Modern Physics
Getting started---
spots.augusta.edu/tcolbert   navigate to this course

You will find:

- Syllabi
- Weekly assignments
- HW solutions (after you turn them in)
- Other useful resources

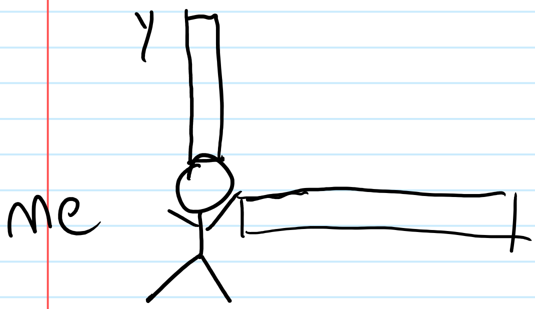
Text

Essentials of Modern Physics by T.R. Sandin

Some broad topics covered in this course are:

- Relativity
- Modern Physics experiments and paradigm changing observations
    - Blackbody radiation (really fundamental)
    - Photons
    - Photon processes
    - Particle wave
- Bohr Model and Hydrogen
- Schroedinger (baby quantum)
- One dim square well
- Other selected topics

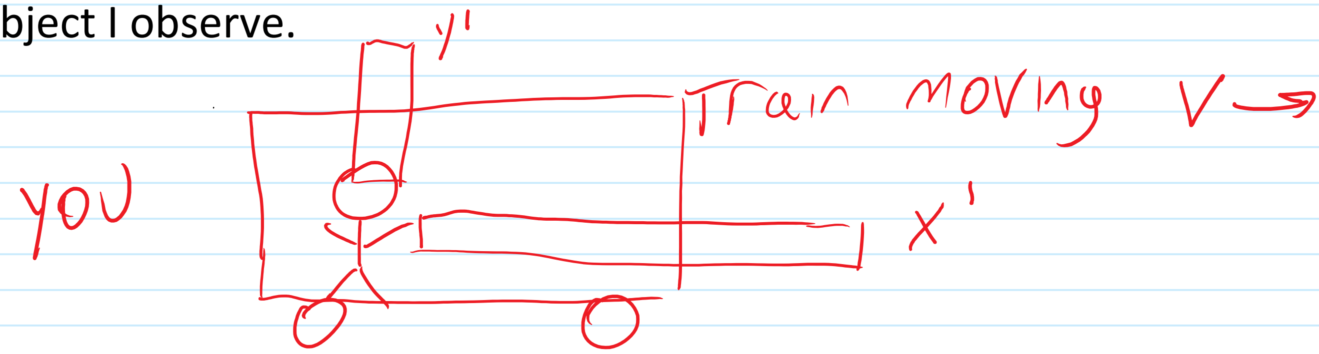
Galilean Relativity and Reference Frames



I define a reference frame simply by holding out some meter sticks. One called "x" and one called "y".

They may be as long as they need to be.

I use my metersticks to make all measurements of any object I observe.



You, moving along in a train whose velocity is "v" in my +x direction (we just agree about the direction for now), shall use your own meter sticks to make observations.

For any given object with a designated motion (you or I give initial conditions)---either of us should be able to figure out what the other sees.

You are going to take a "ball" and throw it on the train.

$V_{ball, train}$ given

$V_{train, ground}$ given

We want to know--how fast the ball moves with respect to the ground (observer-me).

$$V_{ball,ground} = V_{ball,train} + V_{train,ground}$$

The object has a velocity with respect to the reference frame "train"

The "train " reference frame has a velocity with respect to the ground.

All that has happened is velocity vector addition.

Reference frame: What is it?
A place I can sit and hold those metersticks in a consistent way.

INERTIAL REFERENCE FRAMES:Are frames where Newton first law is valid. If no force is applied, then no acceleration observed.   If this is the case for any objects I observe, then I believe I am in an Inertial Frame --holding my three perpendicular meter sticks.

If $\vec{F}$(net)=0, $\vec{v}$=const

[Bill and Ted's great fall](https://www.youtube.com/watch?v=vLt5ei598CY)
https://www.youtube.com/watch?v=vLt5ei598CY

If you and I are falling into a really big black hole--uniform grav. field---we can toss a ball back and forth, can we tell if the reference frame is "inertial" or not?

or Bill + Ted

Like many things---we will assume we understand what such a frame looks like.

Galilean Coordinate Transformations

If you held onto that ball in the train, you would say it sits at the origin. I would disagree and say that at some time it is at positions x_1, y_1 (you might call yours x_2 and y_2).

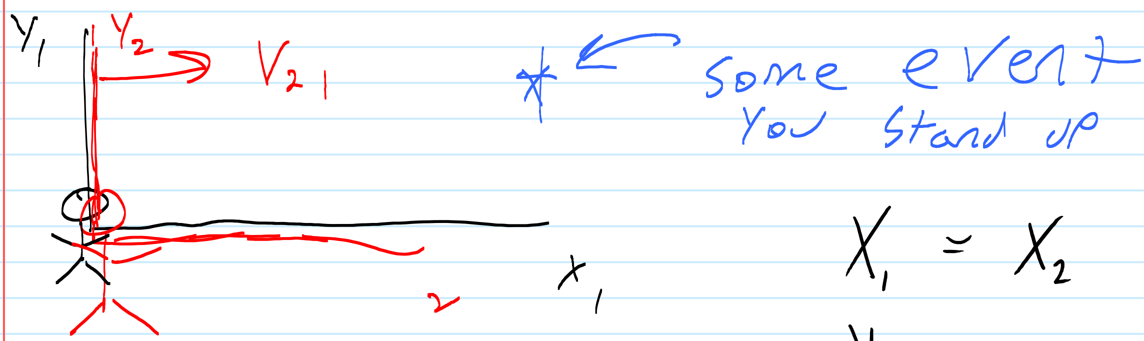
Many properties of the object follow from coordinate transformations. We disagree about the balls position, its velocity, momentum, kinetic energy and so on---there is no "right" or "wrong" there is just viewing an event (or series of events) from a different reference frame.

WHAT DOES THE EVENT LOOK LIKE TO AN OBSERVER IN A DIFFERENT REFERENCE FRAME?

Simplifying assumptions:

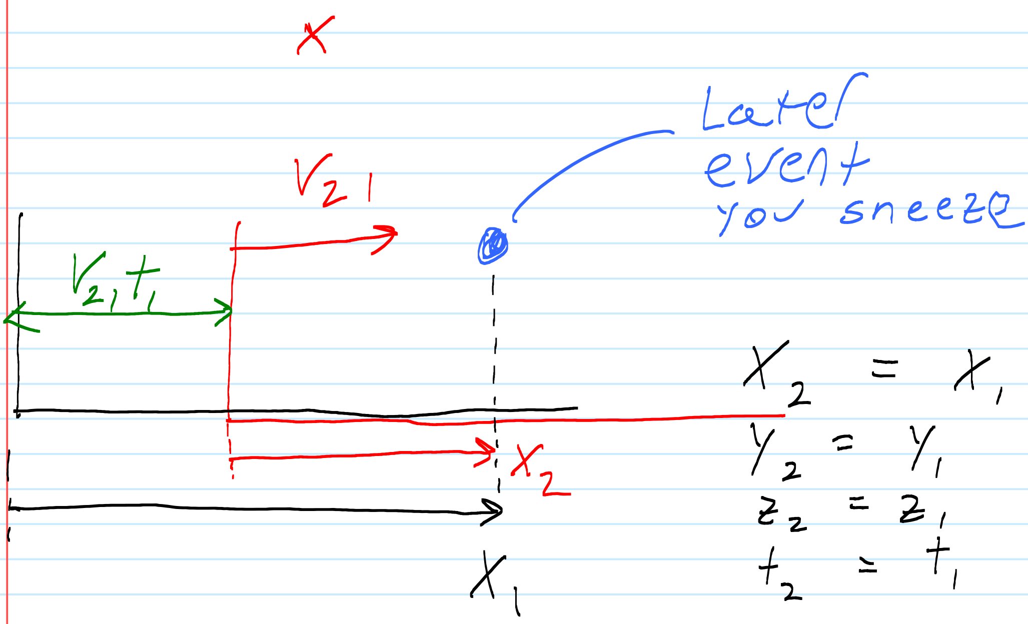
1) The origins of the two reference frames coincide at t=0
2) Both frames use cartesian coordinates oriented the same
3) v means the velocity of frame 2 with respect to frame 1 (we might call this $v_{2,1}$). And the motion is along the positive x axis (arbitrary and we can change later if needed).

Let's describe two events



$$x_1 = x_2$$
$$y_1 = y_2$$
$$z_1 = z_2$$
$$t_1 = t_2 = 0$$

Now let's look at an event that occurs later in time---
when the ref frame 2 has moved some distance.

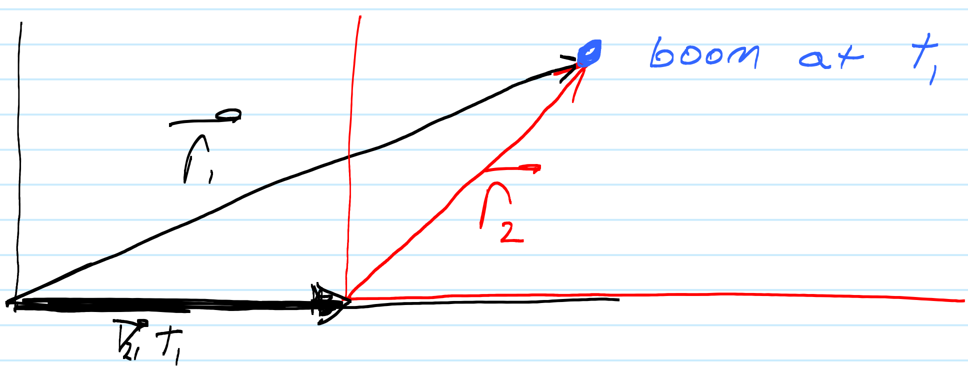


$$X_2 = x_1 - V_{21} t_1$$
$$y_2 = y_1$$
$$z_2 = z_1$$
$$t_2 = t_1$$

The transformation only shifts the x measurement by an amount vt. Only appearing in "x" because of the simple starting assumptions we made, but all the physics has been included.

Note that we have not taken into account the effect of transit times---you being closer to event 2, may receive that sound wave earlier than I do (transit time, or time retardation of event---delay.....just delay).

Vector picture — origins still coincident at t=0



$$\vec{r}_1 = \vec{r}_2 + \vec{v}\, t_1$$

We have the same transformation, but it is generalized--it is still only the x component that changes x2=x1-vt

Other transformations--like velocity.

$$V_{1x} = \frac{dx_1}{dt_1} \qquad V_{2x} = \frac{dx_2}{dt_2}$$

$$dt_1 = dt_2 \qquad = \frac{d(x_1 - Vt_1)}{dt_1}$$

so

$$V_{2x} = V_{1x} - V$$

In general

$$\vec{V}_2 = \vec{V}_1 - \vec{V}_{2,1}$$

(of obj) ← ref frame 2 w/respect to 1

We can continue with Galilean transformations by continuing to take derivatives to get "acceleration" in either frame. Multiply by m, and we get force. We can define momentum now that we have velocities.

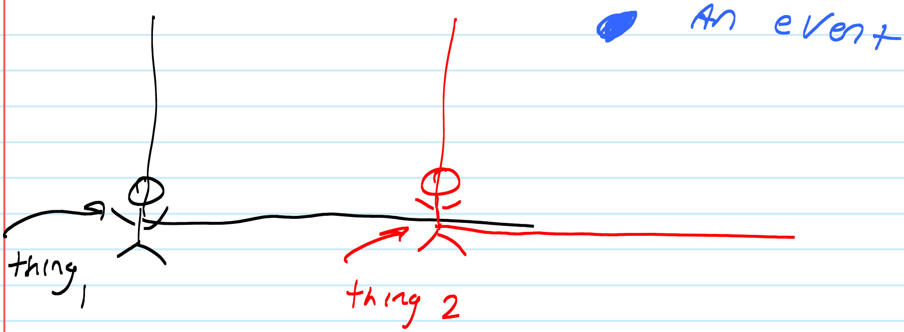
We are used to Galilean transformations---but they ultimately do not work (why).

Overall we have developed the concept that:

- The motion of an object is described within a particular reference frame
- A different frame uses different numbers for v of the object than I use, or for KE, or for momentum, etc

- Remember what the "1" and "2" mean in the subscripts.
- The event we are describing with "v" is the same, one and only event (for the moment)
- v_1 and v_2 describe the same event ---but as seen by observer 1 in ref frame 1, and observer 2 in ref frame 2
- $v_{2,1}$ describes the relative motion of the reference frame 2 with respect to 1.
- In the current context 1 and 2 are not like ---ball 1 and ball 2---as two different objects. Rather, there is a single event being described by two different observers.
- There is no special observer

We are discussing 3 different ? something?



there may be several events to consider.

1) Event-indep
2) observ 1
3) observ 2

Since we do not agree upon "the numbers" from one frame to another, what do we agree upon? We can agree upon the laws of physics---in other words---if momentum is conserved in your reference frame (before and after a collision event), then I will also observe that momentum (a different number than yours) is conserved in my reference frame as I watch the same event.

The laws of physics are "INVARIANT". Those physical statements that have the same form in one reference frame or another--may constitute what we mean by "laws of physics".
INVARIANCE

What comes next: Galilean relativity seems fairly normal to us, but is only a good approximation to observations---IF ALL REFERENCE FRAMES, AND OBJECTS, ARE MOVING SLOW (COMPARED TO WHAT).

WT$-DOES SLOW MEAN?

HOW FAST DOES AN ELECTRON MOVE AROUND A HYDROGEN NUCLEI?

IS "c" THE SPEED LIMIT?