Physics 294H

- Professor: Joey Huston
- email:huston@msu.edu
- office: BPS3230
- Homework will be with Mastering Physics (and an average of 1 hand-written problem per week)
  - **Help-room hours: 12:40-2:40 Monday (note change); 3:00-4:00 PM Friday**
  - **No hand-in problem for this Wed**
- Quizzes by iclicker (sometimes hand-written)
- Average on 2nd exam (so far)=71/120
- **Final exam Thursday May 5 10:00 AM – 12:00 PM 1420 BPS**
- Course website: www.pa.msu.edu/~huston/phy294h/index.html
  - lectures will be posted frequently, mostly every day if I can remember to do so

Enter Fitzgerald and Lorentz

- In 1882, 2 physicists, G.F. Fitzgerald and H.A. Lorentz, suggested a solution to problem posed by Michelson-Morley experiment
- Fitzgerald: moving through ether generates a resisting force which compresses apparatus
  - 1/2 millionth of 1 percent
  - enough to explain lack of ether drift caused by Earths motion through the ether
- Lorentz was looking for transformation equations between inertial frames of reference that would leave electromagnetic forces invariant
- Same transformation as found by Fitzgerald; interesting consequences
  - moving objects would contract
  - time would slow down
- Poincare also pointed out that mass would increase with speed and that the maximum speed for any object would be the speed of light

Albert Einstein, again

- All of the previous ideas are in Einstein's theory of special relativity
- Significance of Einstein's work is that he was able to show simply and directly that they were natural consequences of a profound and insightful reexamination of some basic assumptions about nature of physical measurements

- Circumstances at beginning of 20th century similar to those at time of Newton
- Several physicists were close to making a breakthrough but only one (Newton, Einstein) able to master the situation

- In 1905 paper, *On the Electrodynamics of Moving Bodies*, enumerated 2 special principles that should be applicable in all frames of reference
  - I: laws of physics are invariant in all inertial reference frames
  - II: It is a law of physics that the speed of light is the same in all inertial reference frames independent of speed of the source or detector
  - **Thus, ether can not be detected by experimental means; so should be discarded**
- Einstein realized that it was necessary to reconsider the meaning of space and time, and how they are measured. Space and time are not independent concepts but are intrinsically linked with each other.
  - no such thing as absolute length or absolute time
  - perhaps time is not the same in 2 inertial reference frames

Simultaneity

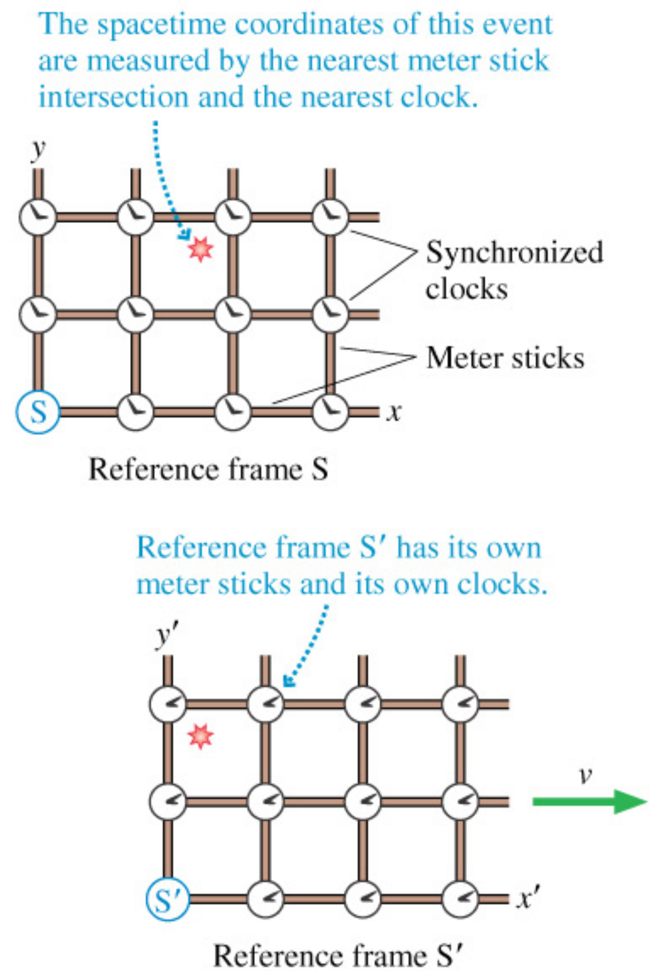
- A basic premise of Newtonian mechanics is that a universal time scale exists that is the same for all observers
- "Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external"
  - Isaac Newton
- Newton took the concept of simultaneity for granted
- Einstein was forced to abandon this assumption

Was Isaac Newton really Q?

- You decide

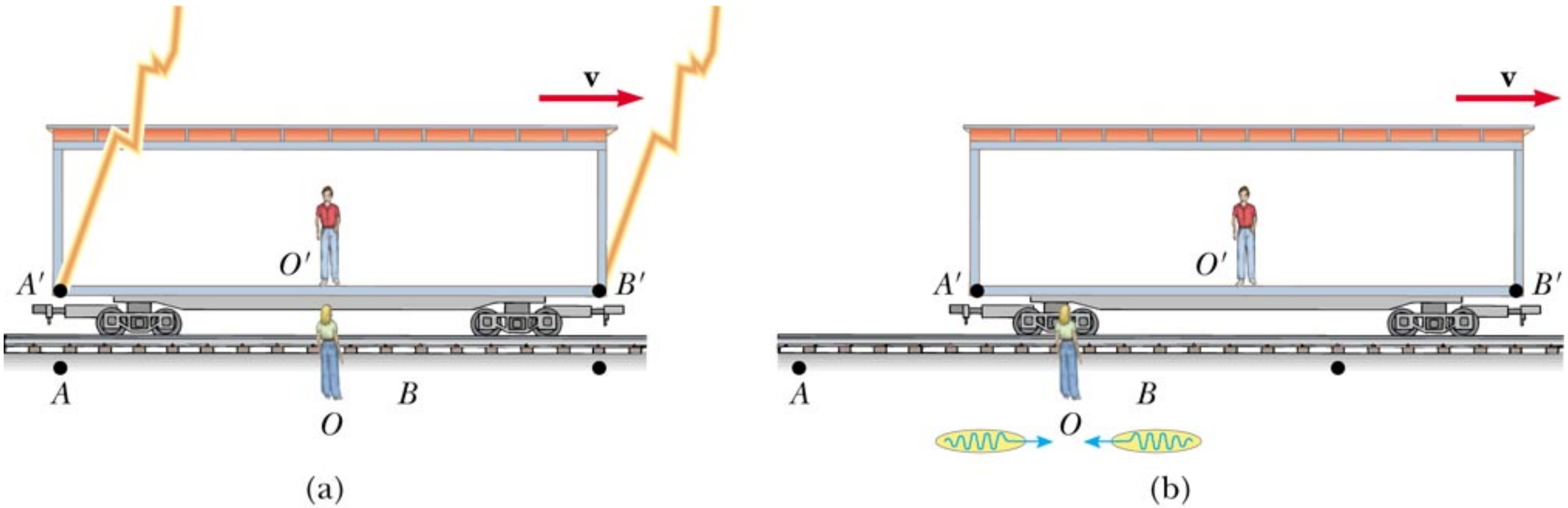
Spacetime

- We identify an event with spacetime coordinates (x,y,z,t)
- The same event will have different coordinates in different reference frames
  - including t
  - a difference from the Newtonian/Galilean point of view



Another gedanken

Consider a train moving with velocity v, two observers O and O’, and lightning striking the two ends of the boxcar



Light signals reach O at the same time; she concludes the two lightning strikes were simultaneous.

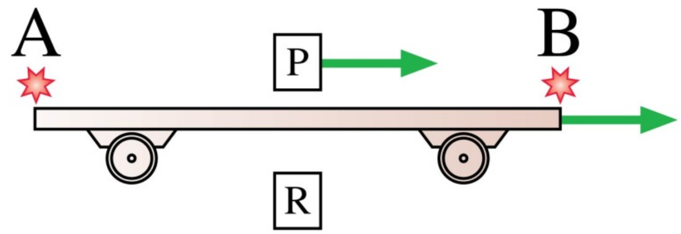
Light from B’ reaches observer O’ before the light from A’; observer O’ concludes that the lightning struck at B’ before it did at A’.

Two events which appear to be simultaneous in one frame of reference are not, in another frame

Simultaneity lost

- Simultaneity is not an absolute concept but one that depends on the state of motion of the observer

Peggy is standing at the center of a railroad car as it passes Ryan. Firecrackers A and B at the ends of the car explode. A short time later, flashes from the two explosions reach Peggy at the same instant. In Peggy's reference firecracker A explodes ___ firecracker B.



A. before
B. at the same time as
C. after

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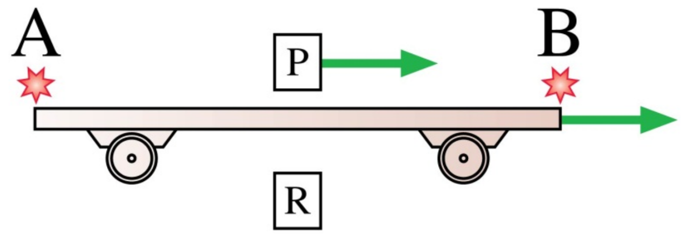

A. before

✔ **B. at the same time as**

C. after

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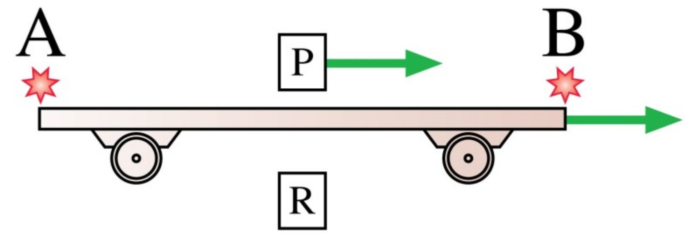

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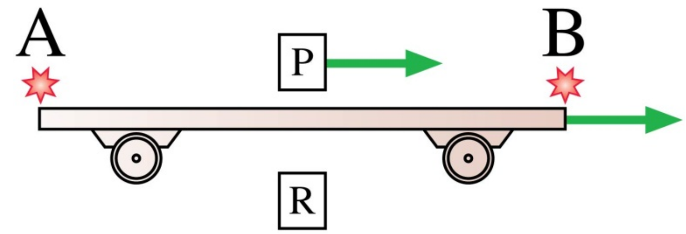


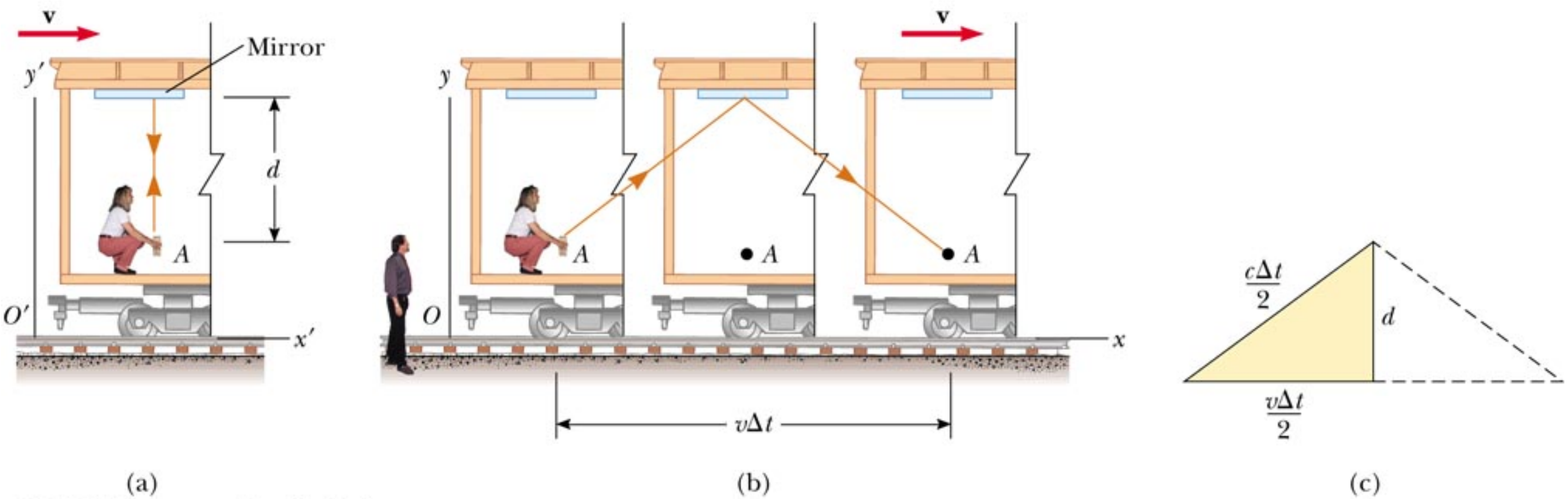
✔ **A. before**

B. at the same time as

C. after

Ryan has to agree that the flashes reach Peggy simultaneously because their arrivals could be measured with detectors. In Ryan's frame, Peggy is moving away from the point in space where A exploded, and toward B. Firecracker A had to explode first if the light waves from A are to reach Peggy at the same instant as light waves from B.

Time Dilation: another gedanken

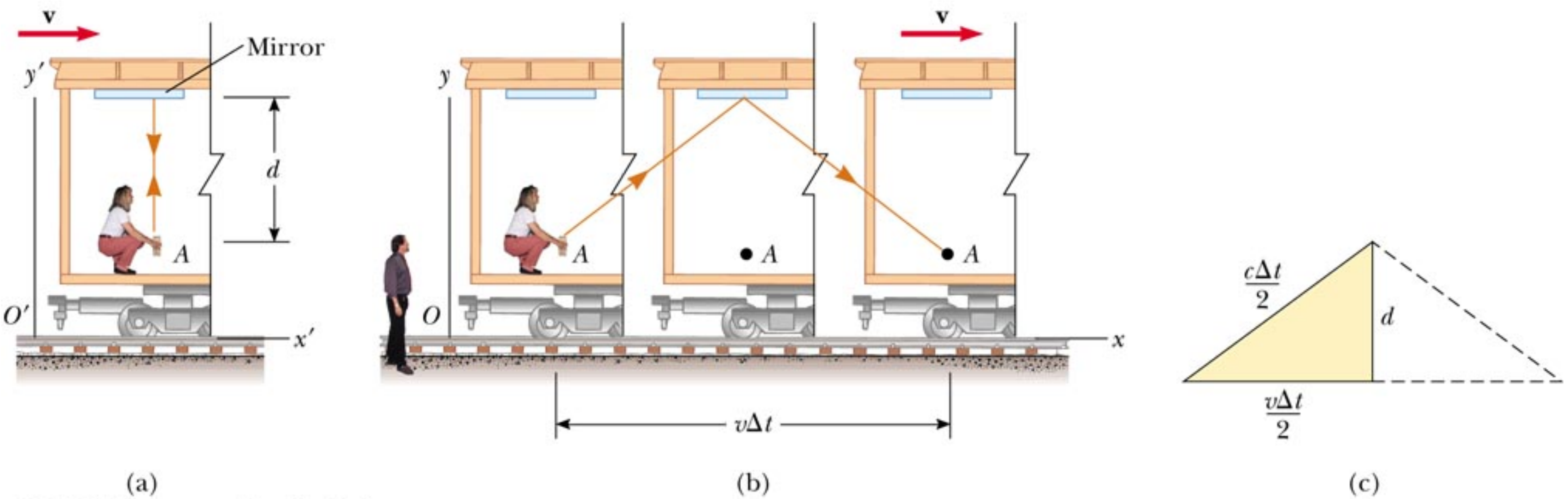


Simultaneity is out the window. Observers in different reference frames may also measure different time intervals between a pair of events.

Consider a boxcar moving to the right with a velocity v. Observer O’ shines a laser and observes it reflecting from a mirror on the ceiling. She’s timing this and observes the total time for the laser to reflect and come back to be: $\Delta t=2d/c$

Now observer O, standing alongside the track, is also observing this event. Because of the velocity of the boxcar, observer O sees that the laser light has to travel along a longer path: $\sqrt{d^2+(v\Delta t/2)^2}$ *2

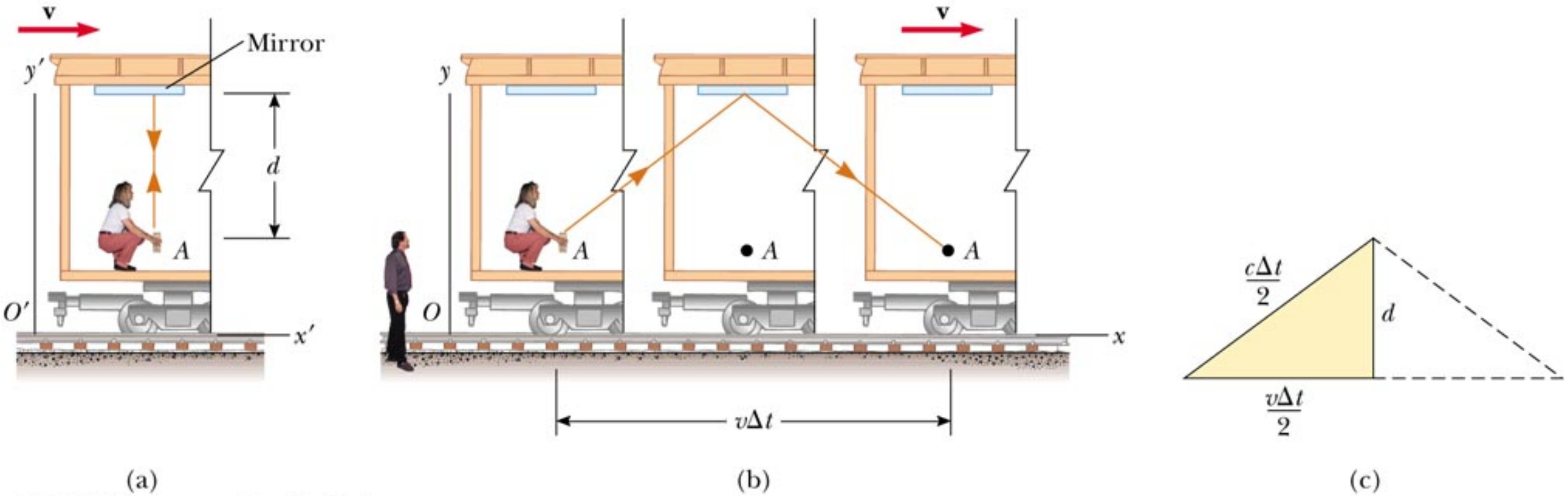
Time Dilation: another gedanken



Now the speed of light c is the same in both frames of reference. Thus, observer O must measure a longer time for the light to reflect from the mirror than observer O’. In other words, time appears to move more slowly in the boxcar according to observer O than according to observer O’.

By how much?

Time Dilation: another gedanken



solve for Δt

$$\left(\frac{c\Delta t}{2}\right)^2 = \left(\frac{v\Delta t}{2}\right)^2 + d^2$$

$$\Delta t = \frac{2d}{\sqrt{c^2 - v^2}} = \frac{2d}{c\sqrt{1 - \frac{v^2}{c^2}}}$$

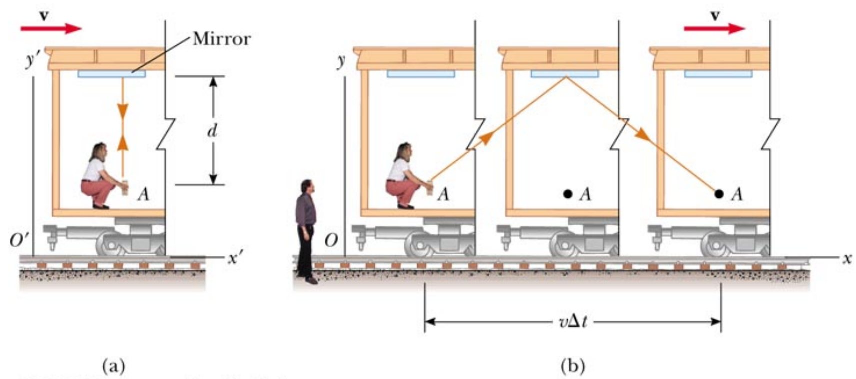
$$\Delta t = \gamma \Delta t'$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1}{\sqrt{1 - \beta^2}}$$

Define Δt' = 2d/c, the time measured by observer O'.
We'll call this the proper time.

Time dilation

- So…the time inverval between two events measured by an observer moving with respect to a clock is longer than the time interval between two events measured by an observer at rest with respect to the clock
- …i.e., a clock moving past an observer at a speed v runs more slowly than identical clock at rest with respect to the observer, by a factor γ^{-1}



Δt_p, the proper time

Everything depends on γ

Velocity (m/s)	γ
100 m/s	1
1000 m/s	1
10,000 m/s	1.000000001
100,000 m/s	1.000000056
1,000,000 m/s	1.000005556
10,000,000 m/s	1.000556019
100,000,000 m/s	1.060660172
200,000,000 m/s	1.341640787
290,000,000 m/s	3.905667329