Chs 2 and 3---intro to special relativity

Special=constant velocities (no accelerated reference frames).

General relativity deals with accelerated reference frames ----(oh--and acceleration seems to be indistinguishable from gravitation)--spaceships, elevators, wonkavators.

Galilean relativity is valid when objects, reference frames are all moving "slow" ----compared to the speed of light. How slow? How good an approximation do you need?

Is there a cosmic "Ether" (medium through which all things move---so that the relative motion must be measured with respect to that Ether?. Like boat on water.

So, the more than 100 year old plus (around 1887) experiments by Michelson-Morley--say NO ETHER.

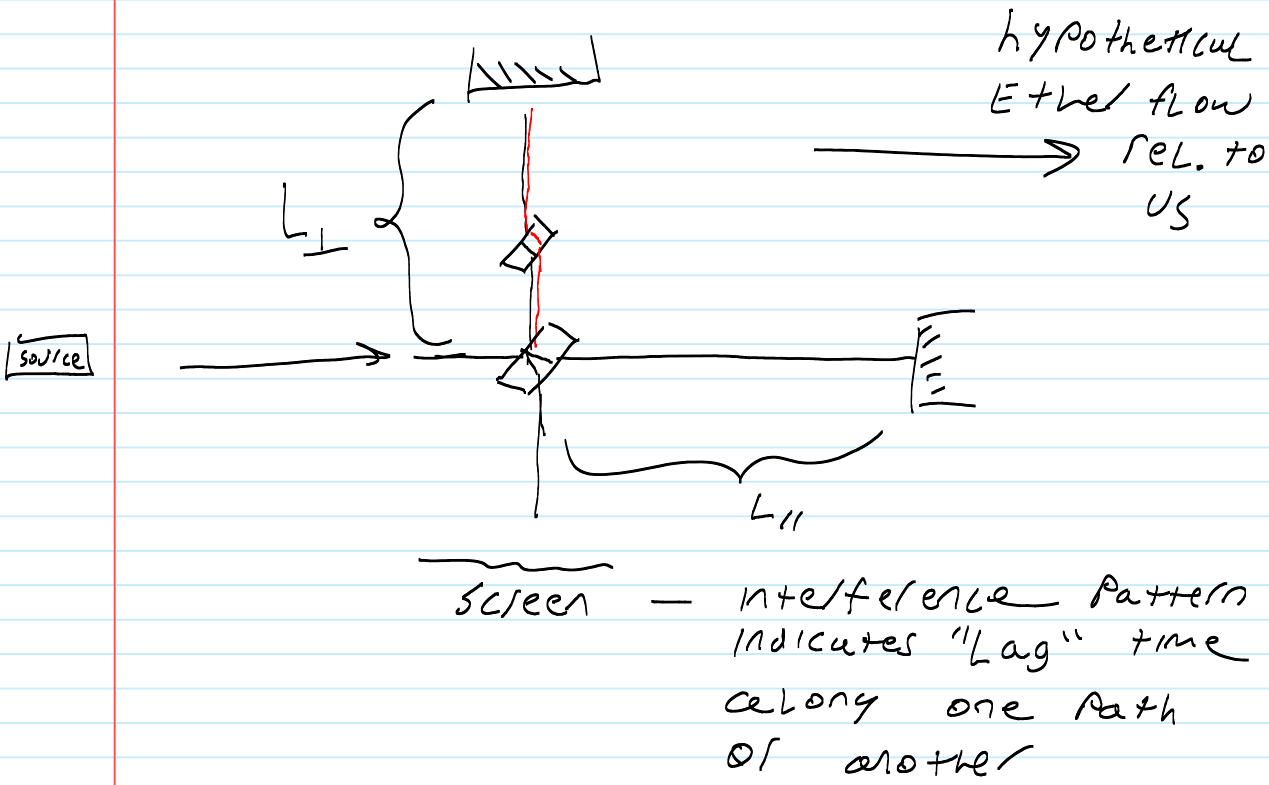
Think of that Ether like water flowing in a river. If you are in a boat paddling downstream, you get different motion (relative to me on the ground) than if you don't paddle at all, or if you paddle upstream.

If there is an Ether through which LIGHT moves---and if LIGHT has a speed relative to the ether, then I get a different result when the Earth is moving one way through the Ether than the other way.

So--Michelson-Morley measured the effects due to different light speeds upstream or downstream or across stream.

They measured the speed of light as the same regardless of our motion, and the same is true today.

The experiment



- Light enters from left to right---and hits a 50/50 beamspliter
  - Division of amplitude occurs--
  - Light--which started in phase (peaks lined up)-- travels down both--horizontal arm and also the vertical arm.
  - An additional plate ensures that both beams travel through the same thickness of glass before exiting the system.
- Horizontal beam hits mirror,
- comes back, and some light is directed out after hitting the beam splitter again (downward on my picture)
- The Vertical beam passes through the plate once, hits mirror, comes back through plate, and then through partial mirror/beamsplitter
  - Some of the vertical beam overlaps with the other and also heads down.
- IF THERE IS A TIME DELAY IN EITHER BEAM, THE PEAKS WILL NO LONGER LINE UP.
- WE WILL OBSERVE THE LAG OR GAIN OF ONE BEAM AS CONSTRUCTIVE OR DESTRUCTIVE INTERFERENCE

If there is an "ether" then when one arm of the apparatus is lined up with the ether ($L_{//}$) will have a different transit time for light than the perpendicular arm ($L_{\perp}$). See the canoe example 1.4

If $L_{\perp} = L_{//}$ then $T_{//} > T_{\perp}$ (if medium) — see canoe example 1.4

If there is a medium then $\Delta T \neq 0$

ALL observations → ΔT is in fact zero.

NO ETHER

$T_{//} - T_{\perp}$

If Ether then $\Delta T = \dfrac{2\,L/c}{1 - v^2/c^2} - \dfrac{2\,L/c}{\sqrt{1 - v^2/c^2}}$

Since no Ether — $V_{Ether} = 0$

In 1887 this was an astounding result---all other waves required some kind of medium (ether). It had also only recently been inferred that the nature of light was "electromagnetic".

The implications are that no matter who, or how, or where--you observe light traveling ---you will observe the stuff to move at "the speed of light".

Two postulates of relativity:

1) The speed of light is the same for all observers regardless of inertial reference frame.
2) Laws of physics have the same mathematical form in all inertial reference frames.
   a. The law is said to be invariant to transformation from one inertial frame to another.

OK--buzzkill and headache time.

But---let's consider two experiments.

1) I am on the ground you are on a train moving "v"
   a. You roll the ball forward a speed v_{ball}
   b. I observe the ball to move a speed $v_{ball}+v$
   c. This experiment works fine if all is slow (v's<<c)
2) Experiment 2--I am still on the ground
   a. You are going to do a flyby in the [insert your favorite spaceship here]---"heart of gold" which is moving at a speed v= 0.9c.
   b. On your ship, you point a laser forward and the light comes out of the laser moving a speed "c" in the forward direction.
   c. I DO NOT OBSERVE YOUR PULSE OF LIGHT TO MOVE FORWARD AWAY FROM ME AT 1.9c. NO, NO, NO. (https://www.youtube.com/watch?v=OwFj9EO2_1k).
   d. I DO OBSERVE THE LIGHT PULSE (IT IS LIGHT) PULLING AWAY FROM ME AT c. -----WHAT ---UH---HUH----LIGHT IS CONSTANT, TIME AND DISTANCE ARE NOT THE SAME FOR ALLOBSERVERS. LIGHT SPEED IS.

We have not derived how to do the correct non-Galilean transformation yet. We need to figure out how to add velocities in such cases--not easy.

Right now---YOUR HEAD SHOULD BE HURTING.

We must give up our notion that space (distances) and times are the same for all observers---they are not. No No No.

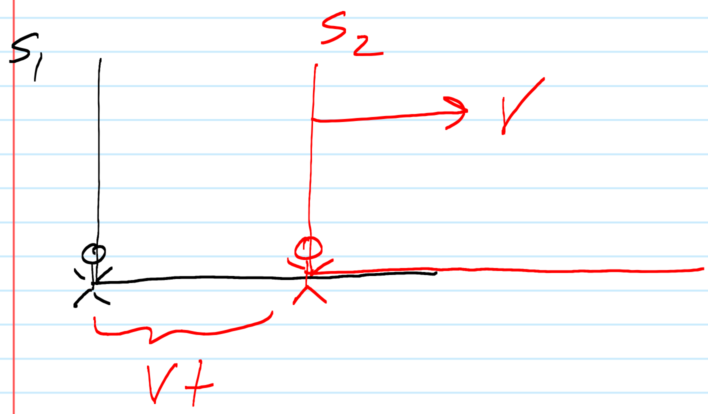
When I (standing on the ground) look at your watch/clock on phone---as you pass by in the Heart of Gold, I observe your watch to run slowly. (many ticks on my watch--few on yours---this is what I see). TIME DILATION

When I see you holding a meterstick pointer --pointing at your pulse of light---I observe that your pointer (your meterstick) is shorter than one I am holding as you pass by. LENGTH CONTRACTION

YOU MAY NEED TO READ THIS PAGE MANY TIMES. (FOR i=1 TO 20---RE-READ PAGE)

Ch. 3--Lorentz Coordinate Transformations

We start with the same picture we had previously

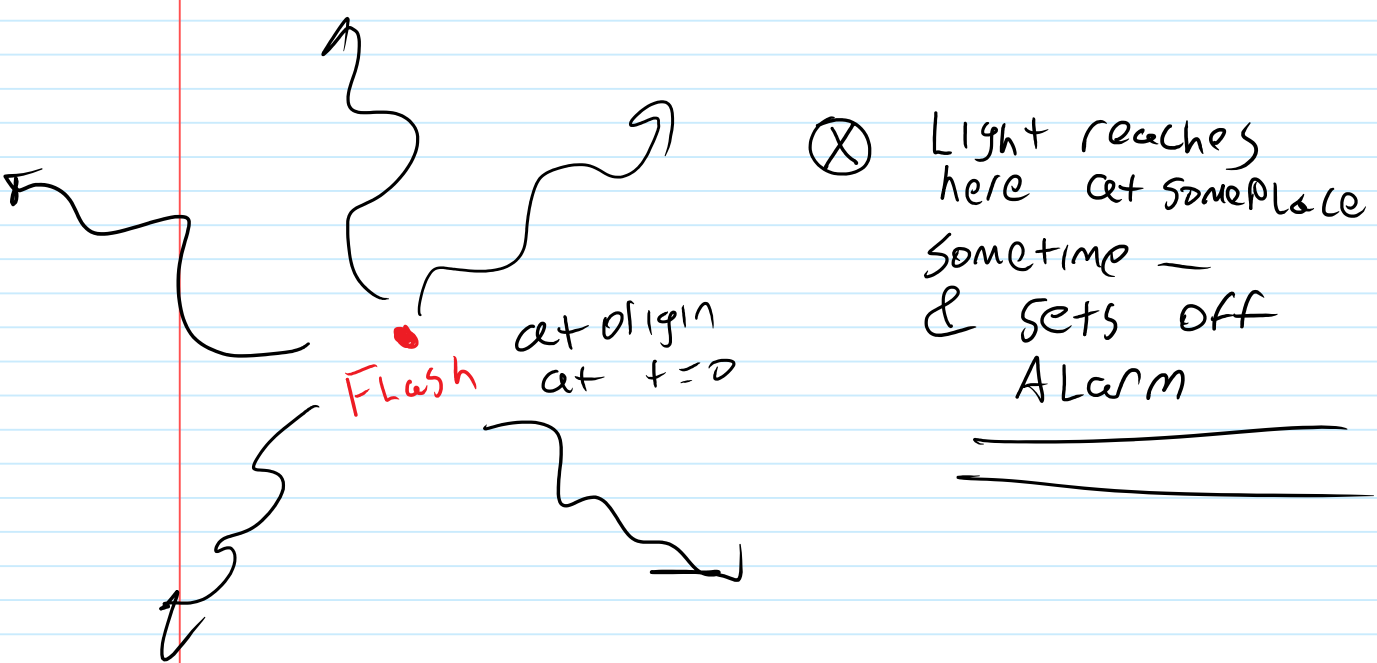


The origins of the two reference frames coincide at t=0 (that is a decision on when to start clocks).

Light travels speed c for all observers

The motion of frame 2 with respect to frame 1 is "v" in the positive x direction (v can be made negative if needed).

- Next-we consider an event and do some math.
- A light flashes at the origin heads outward and passes ---- someplace (x,y,z) and some time (t).
- The flash proceeds outward at speed "c" (the light, not the superhero-)
- We will start with a description of how far light travels outward in some time---as described in each reference frame.



Regardless of Frame 1 or 2 (write out both)--- where ct is the distance the flash travels at c in time t.

$x_1^2+y_1^2+z_1^2=c^2t_1^2$ $x_2^2+y_2^2+z_2^2=c^2t_2^2$

Whatever transformation we come up with must be consistent with this.
Recall-Galilean Transforms look like
$x_1=x_2+vt$
$y_1=y_2$
$z_1=z_2$

The Galilean transforms suggest linearity, and also suggest leaving y and z alone.

The limiting case of ---slow, which leads to linear relations---suggests that we try a transformation that looks like

x_2= some linear combination of x_1 and t_1
and
t_2=some linear combination of x_1 and t_1

Again--we picked our geometry with motion so that y,z would not matter. We can always reverse the transformations by making v negative.

With these clues and some historical benefits--we start by trying

$$X_2 = \gamma(X_1 - Vt)$$

and $$t_2 = At_1 - BX_1$$

And we insert in our distance formula equations (the requirements that c=constant in both frames) and see what we are forced to make γ, A, B

We are going to set 0=0 --(we could throw in any arb constant on one side or other but that is a stretching or units only).

$$x_1^2 + y_1^2 + z_1^2 - c^2 t_1^2 = x_2^2 + y_2^2 + z_2^2 - c^2 t_2^2$$

$$x_1^2 - c^2 t_1^2 = \gamma (x_1 - V t_1)^2 - c^2 (A t_1 - B x_1)^2$$

OK--now some algebra and math memories. Each term with x in it is linearly independent from terms with t in it. Likewise, different powers in each are linearly independent. That means our equation above can parse out into different equations.

EXPAND OUT--AND REARRANGE---DO IT.

$$x_1^2 (1 - \gamma^2 + B^2 c^2) + t_1^2 (-c^2 - \gamma^2 V^2 + c^2 A^2) + t_1 x_1 2 (\gamma^2 V - c^2 A B) = 0$$

Linear indep terms (can change t without changing x) means that each term in parentheses is itself equal to zero.

$$1 - \gamma^2 + B^2 C^2 = 0 \quad (1)$$

see p27

$$-c^2 - \gamma^2 V^2 + c^2 A^2 = 0 \quad (2)$$

$$\gamma^2 V - c^2 A B = 0 \quad (3)$$

solve γ, A, B

Process---solve eq 3 for A, sub into eq 2---yields new equation 2 with gamma and B. Solve eq 1 for B and sub into new equation 2. Now we have "gamma" Then, A, B. DO IT.

Results:

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

$$A = \gamma \qquad B = \gamma v/c^2$$

The useful constants. And then the Lorentz transforms

beta not "B"

$$\beta = v/c$$

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

Lorentz

These transformations work for
Frame S_2 moving in $+x$ direction
with coincedent origin at $t = 0$

$$x_2 = \gamma (x_1 - v t_1)$$

$$y_2 = y_1 \qquad z_2 = z_1$$

$$t_2 = \gamma (t_1 - \beta/c \, x_1)$$

MEMORIZE---KEEP WITH YOU---SHARPIE PEN ON WALL---IN FRONT OF YOU.

To get the inverse transforms (from frame 2 to frame 1) --- switch labels $1 \leftrightarrow 2$

And replace v_{21} with $-v_{12}$ (the direction of the motion of frame 2 is still along positive x_1 axis). So motion of frame 1 relative to frame 2 is along frame 2's negative x axis. Pretend you are observer--get your finger out and point.

But -uh---huh--

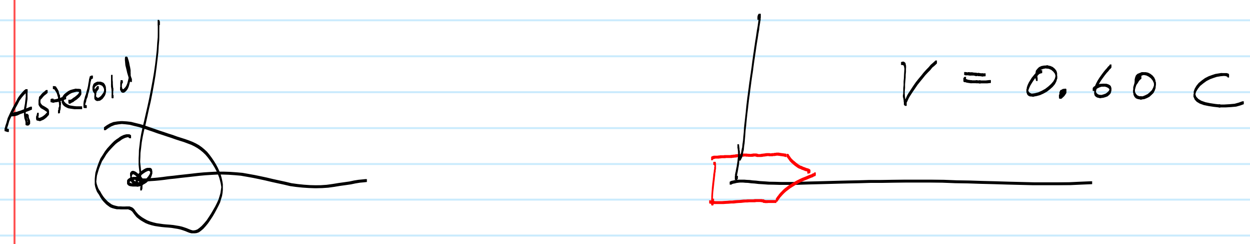
So where and when I say something happened are fundamentally different than we thought, and different for different relative observers. BUT---A REALLY SMART GUY---REALIZED ....that going back to "slow"---back to the conditions we are all used to--the new rules must reduce to the old rules (at low speeds the Lorentz transformations must reduce to the good old Galilean transforms).

------take limits, keeping first order (power) terms in v, as v tends to zero (that does not mean make v=0)

This idea--that we must reduce back to the "old" way---(when it is a good physical approximation) is known as: "THE CORRESPONDENCE PRINCIPLE"

It just means---just because we have made more detailed broader observations, does not mean we can blow off the old observations. How things behave at slow speeds is still valid.

Consider example 3.2



So we have two reference frames---the asteroid, and the rocket.

In the Asteroid ref frame an event occurs at a location of (3.000, 0.5000, -0.2000)km and a time of 5.000μs

When/Where does same event take place according to spaceship captain.

OK--you can follow through the text on the example--but here are some comments.

- The observer on the asteroid (you) is at the origin holding three long metersticks and a stop watch---the event is not at the origin.
- The observer on the rocket ship (my ship) is at the origin holding three long metersticks and a stop watch---the event is not at that origin either.
- We are assuming that you and I can somehow figure out where when "the fireworks starburst" went off---even though it takes some transit time for the signal to get you us.
- I know the starburst went off some time back ---before I received the signal---again---transit time.
- We could ask questions like ---at what time after the event occurred at it's location---did I receive the signal? (this adds in transit time).
- UH--Transit time matters and must be taken into account in many measurements (up and coming).
- Keep enough digits ---our Author (many, and me too) often don't keep enough sig figs. Pretend the extra zero's are there---and don't round off the small effects that may occur. Keep enough digits.
- Rule #2:--Double tap---OK--I got side tracked---where is that from?

OK--we have Lorentz transforms--but now we need to start looking at what to do with these, and asking--in what kind of measurements will this matter?

The observer at the origin of S_2 — says that the event occurs at

$$t_2 = -1.25\ \mu s$$

and

$$\vec{r}_2 = (2.6,\ 0.50,\ -0.20)\ km$$

Using Lorentz transforms with $\gamma = 1.25$ $\beta = 0.60$

Example 3.3----beware simultanaity

What happens at the same time for you does not happen at the same time for me.

https://www.youtube.com/watch?v=5PkLLXhONvQ

3.3 The Doppler effect---for light---the right way
(special relativity).

What is the Doppler effect in the first place?
http://physics.bu.edu/~duffy/HTML5/doppler.html

In the simulation it is clear that if the source of waves is moving toward an observer, more wave pulses (flashes if you like) will pass by or cross the observer in a time interval. Likewise if the observer moves toward the source of waves--the observer will cross more wavecrests and also observe a higher frequency.

BUT--THE VERY FACT THAT THE CLOCK--EMITTER--SOURCE---OF WAVES/PULSES IS MOVING--ALSO MEANS THAT THE TIMES I MEASURE FOR PULSE EMISSIONS ARE ALTERED BY RELATIVITY.

THE Doppler effect has all the normal stuff in it--plus relativity. So we need to relearn, draw some pictures, and do some geometry.

We will stand in our reference frame (1) and watch two consecutive flashes emitted from a source ---make their way to us---and we will observe the time between pulses/flashes that we receive. The moving source defines the speed of frame 2 (moving in direction parallel to x axis---uh--whatever way its moving we shall call "x"). But it does not need to be "on the x axis" ----see fig 3.4 right now.

- Light has peaks that repeat at "f"or "ν"--
- Light may come from moving atoms, molecules--spectroscopy
- Light may come from stars--how they move
- Light may come from ---a cloud---or air mass (Doppler radar/windshear)
- Light may come from --reflected from a planet (round and round)-
- Light may come from a star wobbling ---because it is pulled by a small planet
- You may get a speeding ticket