<u>Today</u>
I.   Short logistics: in-person meetings, first computing posted, recording

II.   Last Time

III. The oddity of the Universal Speed of Light

IV. Deriving the Geometrical Consequences of Special Relativity.

I.   Talked about two postulates of Special Relativity:

(1) <u>Principle of Relativity</u>

(2) <u>Universal Speed of Light $c = 3 \times 10^8$ m/s</u>

We revised the first postulate so that we didn't have to refereeto rest frames. Instead we talk about "inertial reference frames" , which is a frame in which Newton's law of inertia holds.

I. The Oddity of the Universal Speed of Light

Remarks: 1. Is old stuff. (Galileo said it.) Embarrassing implication though, there's no such thing as a "rest system". Thinking about this led us to the idea of an <u>inertial reference frame:</u> this is a frame in which Newton's 1st law (the law of inertia) holds.

The second postulate is revolutionary because it forces us to revise our notion of how velocities add. Let's first how Galileo added velocities:

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

Here the subscripts are supposed to remind us that velocities are always relative. The first one reads as the velocity of object A with respect to object (or frame) C. In my train and ball example, A=the ball, object B=train, and object C=ground. So, specifically,

$$v_{ball/ground} = v_{ball/train} + v_{train/ground}.$$

This law of velocity addition must be wrong! (If Einstein is right.)

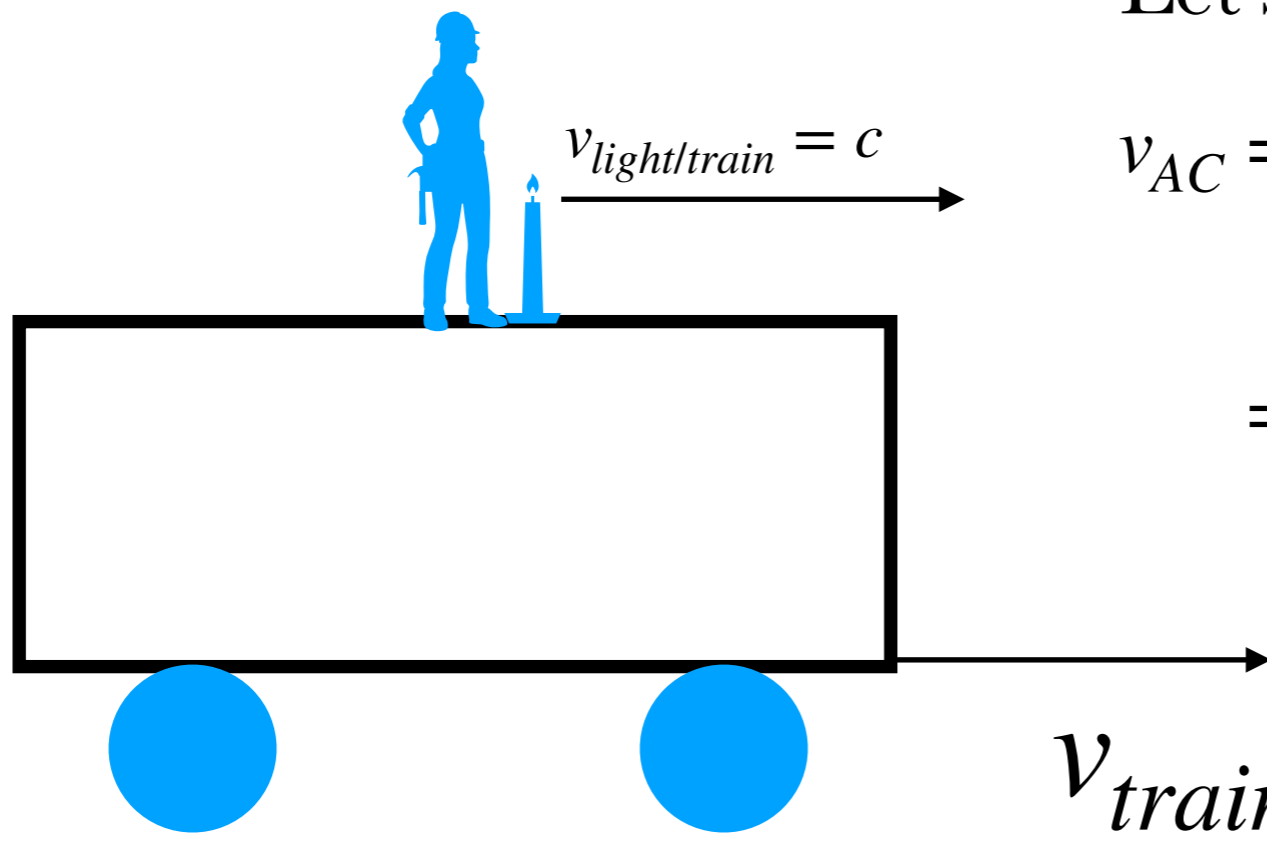# I. The Oddity of the Universal Speed of Light

We must modify the law of velocity addition. Einstein's velocity addition works the following way:

$$v_{AC} = \frac{v_{AB} + v_{BC}}{1 + \frac{v_{AB}v_{BC}}{c^2}}.$$

Let's compute

$v_{light/train} = c$

$$v_{AC} = v_{light/ground} = \frac{v_{light/train} + v_{train/ground}}{1 + \frac{v_{light/train}v_{train/ground}}{c^2}}$$

$$= \frac{c + v}{1 + \frac{c \cdot v}{c^2}} = \frac{c}{c} \frac{c + v}{1 + \frac{v}{c}} = c$$

$$v_{train/ground} = v.$$

I. The Oddity of the Universal Speed of Light

How does the law of velocity addition

$$v_{AC} = \frac{v_{AB} + v_{BC}}{1 + \frac{v_{AB}v_{BC}}{c^2}},$$

not just complete invalidate Galileo altogether? The answer is subtle and has to do with the numbers involved: what is the velocity of my son's ball with respect to the ground? I'm driving at 60mph=27m/s and my son throw's the ball at 3mph=1.3m/s with respect to the car.

Let's compute

$$v_{AC} = v_{ball/ground} = \frac{v_{ball/car} + v_{car/ground}}{1 + \frac{v_{ball/car}v_{car/ground}}{c^2}}$$

$$= \frac{1.3m/s + 27m/s}{1 + \frac{1.3 \cdot 27m^2/s^2}{9 \times 10^{16}m^2/s^2}} \approx (1.3 + 27)m/s$$

I hope to have convinced you that the 2nd postulate can and does make sense!

I.   There are 4 wonderful results in Special Relativity:

1.   Relativity of Simultaneity

2.   Time Dilation

3.   Length Contraction (Lorentz Contraction)

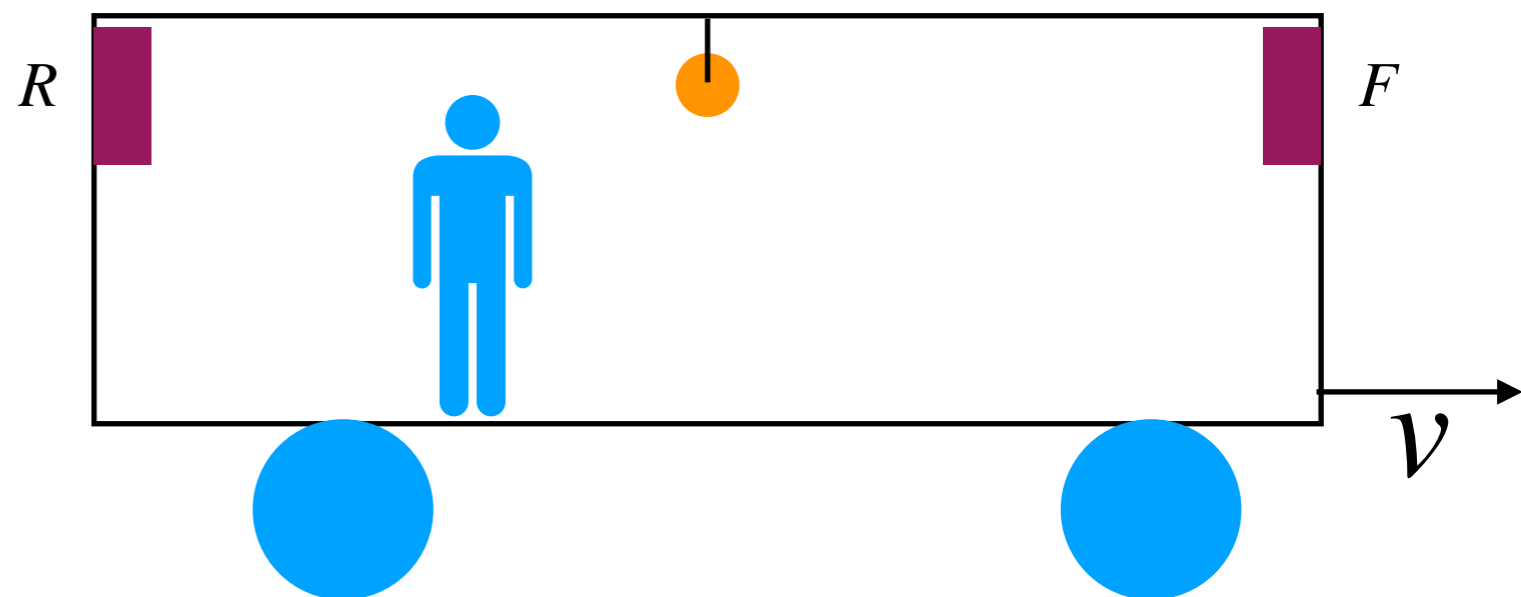4.   Einstein Velocity Addition

Let's derive these.

(1) Relativity of Simultaneity:

Def: An event is something that happens at a particular location and at a particular time.

Which detector fires first?

(A) According to an
      observer on the train?

R and F fire
simultaneously.

Which detector fires first?

(A) According to an observer on the train?

R and F fire simultaneously.

(B) According to an observer on the ground?

R fires first and F second.

The fact that they disagree has massive consequences. There is no universal notion of simultaneity!!!