Physics 100 – January 29, 2007

- Can we find time to Make up Jan. 24 lecture?
  Friday, Feb 2 ?

- Final exam is Tuesday May 8, 2007
  at 4 pm

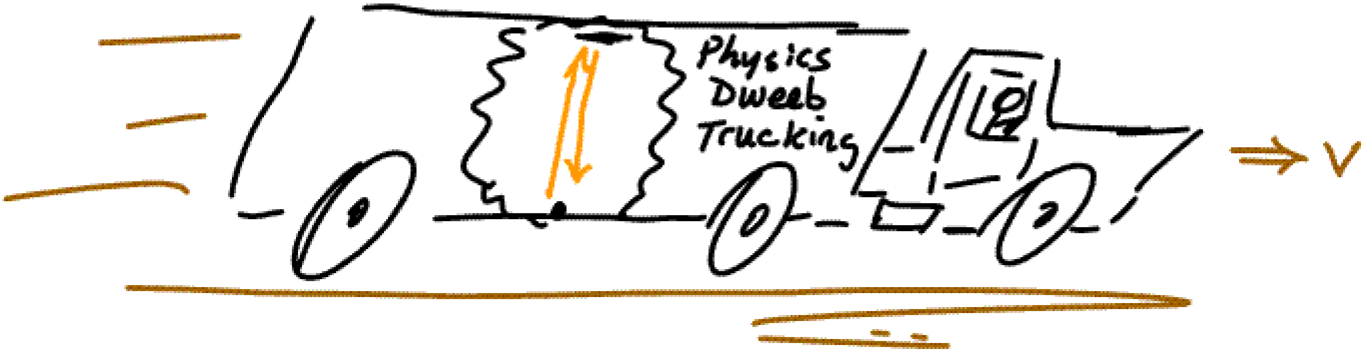
  date on distributed version of syllabus is incorrect

- Recitations begin this week

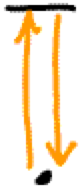
- Expectations for recitations

Presentation Project

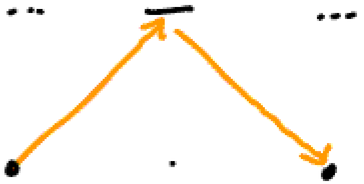
Last Time



Observer on truck



observer on ground



Frame of Reference

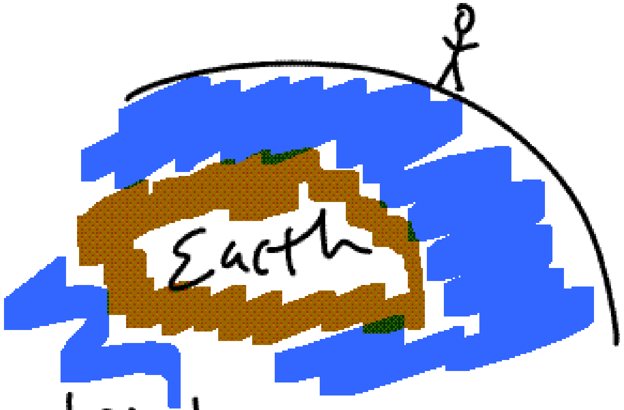
Speed of light invariant

distance light travels depends on point of view

⇒ light travel times differ → Time is relative

$v = 0.98c$

what is lifetime of human on spaceship as seen by observer on Earth?



Let human on spaceship live 70 years as measured by clocks on spaceship

human on spaceship lives normal biological life

$$\Delta t' = \gamma \Delta t$$

relation of times (Δt) as measured in two frames of reference

$$\gamma > 1$$

$$\gamma = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}} = \frac{1}{\sqrt{1-\left(\frac{.98c}{c}\right)^2}} = 2.3$$

How do I know which frame is "primed"?

Trick to remember:

We are discussing relativistic time dilation

Time is shortest in frame where event is at rest. The frame where event is at rest is called the "proper" frame

measured time is longer in any other frame of reference

$$\Delta t' = \underset{>1}{\gamma}\,\Delta t \rightarrow \overset{\text{Earth}}{\Delta t'} = \overset{2.3}{\gamma}\,\overset{70\text{ years}}{\Delta t}$$

$$\Delta t' = \Delta t_{\text{Earth}} = \boxed{161\text{ years}}$$

$\Delta t' > \Delta t$

because $\gamma > 1$

This means Δt is shortest

Δt is proper frame

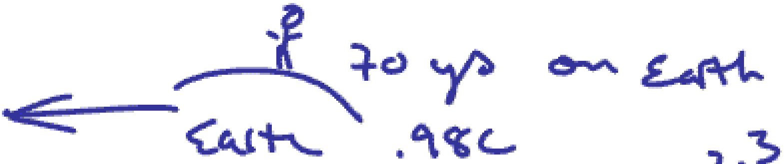
Proper frame is spaceship because that is where person in question is at rest.

v = 0.98c   Person on spaceship lives 70 years

To observer on earth, person on spaceship lives 161 years

How long does person on STATIONARY spaceship perceive earthling to live as earth zooms by at 0.98c ?

From other point of view



$$\Delta t_{sp} = \overset{\overset{2.3}{\downarrow}}{\gamma}\ \overset{70}{\Delta t}_{Earth}$$

161 years ↗

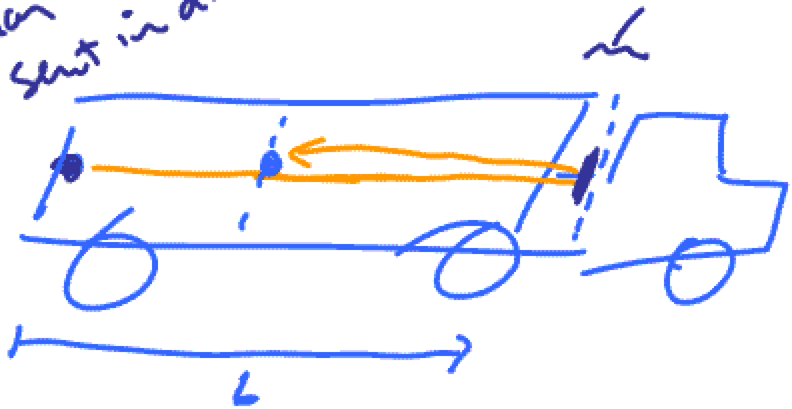
↗ Proper time
Person born + dies on Earth at rest ..

proper frame ↙

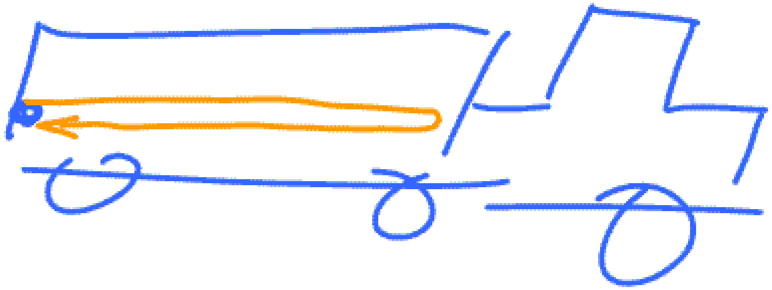
Discussed twin paradox briefly

One issue not discussed yet is what happens to <u>space</u> at large speeds

can do thought expeiment similar to what we did earlier but light sent in direction along motion



From point of view of someone on ground. (as light travels, truck moves)



From point of view of someone riding on truck

We will not bother with derivation but . . .

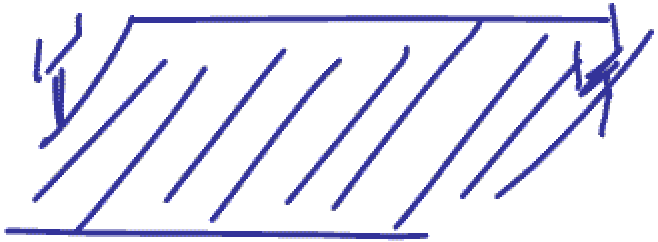
Length Contraction

$$\underset{\text{proper frame}}{\Delta x'} = \underset{>1}{\gamma}\, \Delta x$$

Along direction of Motion
Length is "longest"
in proper frame

$v = 0.98c$

Spaceship Zooms by
Superbowl



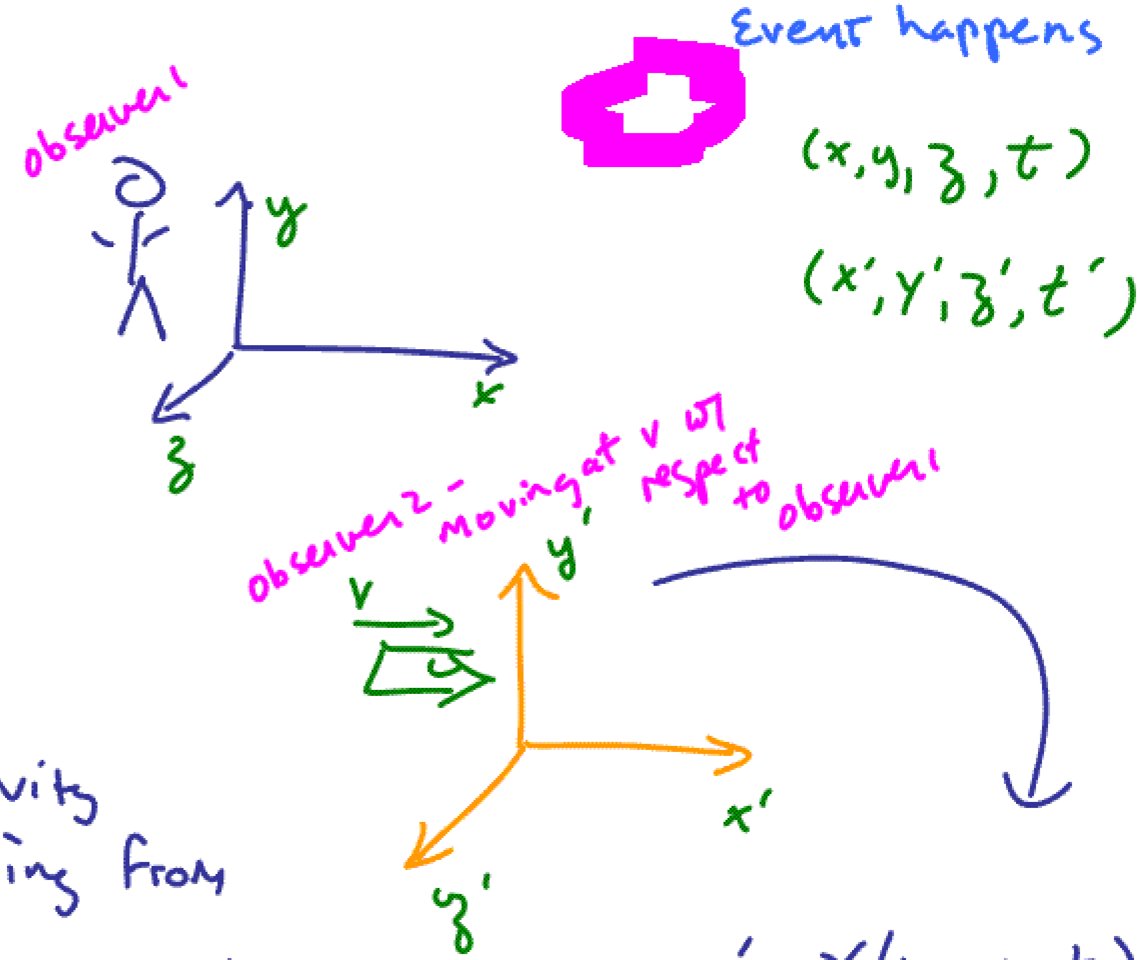
How long is foot ball
field as Measured
by Aliens

$$\Delta x' = \gamma \Delta X$$

$$100\text{yds} = \underset{2.3}{\gamma}\ \Delta x$$

$$\text{footballfield} = \frac{100\text{yds}}{2.3} = 43\text{yds}$$

Aliens measure field to be shorter than
100 yds by factor of 2.3



Special relativity gives mapping from

(x,y,z,t) to (x',y',z',t')

and vice versa

Transform coordinates

(Lorentz Transformation)

$$x' = \gamma(x - vt)$$

$$y' = y$$

$$z' = z$$

$$t' = \gamma\left(t - \frac{vx}{c^2}\right)$$

These eqns transform space + time coordinates of event in one frame of reference to that seen in another frame of ref.

→ critical for Science since science involves different observers comparing experimental results

Note that Space + Time get all mixed up in this transformation

Spacetime

Other things we can measure such as Velocity, Force, Energy, etc. also have similar transformations relating their values from one point of view to another.

They also get mixed up ... Origin of $E = mc^2$

Let's look at some of these other variables:

$$\text{Speed} = \frac{\Delta\,\text{distance}}{\Delta\,\text{time}} = {}^{m}/_{s}$$ meters per second

instantaneous speed $\Delta t \longrightarrow 0$

Velocity — Speed + direction

Acceleration — rate of change of velocity

$$\overset{\parallel}{a} : {}^{m}/_{s^2} \qquad = \frac{\Delta V}{\Delta t}$$ sign tells you direction

$x, v, a, t \longrightarrow$ Known as Kinematic variables

position velocity acceleration time

Defines STATE of object.

Force ≡ F   That which causes an acceleration

can define mass two independent ways

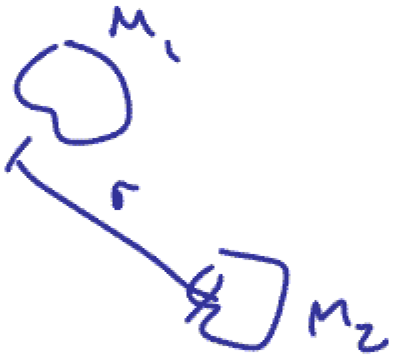
$$\underbrace{F = ma}_{\text{intertial mass}}$$

Newton's Second Law

Mass

force of gravity between 2 masses

$$F = \frac{G M_1 m_2}{r^2}$$



gravitational Mass

It turns out that inertial mass is the same as gravitational mass.

Weight = force ... not mass