Modern Physics

Day 1

Outline

0. Review Syllabus

I. Special Theory of Relativity

I. Theory of space & time (Einstein 1905)

Einstein's Two Postulates

(1) Principle of relativity: The laws of physics apply just as uniformly well in a moving system as in one at rest.

In a train car my expmts just the same as at rest.

Embarassing implication: no such thing as "rest system".

∴ 1st postulate defective.

(2) Universal Speed of Light: The speed of light (in vacuum) is the same (3×10^8 m/s) regardless (of the motion of its source, or the observer).

(1) Princ. of rel. Old Stuff (Galileo said it.)

Def.: An inertial reference frame is one in which

Newton's 1st law (the law of inertia) holds.

(1') The ordinary laws of physics apply in any inertial frame.

(2') Speed of light is the same for all inertial observers.

Example of 1st postulate p2/4

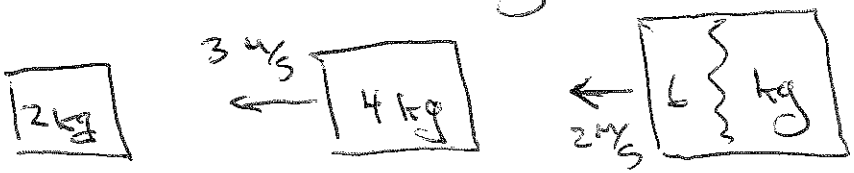
Before After

Cons. of momentum:

$2 \cdot 3\ \text{kg m/s} = 6\ \text{kg} \cdot v$

$\Rightarrow \boxed{v = 1\ \text{m/s}}$

In frame S' moving at +3 m/s



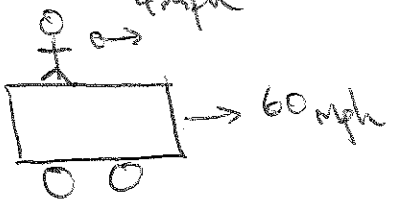
Before After

Was momentum conserved?

$4(-3)\ \text{kg m/s} \stackrel{?}{=} 6(-2)\ \text{kg m/s}$

Yes!

(2') 2nd postulate. Revolutionary. Absurd on its face



How fast is the ball going relative to the ground?

64 mph

Galileo's velocity addition:

$v_{AC} = v_{AB} + v_{BC}$

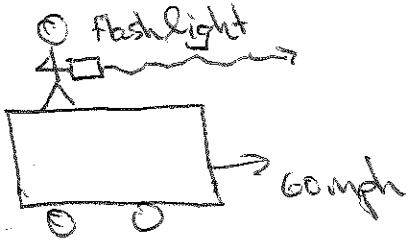
ball/ground, ground/train

Einstein's velocity addition:

$$v_{AC} = \frac{v_{AB} + v_{BC}}{\left(1 + \frac{v_{AB} \cdot v_{BC}}{c^2}\right)}$$

$$v_{light/ground} = \frac{c + v}{1 + \frac{c \cdot v}{c^2}}$$

$$= c \cdot \frac{c+v}{c+v} = c \; !$$



This is the one first of four "elementary geometrical" consequences of the 2 postulates:

How Einstein's rule saves 2nd postulate:

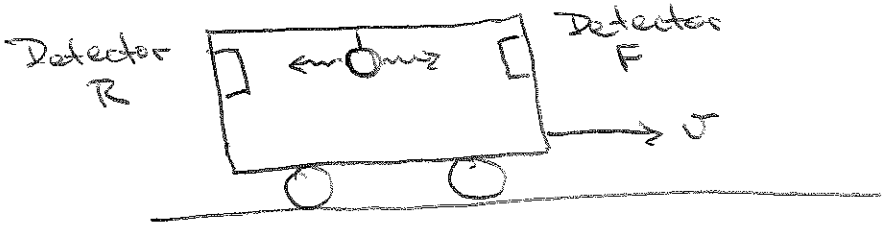
Def: An event happens at a particular location at a particular time.

(1) Relativity of Simultaneity

(2) Time dilation

(3) Lorentz contraction

(4) Einstein velocity addition



Which detector (R or F) fires first?

Let's derive these

(1) Relativity of simultaneity

(A) Observer on the train:

R & F simultaneously.

(B) Observer on the ground:

R before F.

Conclusion: Two events simultaneous to one (inertial) observer, may not be to another!

"Observation": what you get after correcting for how long the message took to reach you. You could think of a custodian attached to each reference frame.