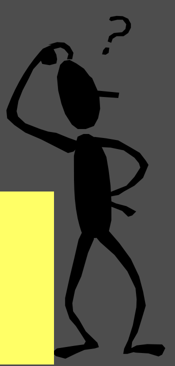
Speed with respect to you is 4 mi/hr

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.

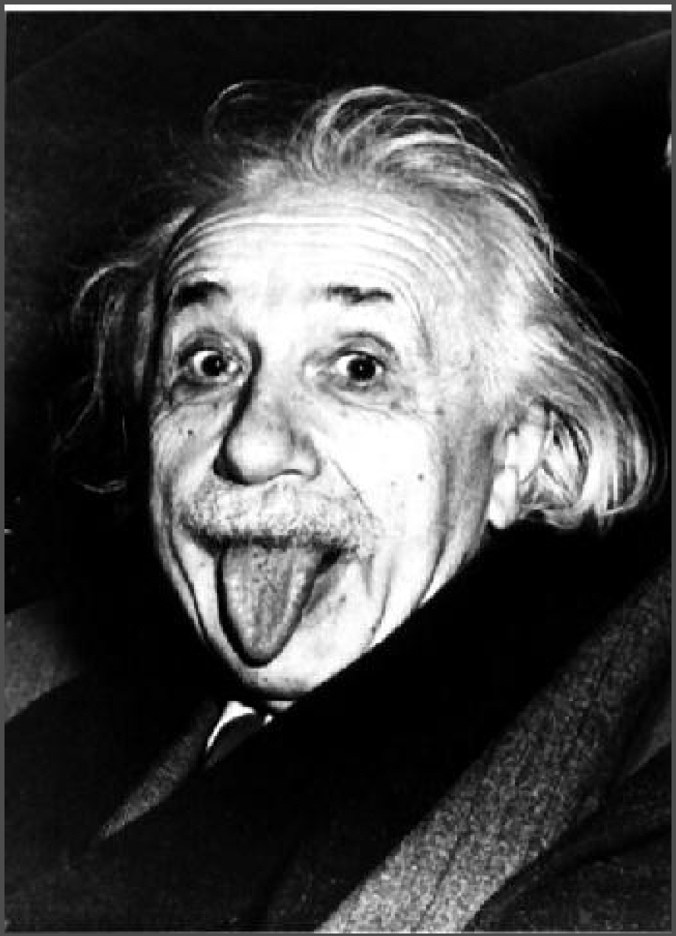




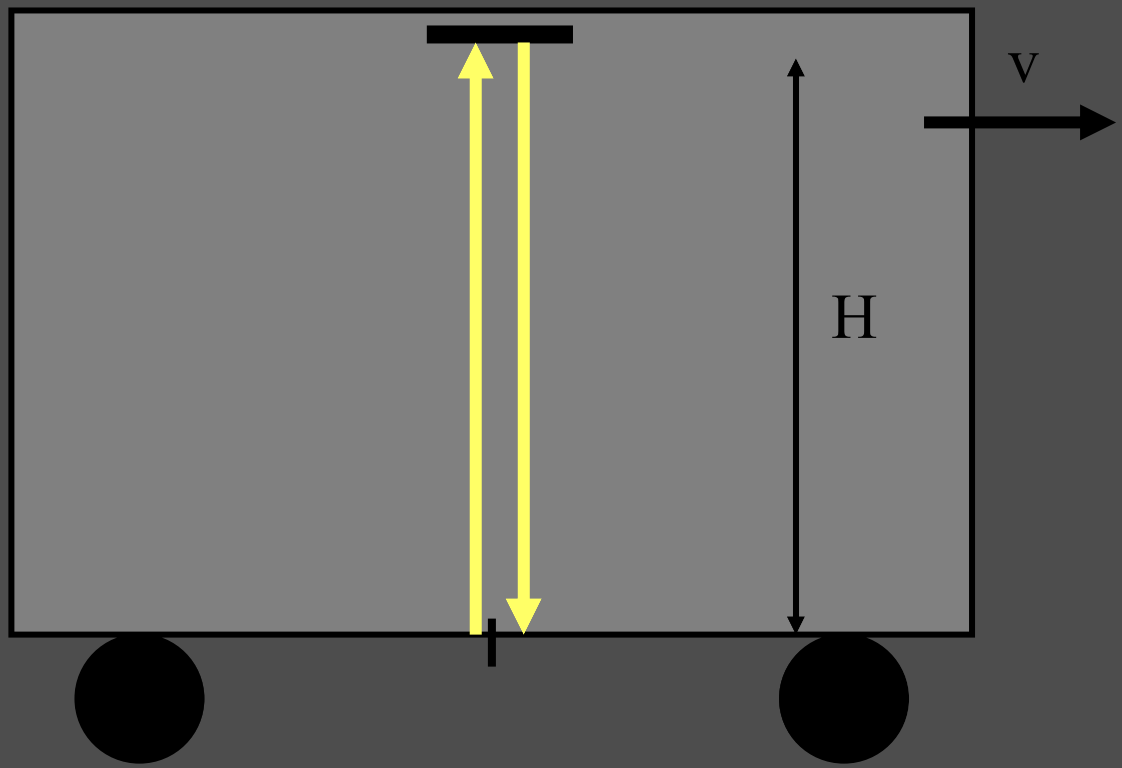
Experiment says the speed of light is the same in all directions!!

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

Enter our man Einstein!

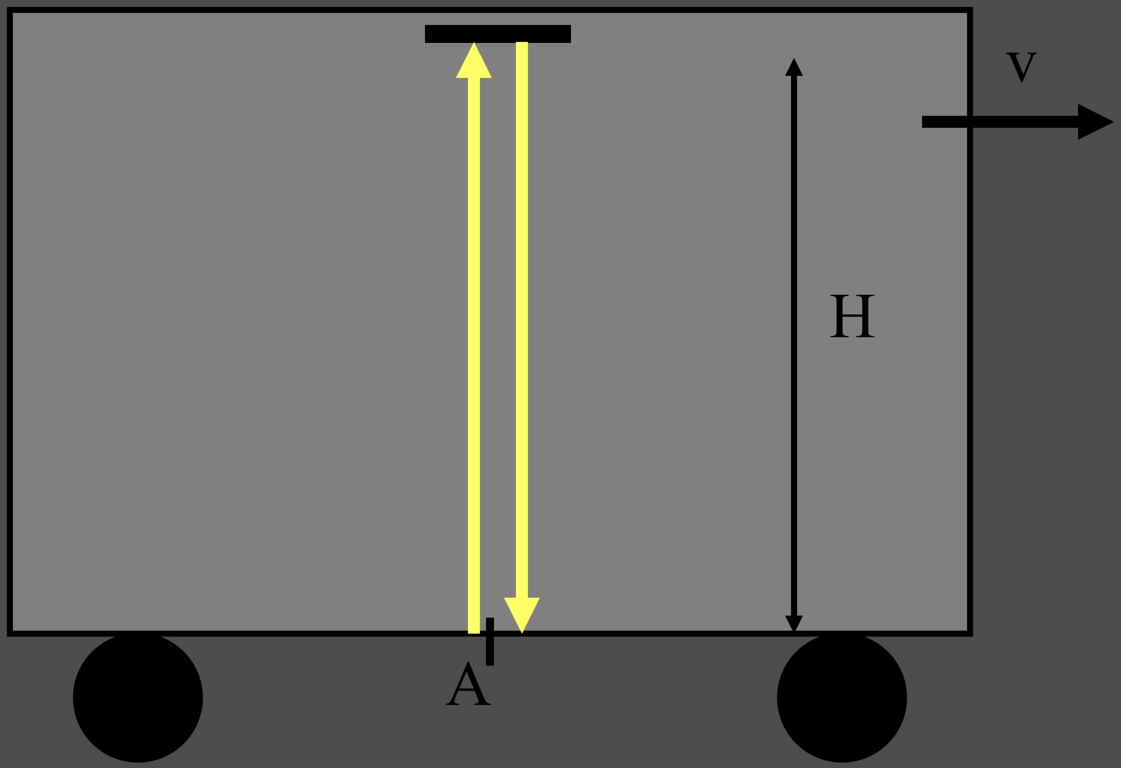


Einstein thought experiment:
Consider a beam of light that is emitted from the floor of a train that bounces off a mirror on the ceiling and returns to the point on the floor where it was emitted.

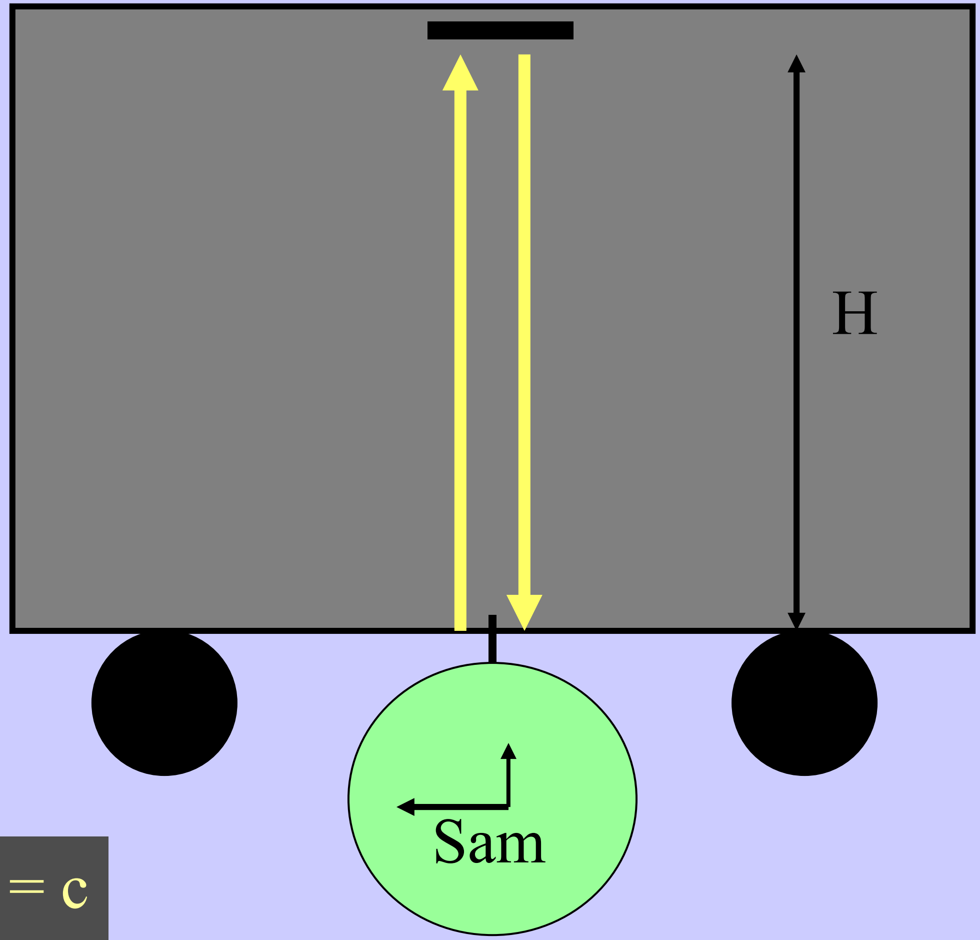


Fact: Light is emitted and detected at point A.

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



Sam is on the train



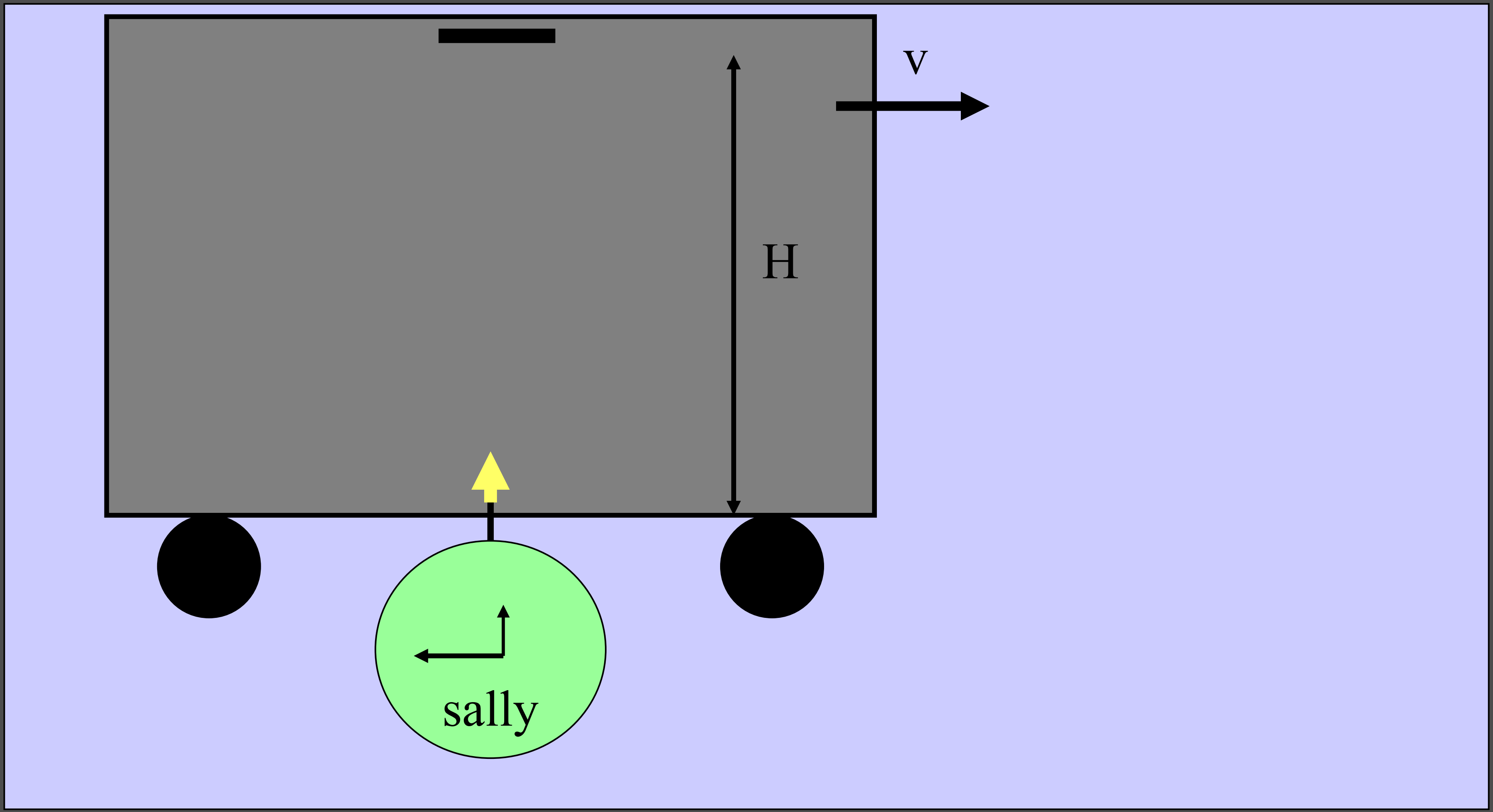
Velocity of light = c

c = distance/time

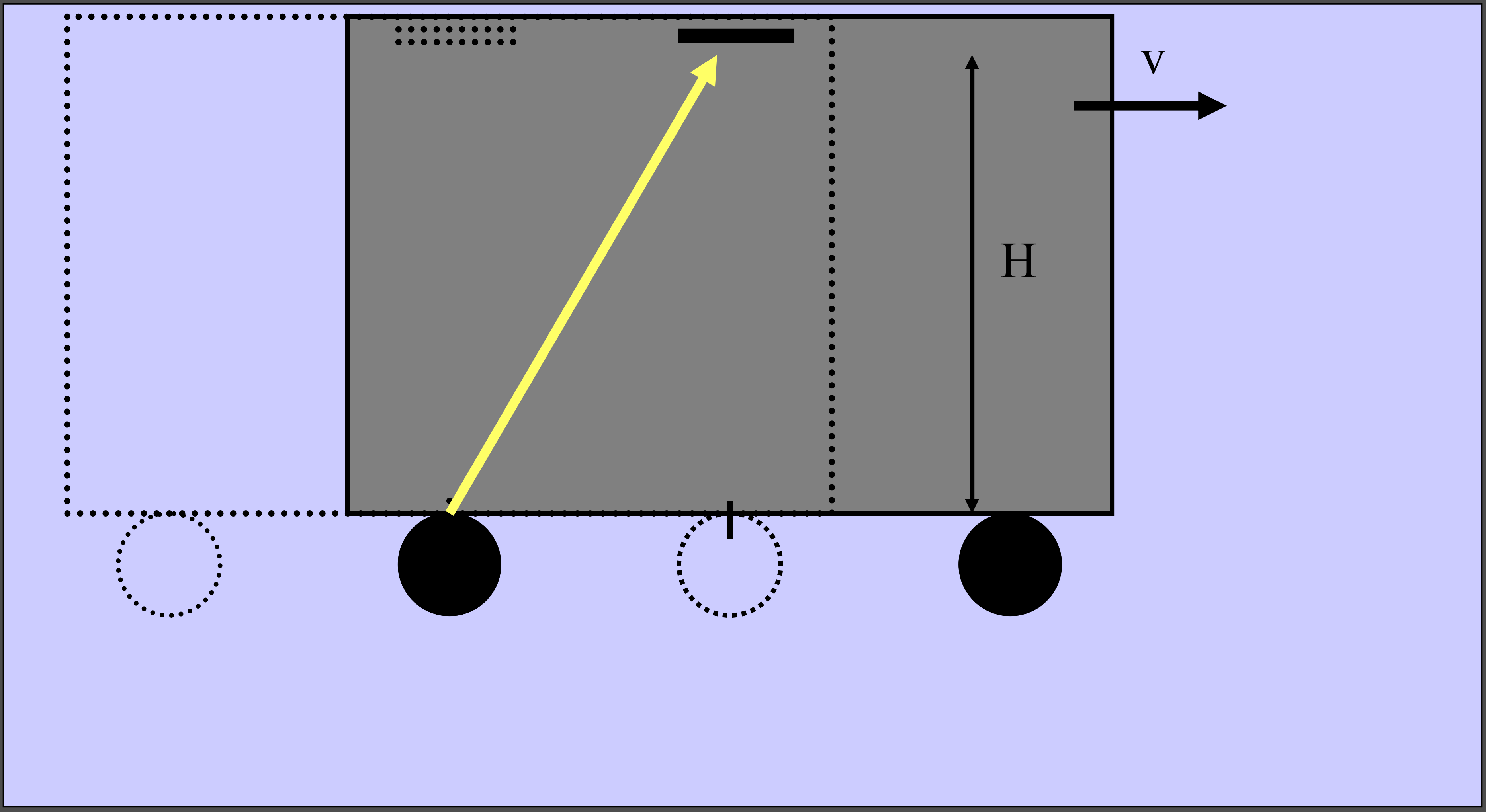
$c = 2H/T_{sam}$

$T_{sam} = 2H/c$

Sally watches the train pass and makes the same measurement.

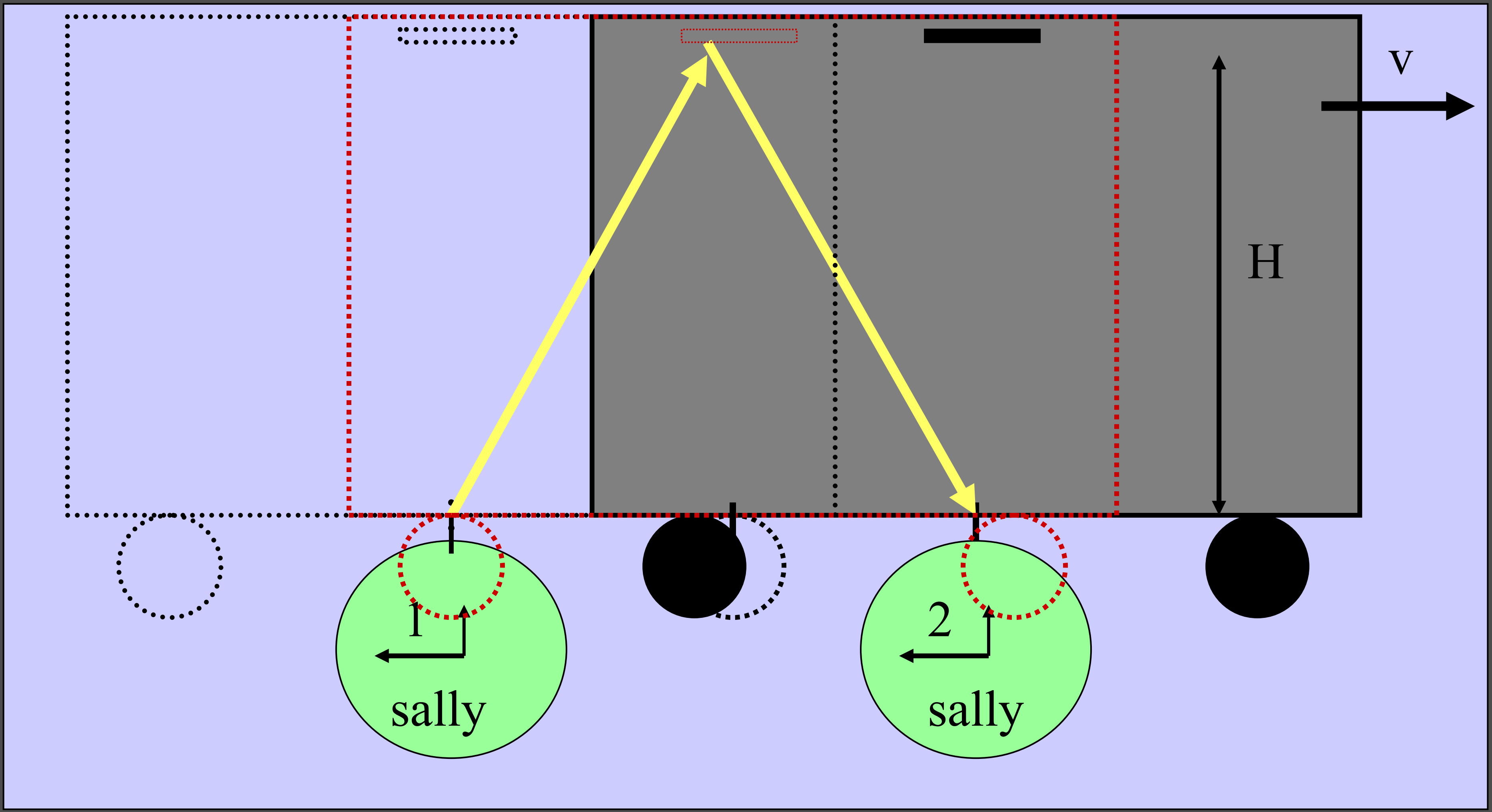


Light is emitted



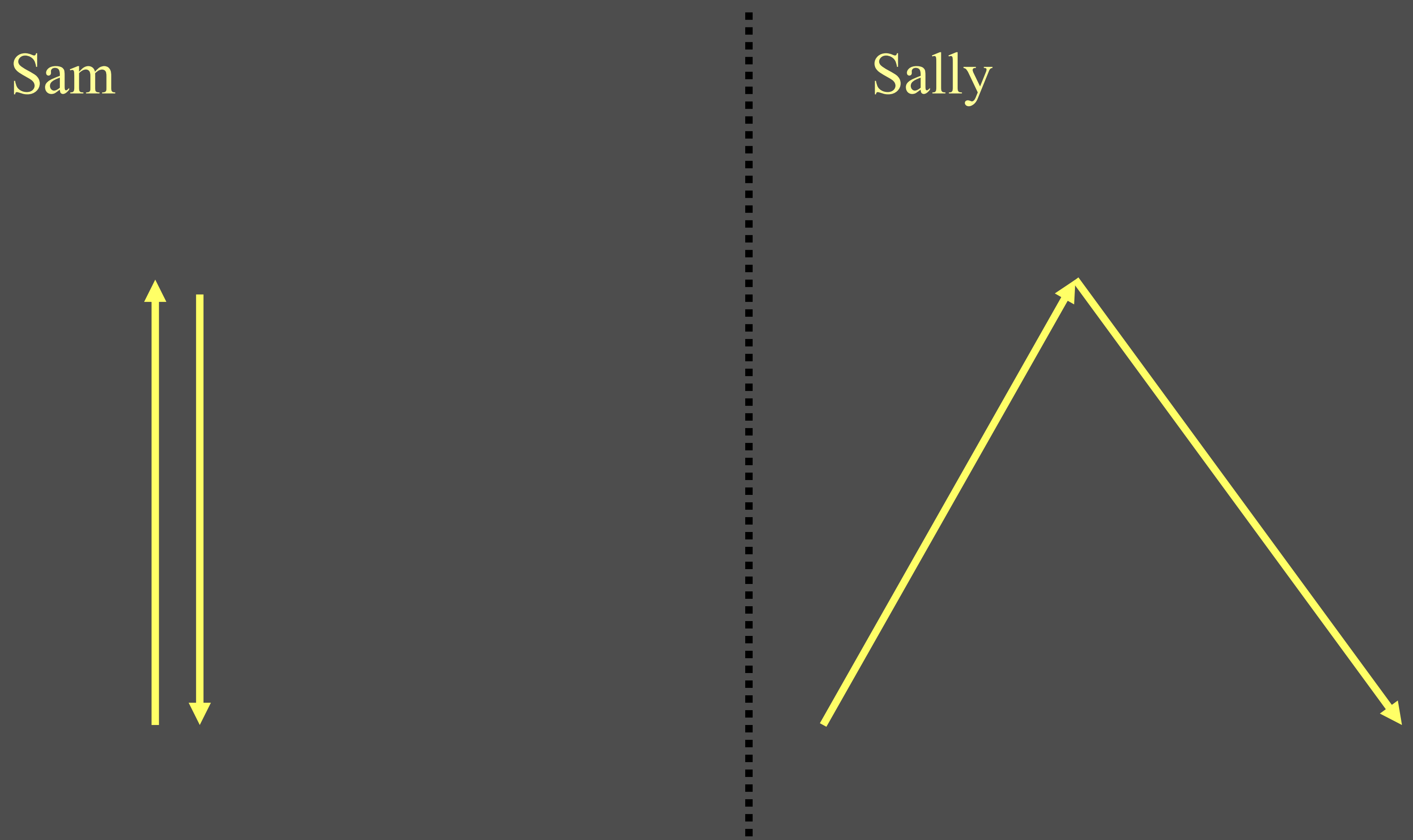
v
H

Sally is standing still, so it takes two clocks.



Light is emitted

Light returns

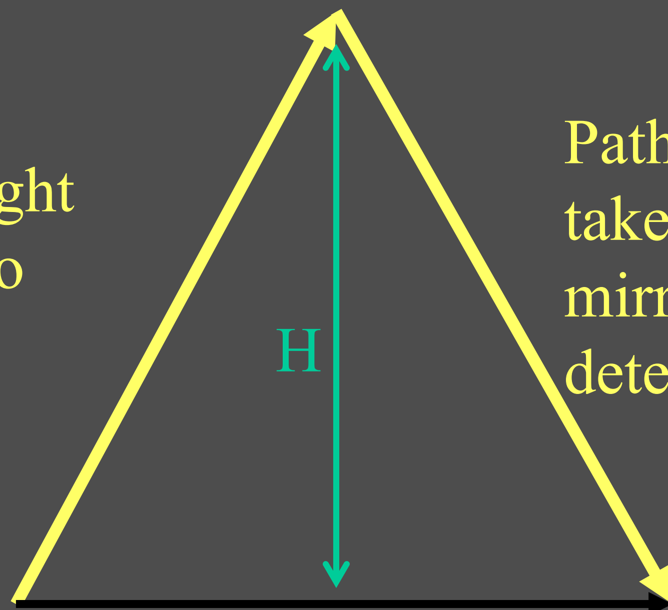


Sally sees the light traveling further. If light travels at a constant speed, the same "event" must seem to take longer to Sally than Sam!

Time is relative … not absolute!!

From Sally's point of view

Path light takes to mirror



Path light takes from mirror to detector

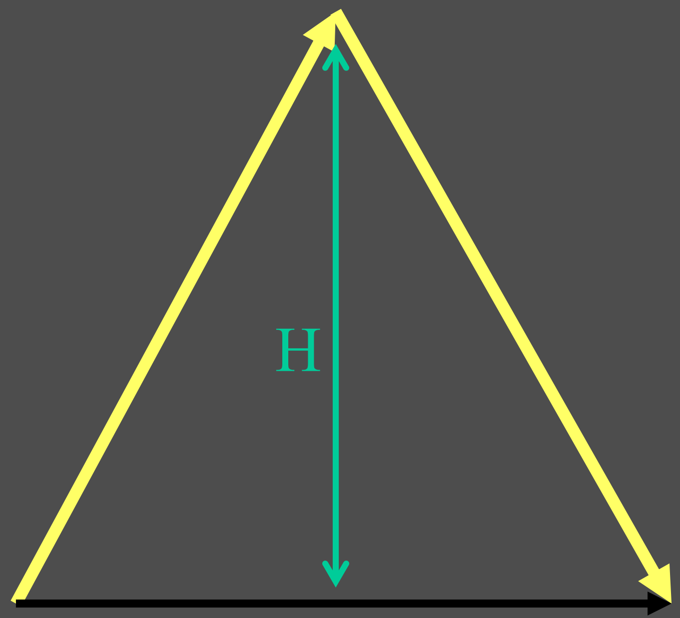
Distance train travels while light is traveling

$= VT_{sally}$

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

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)

$2H/T_{sam} = c$

$c = 2D/T_{sally}$

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

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

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

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

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

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

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

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

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.

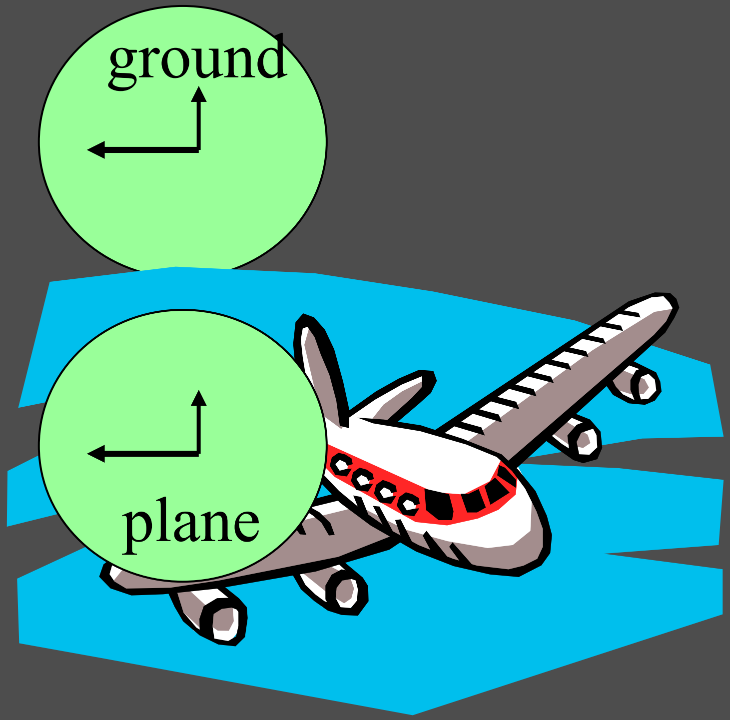
Yet, $T_{sally} > T_{sam}$

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!



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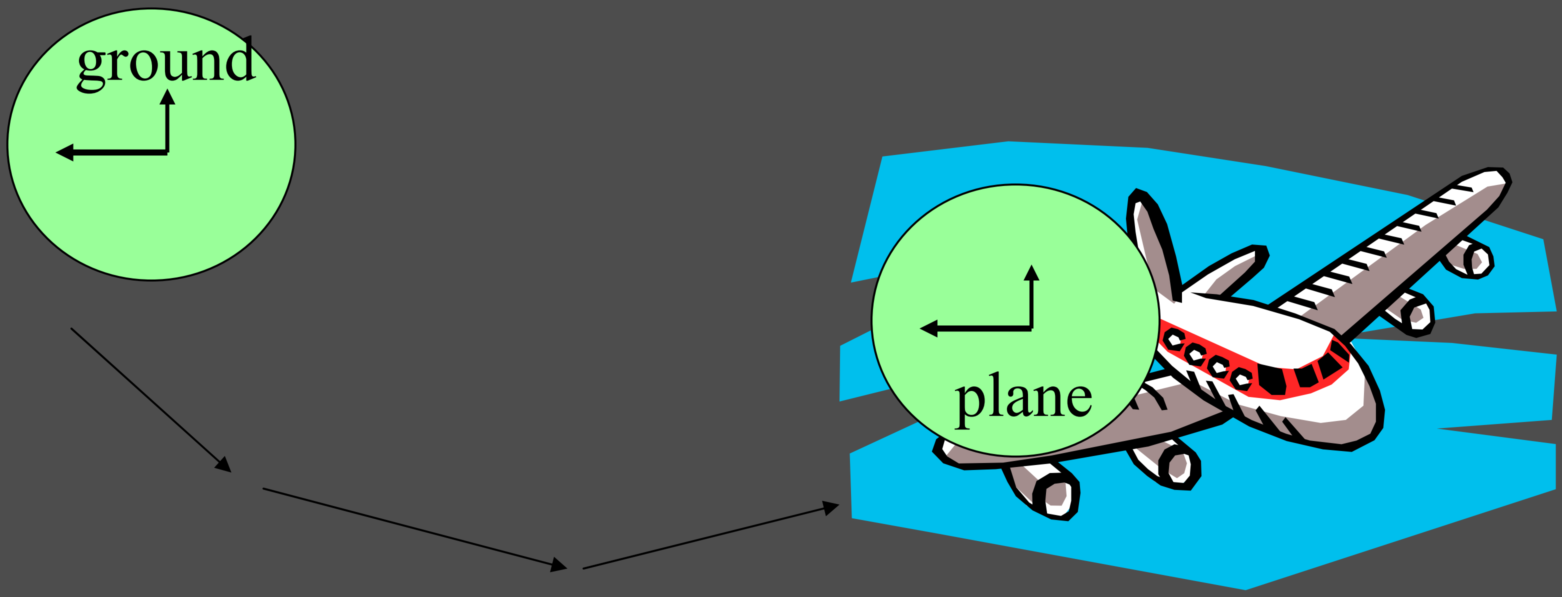
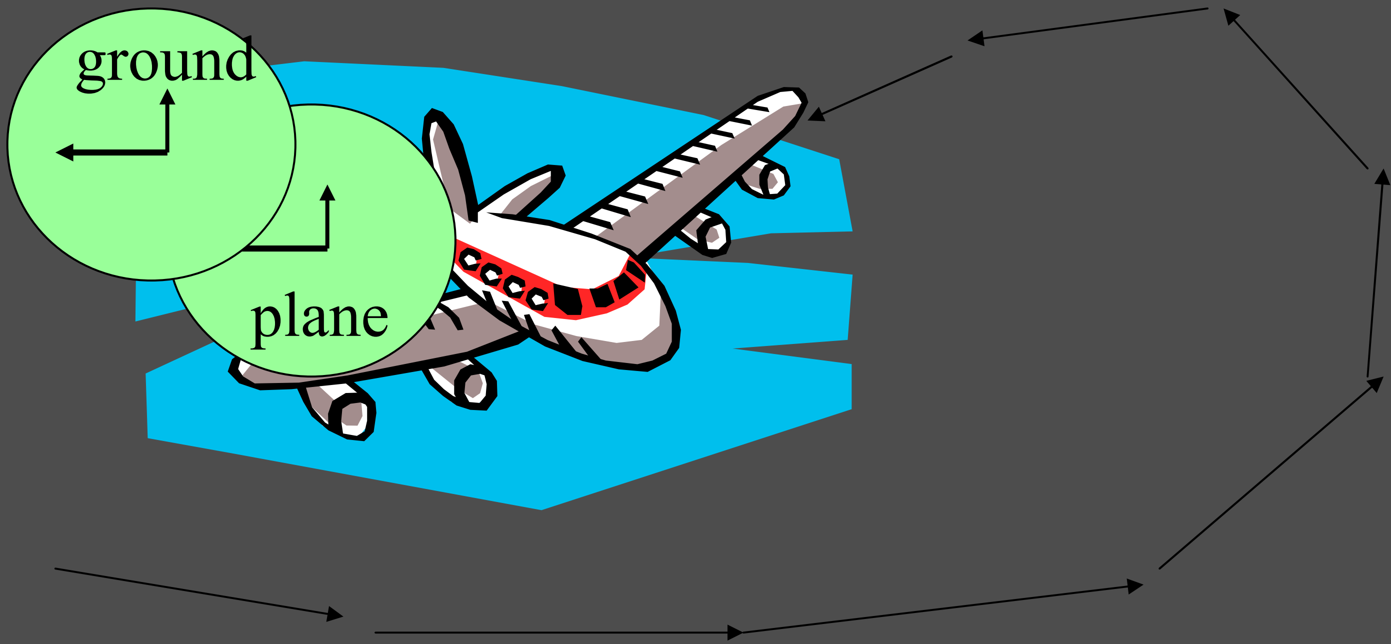
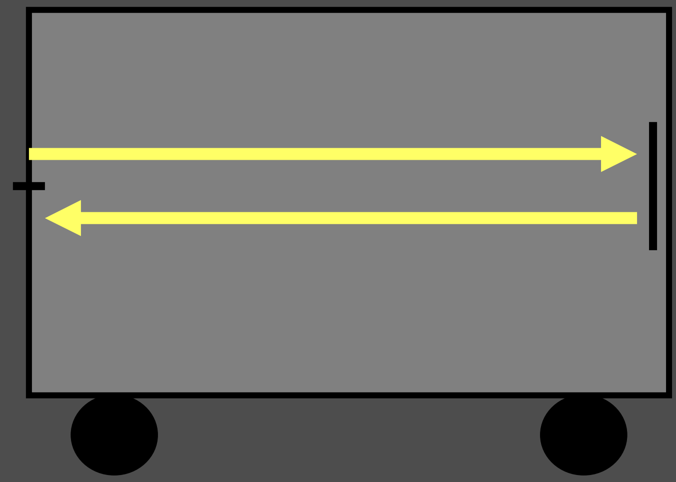
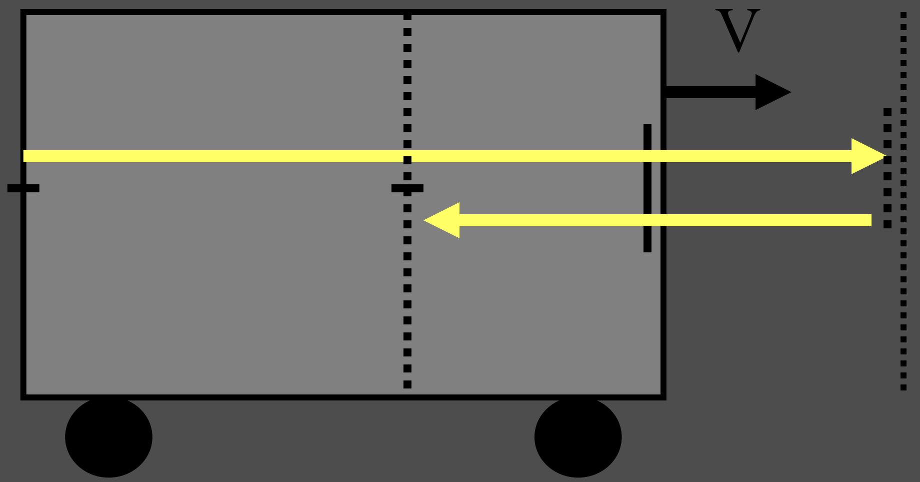


Less time elapsed on the clocks carried on the airplane





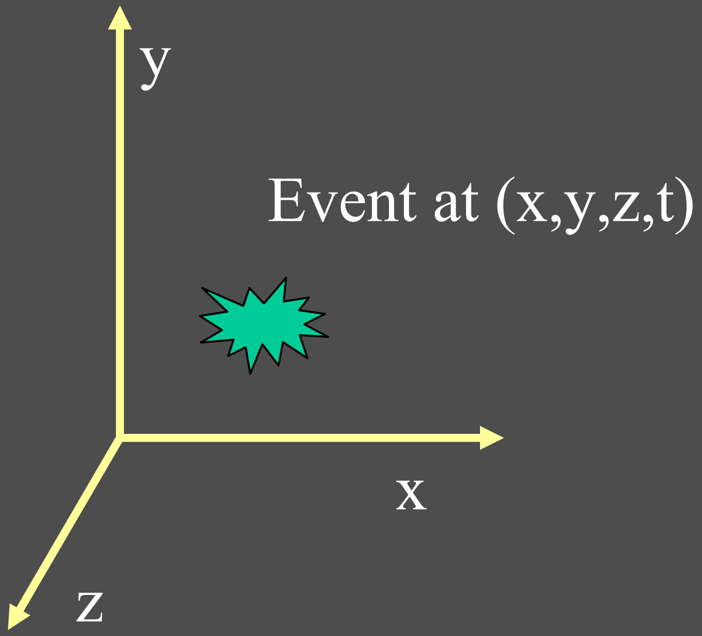
Measure the length of a boxcar where you are on the car.



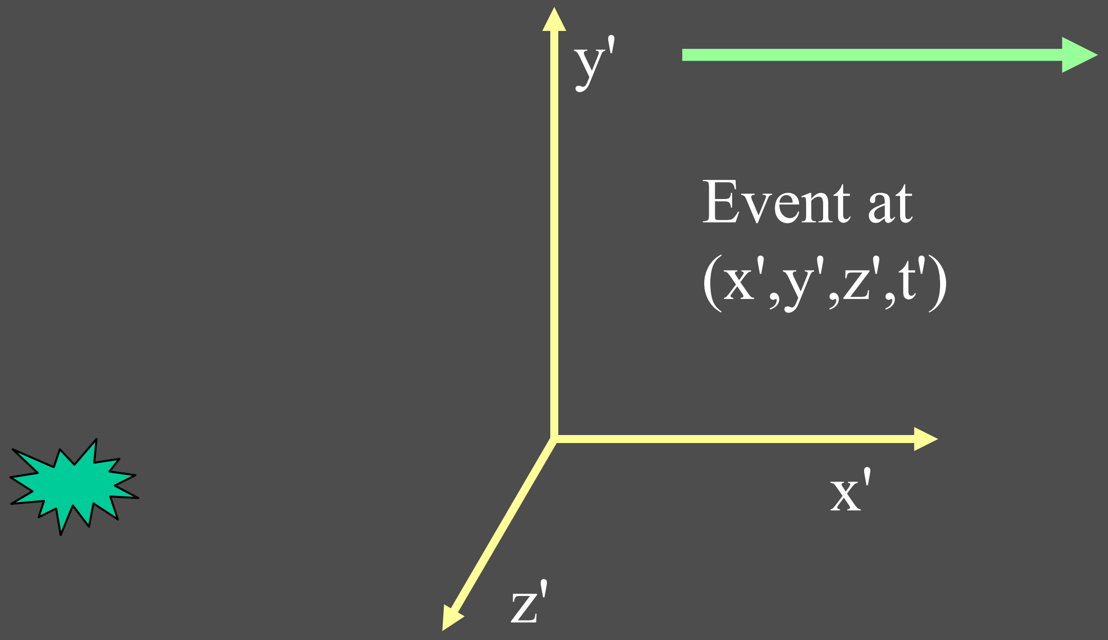
Measure the length of a boxcar moving by you.

Length is relative, too!

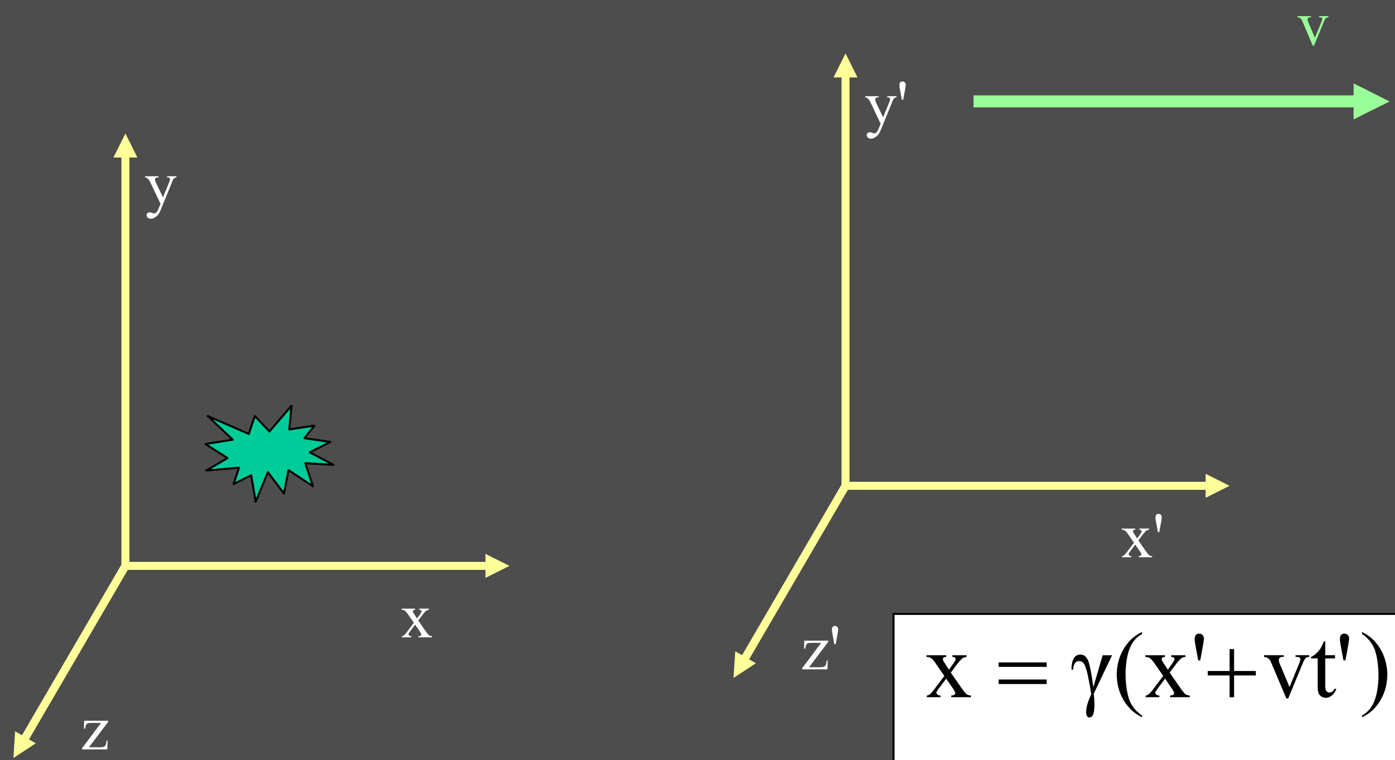
Lorentz transformations



Lorentz transformations



Lorentz transformations



How are (x,y,z,t) related to (x',y',z',t')?

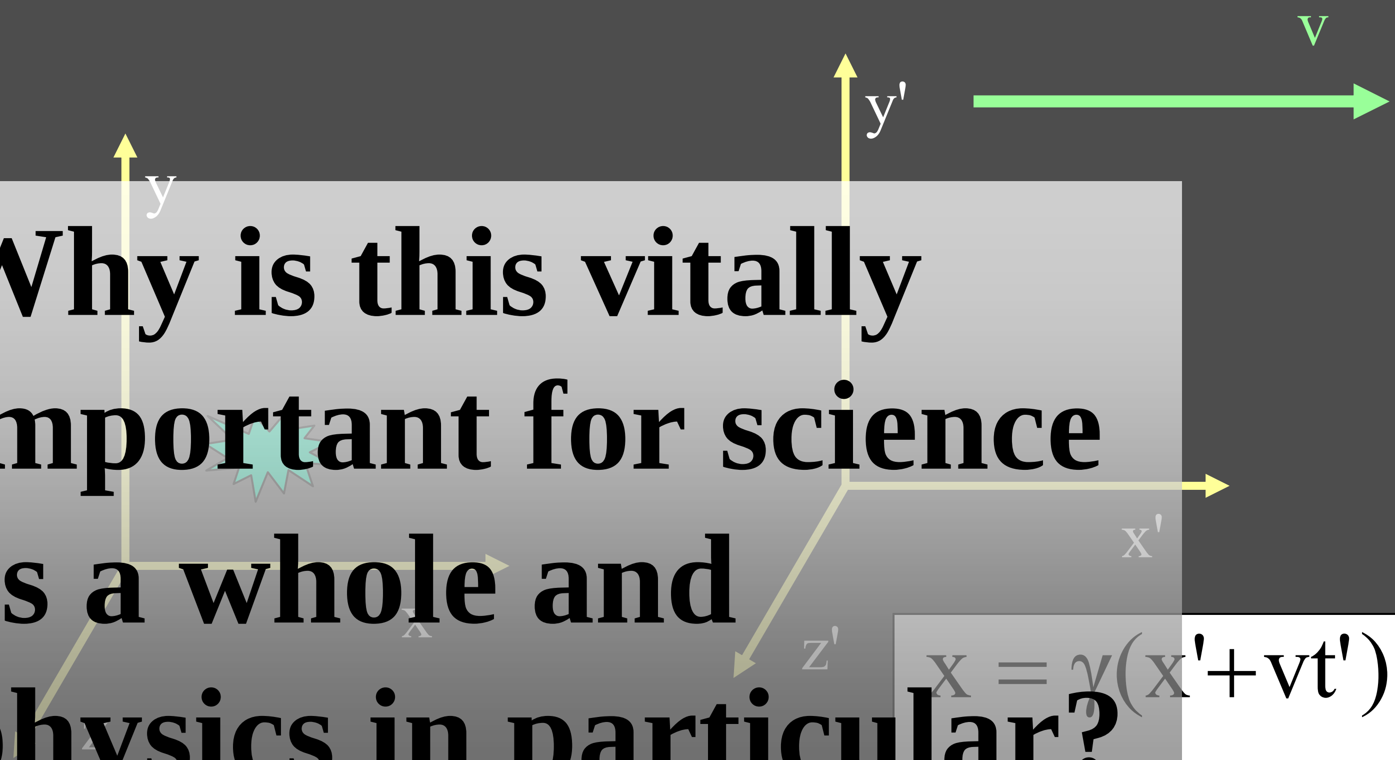
$$x = \gamma(x' + vt')$$

$$y = y'$$

$$z = z'$$

$$t = \gamma\left(t' + v\frac{x'}{c^2}\right)$$

Lorentz transformations



Why is this vitally important for science as a whole and physics in particular?

How are (x,y,z,t) related to (x',y',z',t')?

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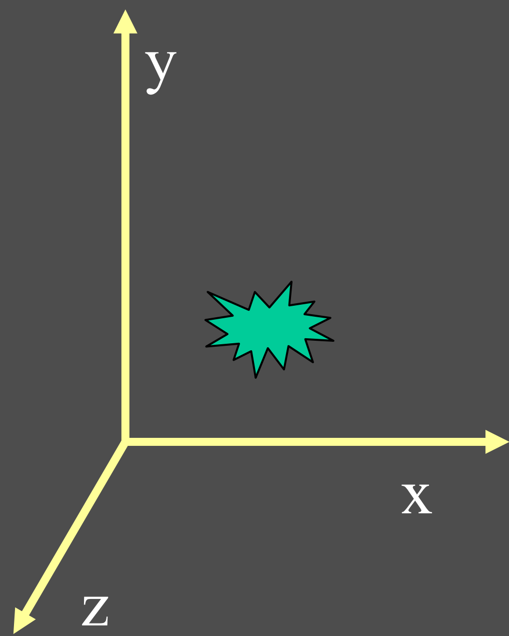
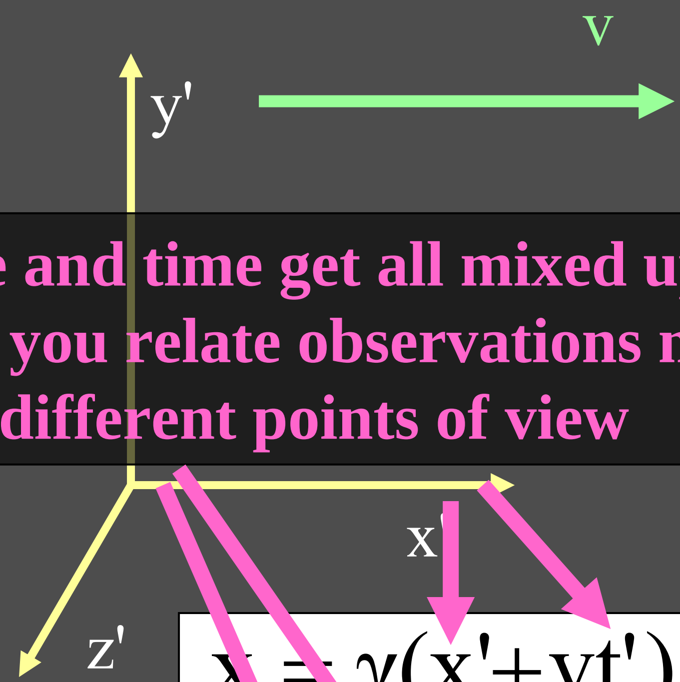
Lorentz transformations





Space and time get all mixed up when you relate observations made from different points of view

$$x = \gamma(x' + vt')$$

$$y = y'$$

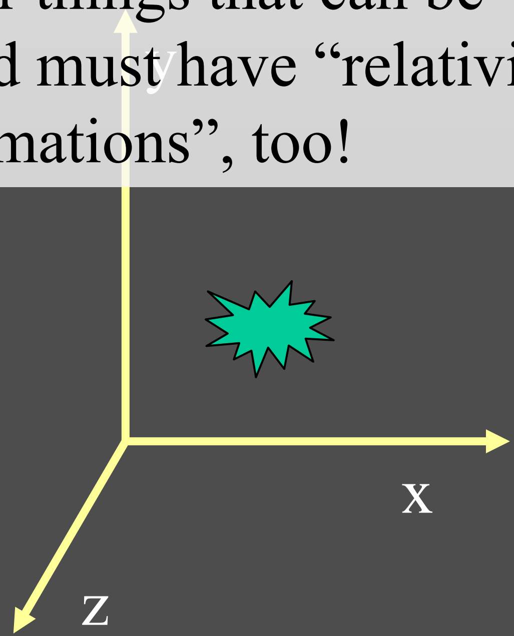
$$z = z'$$

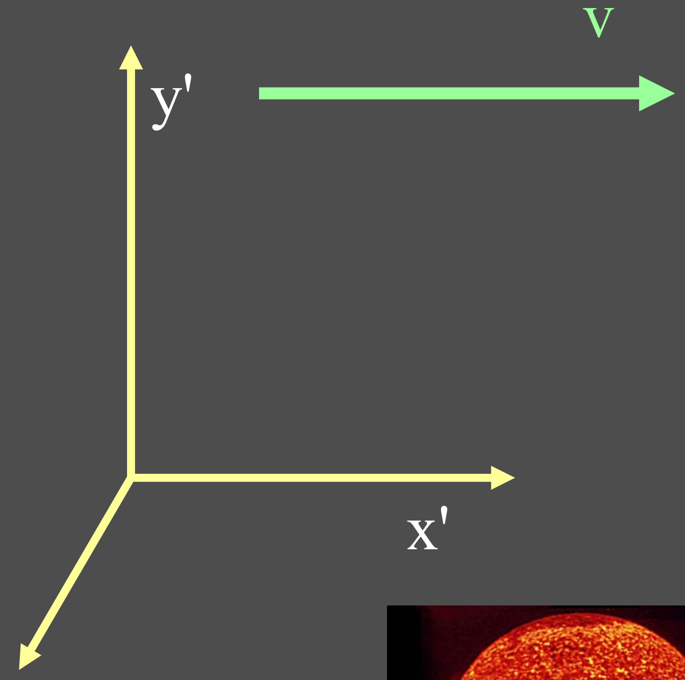
$$t = \gamma\left(t' + v\frac{x'}{c^2}\right)$$

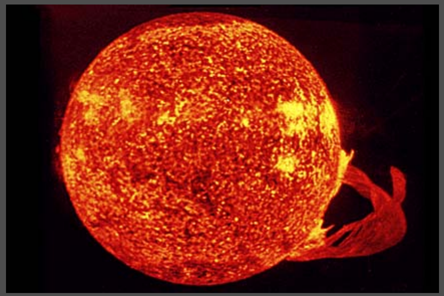
How are (x,y,z,t) related to (x',y',z',t')?

Spacetime

All other things that can be observed must have “relativisitic transformations”, too!







$$x = \gamma(x' + vt')$$

$$y = y'$$

$$z = z'$$

$$t = \gamma\left(t' + v\frac{x`}{c^2}\right)$$

$$p = mv$$

$$\mathbf{E=mc^2}$$