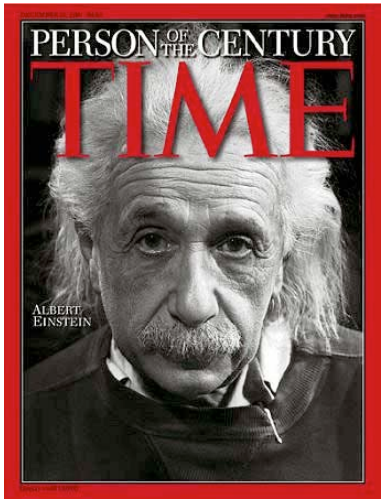
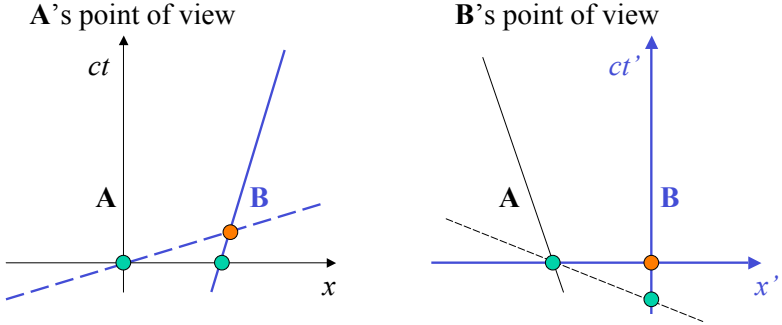
Special Relativity (1905)

- Two Invariants
  - Speed of light, c
  - Spacetime distance ($ds^2=c^2dt^2-dx^2$)
- Unification of space and time
  - No absolute space or time exists: **Relativity**
- Special relativity does not include gravity
  - Spacetime is not yet Riemannian, but *Minkowskian*



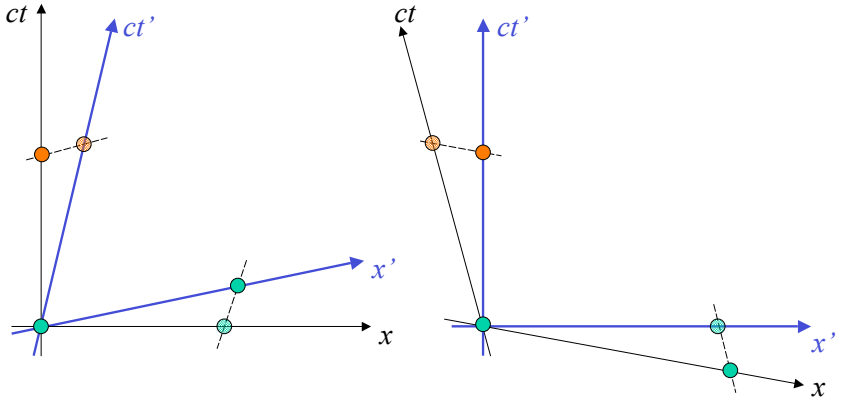
Albert Einstein (1879-1955)

Relativity of Space and Time

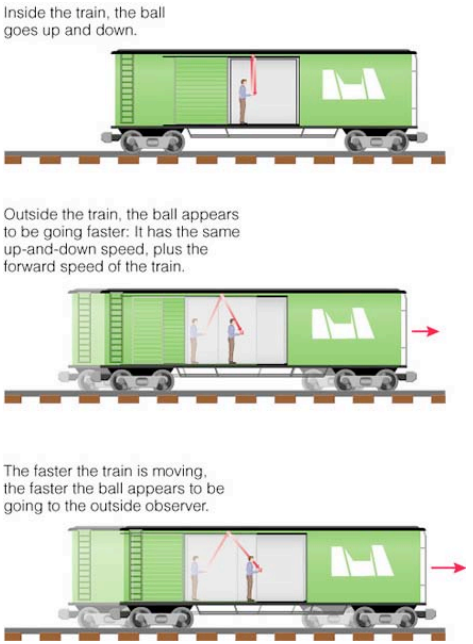


- A's space coordinate, ***x***, does not coincide with B's, ***x'***. Rather, ***x*** is a combination of ***x'*** and ***ct'***.
- The same is true for time coordinate.
  - This means that simultaneous events in A's coordinate would not appear simultaneous in B's coordinate!
- But, spacetime distance remains unchanged.

Time Dilation and Length Contraction



- When A sees B moving, B's time interval appears to be longer (clock ticks more slowly; *time dilation*) ed and B's length appears to be shorter (*length contraction*). And vice versa.



Intuitive way to understand it

- From your point of view, the ball appears to move faster; however, light cannot travel faster!
- Therefore, it must take light **more time** to come back down to the laser
  - Time Dilation

Formulae

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

- γ is always greater than 1.
- As v approaches c, γ becomes large.
- When $v=c$, γ is infinite.

- B's unit time in A's frame equals A's unit time in A's frame **multiplied** by γ. (Hence *time dilation*)
  - Be careful! **The time actually elapsed** in B's frame gets shorter because **the unit time** gets longer.
- B's unit length in A's frame equals B's unit length in B's frame **divided** by γ. (Hence *length contraction*)

Mass Increase

- A pushes B (whose mass at rest is m) by applying a force F.
  - Acceleration is given by $a=F/m$.
  - Velocity acquired would be $v=a\,dt=Fdt/m$
- When B is moving, the clock ticks more slowly
  - B feels the force for a shorter time
  - $v'=a\,dt'=Fdt'/m=Fdt/(m\gamma)$
- Thus, the mass of B appears to be bigger by γ!
- Nothing can be accelerated to the speed of light, because the mass becomes infinite.