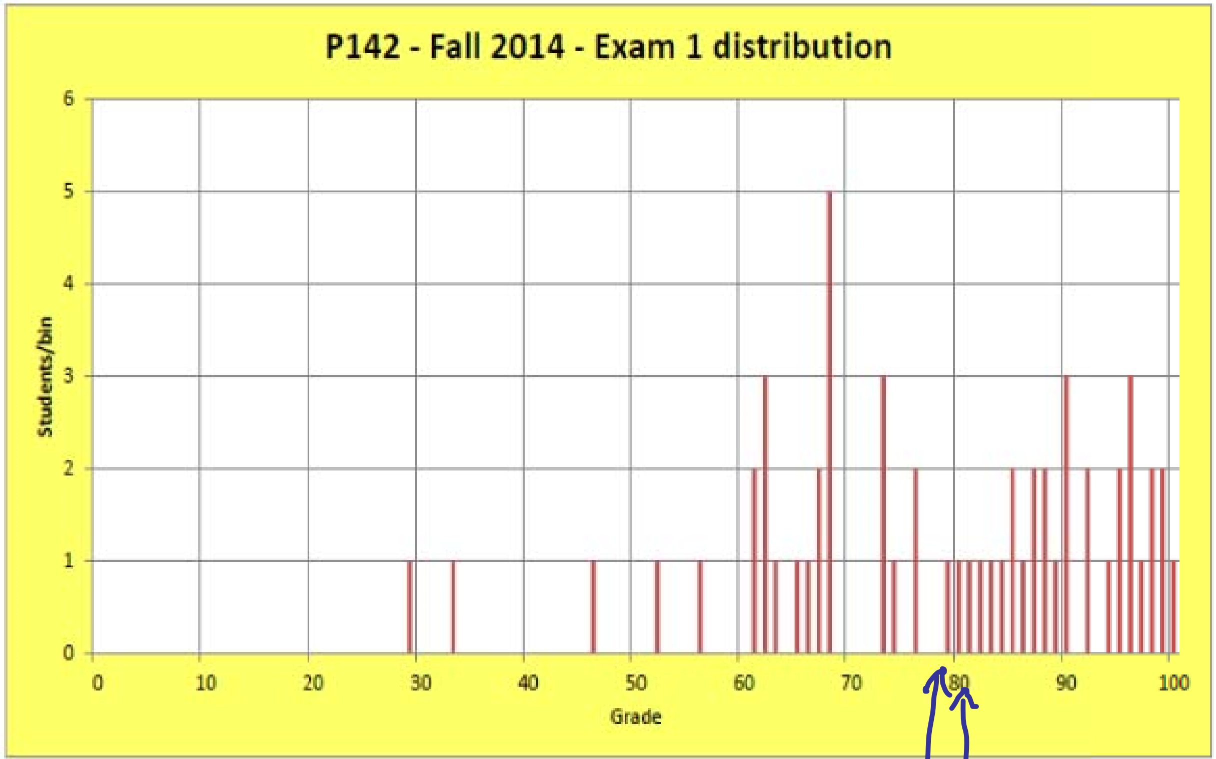
Physics 142 - October 21, 2014

- Project Topic Preferences to me today
  Here or under my office Door

- Exam 1 graded

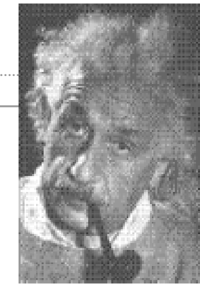
  1 w/ no name

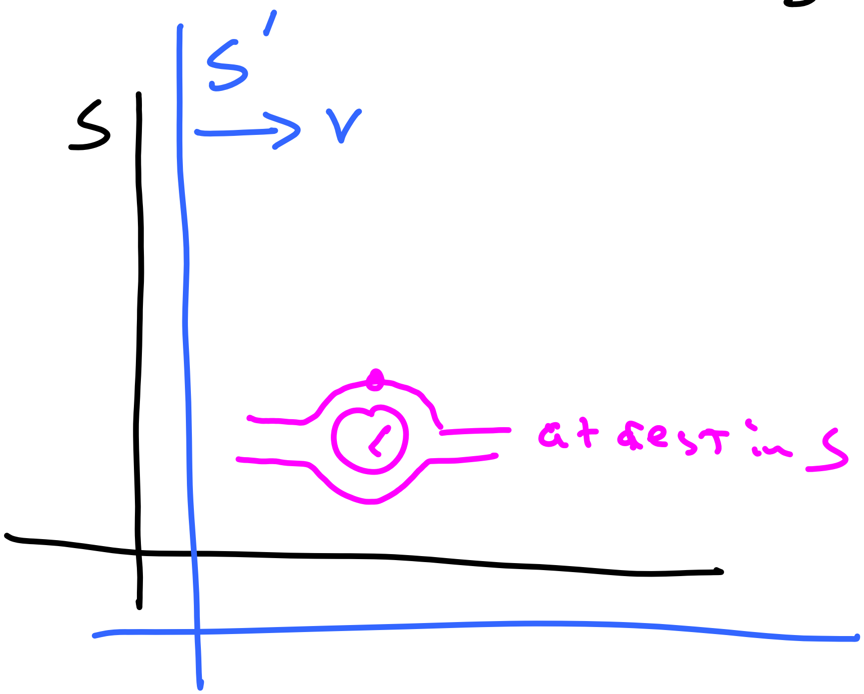


Mean
78

Median
80

Special Theory of Relativity





S is proper frame

event at rest

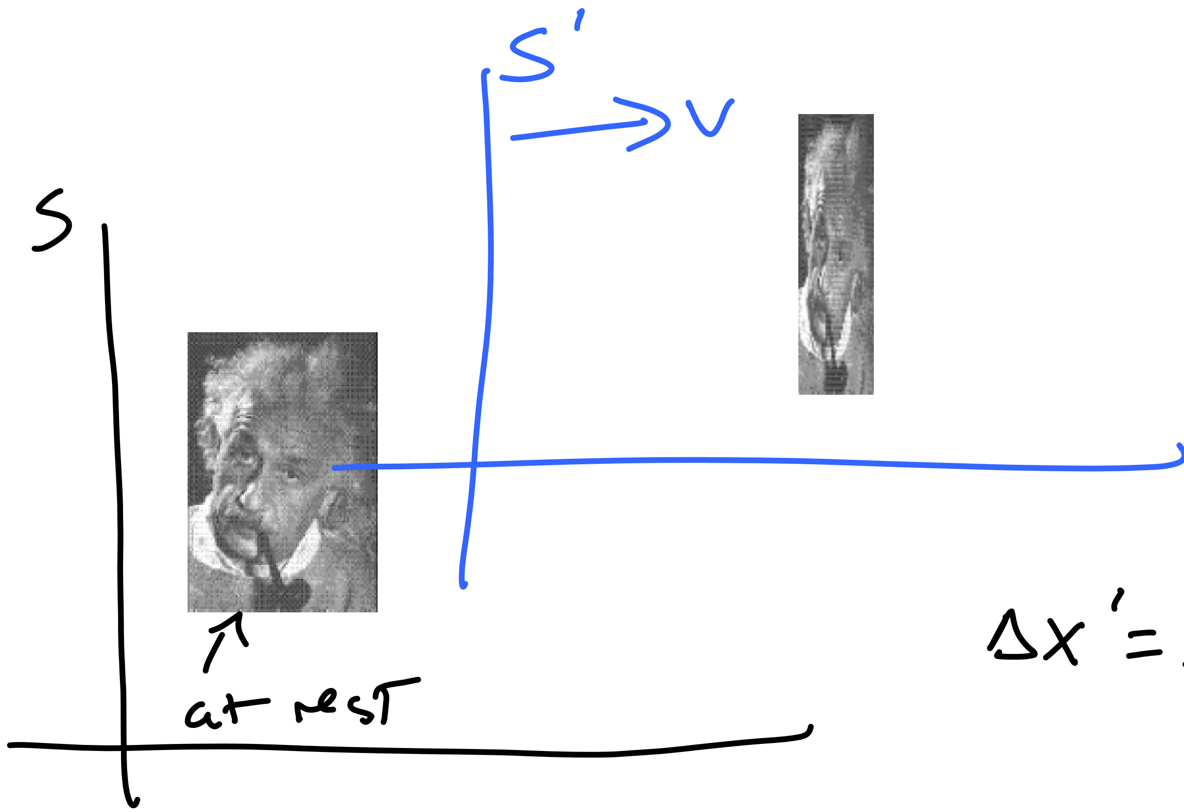
$$\Delta t' = \gamma \Delta t$$

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

> 1

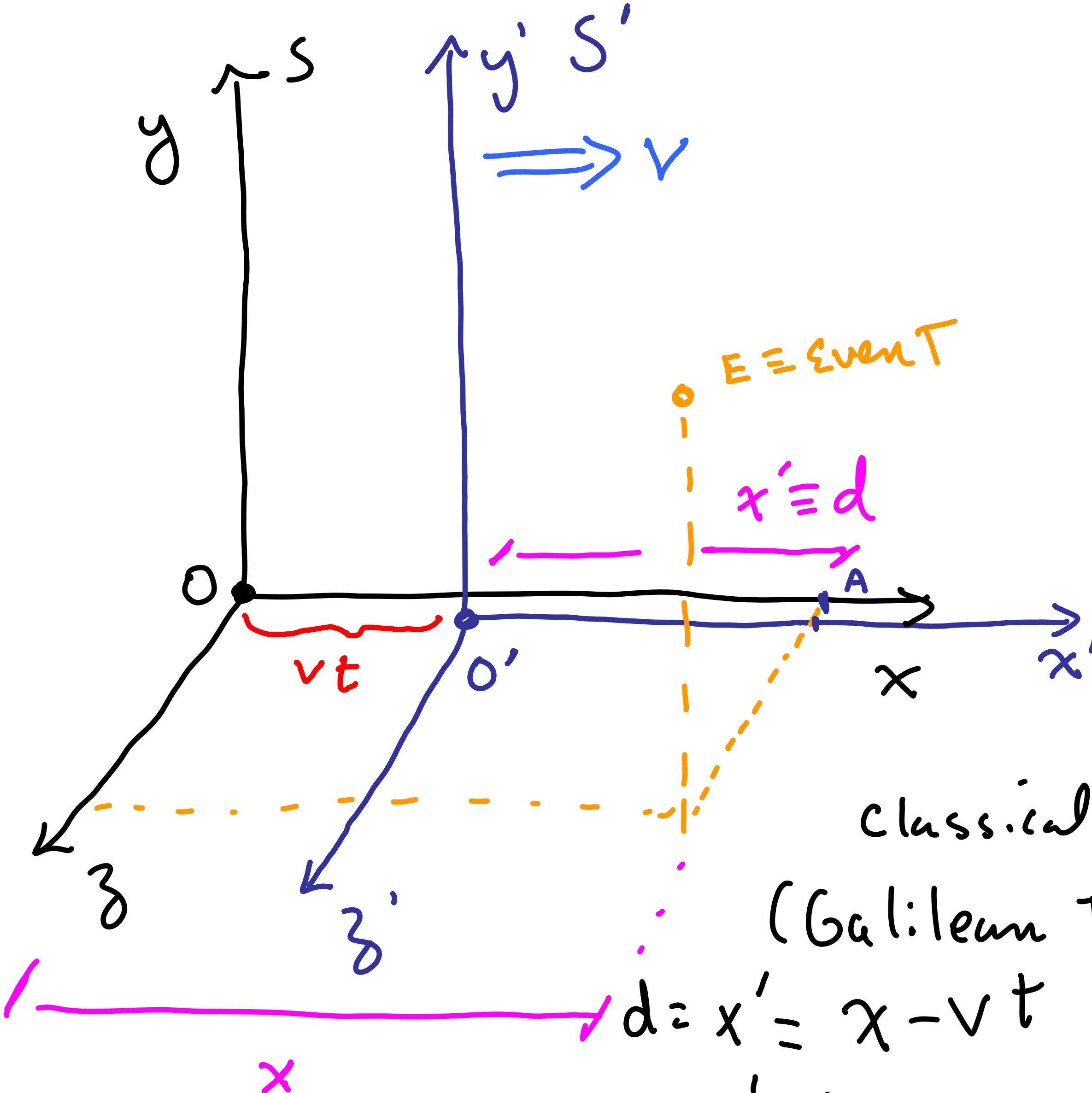
measured time is shortest in <u>proper</u> frame

where event at rest



$$\Delta x' = \frac{\Delta x}{\gamma}$$

Length is greatest in proper frame of reference



at $t=0$, $t'=0$

two systems overlap

$O = O'$

classical physics

(Galilean Transformations)

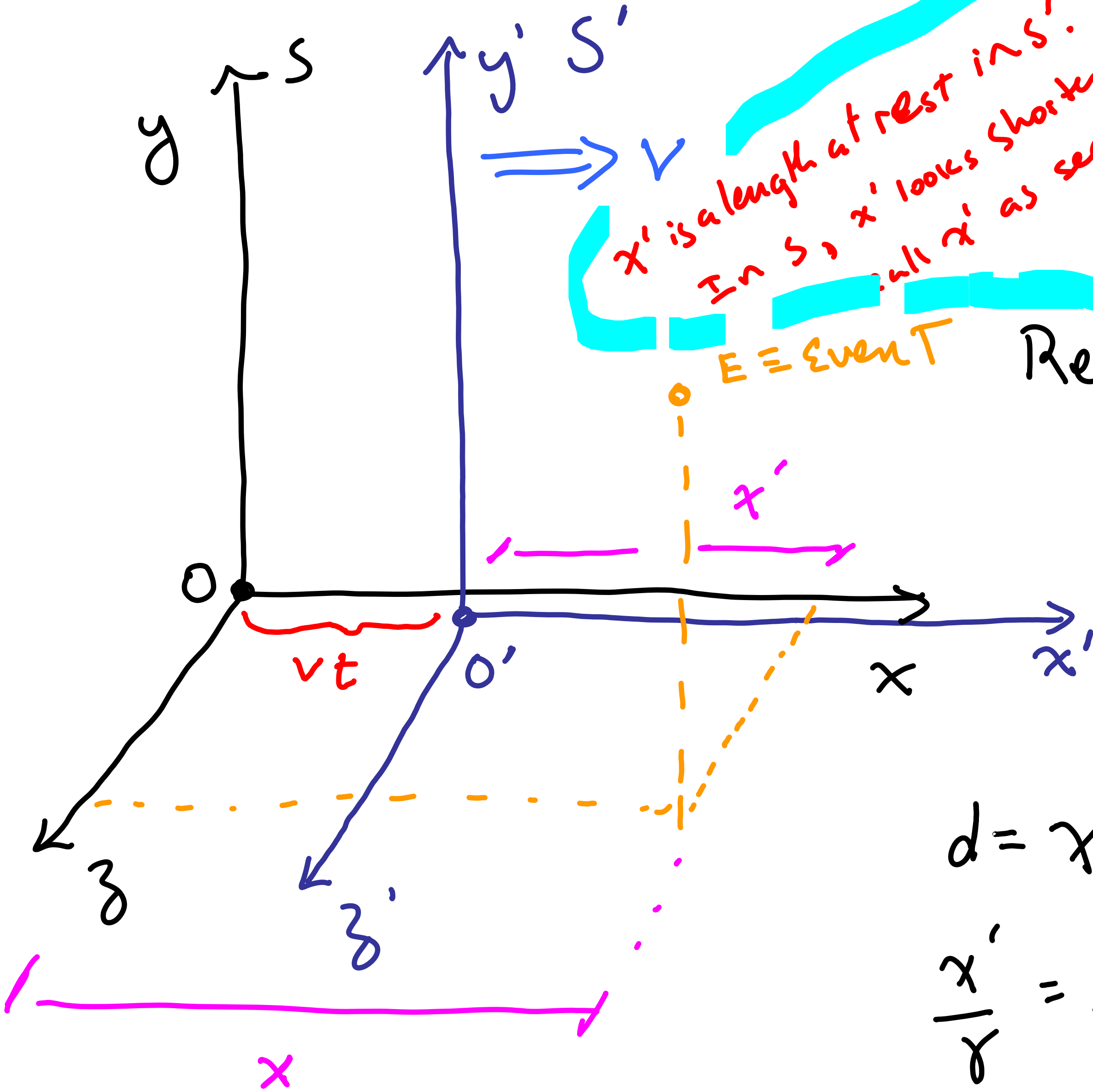
$d = x' = x - vt$

$y' = y$

$z' = z$

$t' = t$

d is x' as seen in S



x' is a length at rest in S'.
In S, x' looks shorter by $1/\gamma$
call x' as seen in S → d
$d = x'/\gamma$

Relativistic Transformations

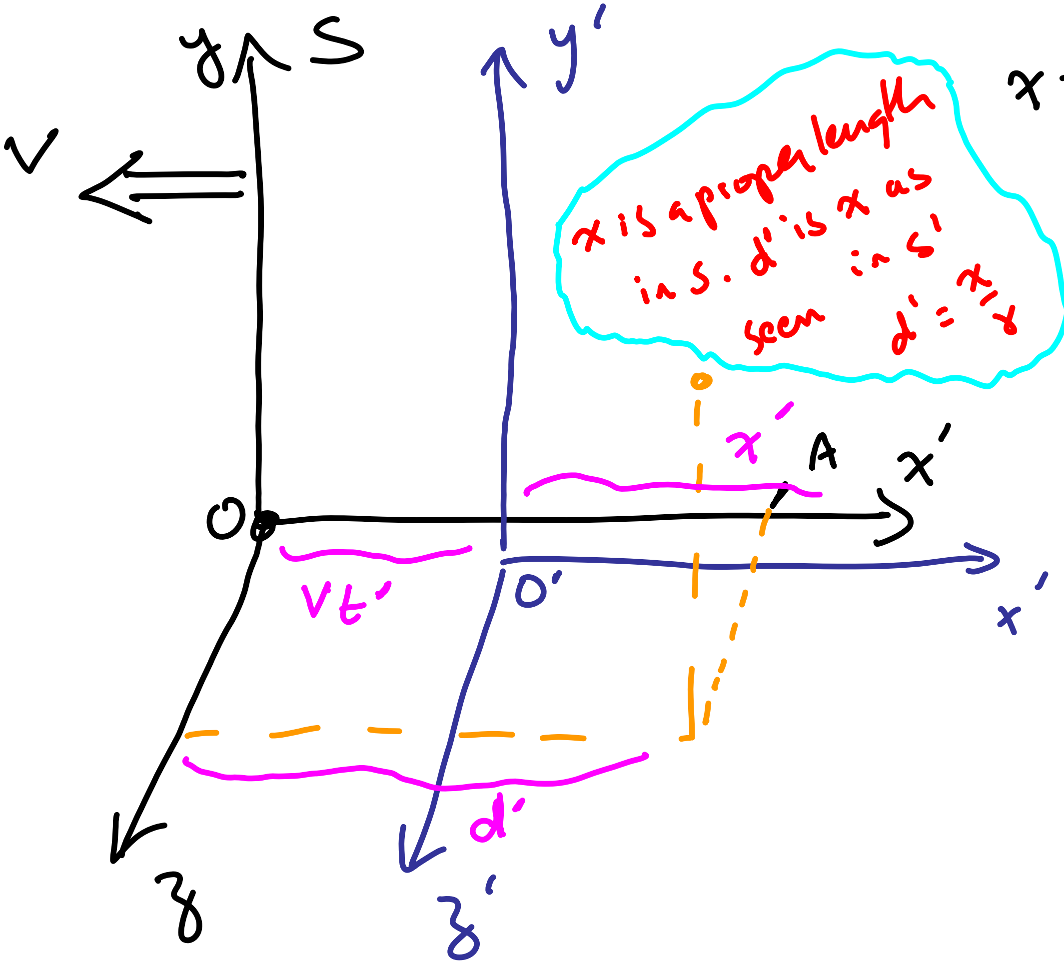
$$d = \frac{x'}{\gamma}$$

$$x' = d\gamma$$

$$d = x - vt$$

$$\frac{x'}{\gamma} = x - vt$$

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



x = dist from O to A in S

$$d' = \frac{x}{\gamma}$$

$$x' = d' - vt'$$

$$x' = \frac{x}{\gamma} - vt'$$

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

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

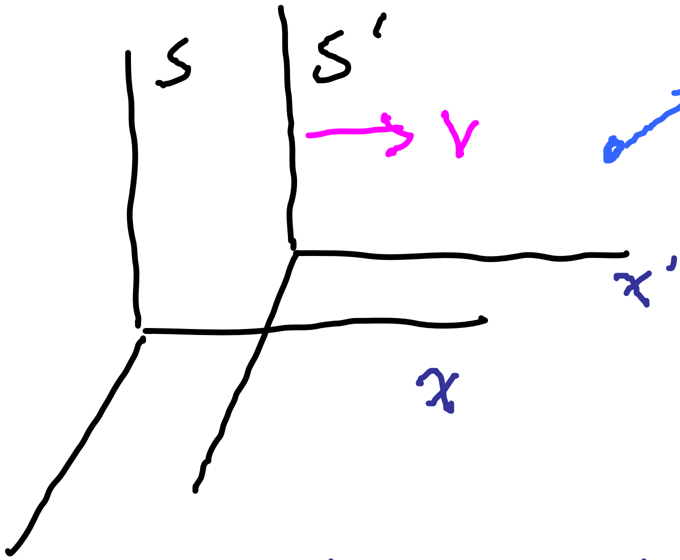
substitute in

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

bit of Algebra

$$t = \gamma\left(t' + \frac{v}{c^2}x'\right) \qquad t' = \gamma\left(t - \frac{v}{c^2}x\right)$$

Velocity Transformation



$\vec{U}$ = 3 vector velocity in S

what does $\vec{U}$ look like in S'

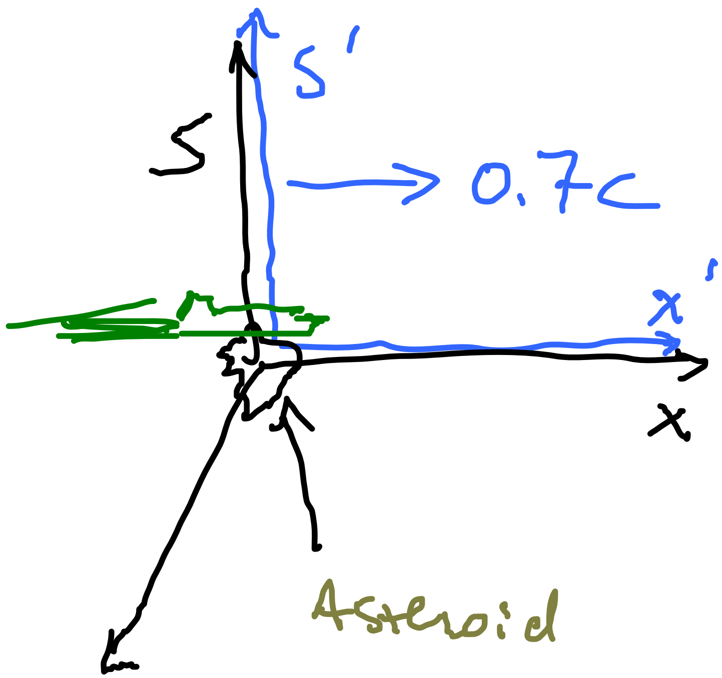
U_x

$$U_x' = \frac{dx'}{dt'} = \frac{\gamma(dx - v\,dt)}{\gamma\left(dt - \frac{v}{c^2}dx\right)} = \frac{\gamma\left(\boxed{\frac{dx}{dt}} - v\right)}{\gamma\left(1 - \frac{v}{c^2}\boxed{\frac{dx}{dt}}\right)}$$

$$\boxed{U_x' = \frac{\gamma(U_x - v)}{\gamma\left(1 - \frac{v}{c^2}U_x\right)} = \frac{U_x - v}{1 - \frac{v}{c^2}U_x}}$$

$$U_y' = \frac{dy'}{dt'} = \frac{dy}{\gamma\left(dt - \frac{v}{c^2}\,dx\right)} = \frac{dy/dt}{\gamma\left(1 - \frac{v}{c^2}\frac{dx}{dt}\right)}$$

$$\boxed{\begin{aligned} U_y' &= \frac{U_y}{\gamma\left(1 - U_x \frac{v}{c^2}\right)} \\[2em] U_z' &= \frac{U_z}{\gamma\left(1 - U_x\, v/c^2\right)} \end{aligned}}$$



$$\gamma = \frac{1}{(1 - .7^2)} = 1.4$$

Event 1 ≡ Rocket passes Asteroid

$t = 0, \; t' = 0$

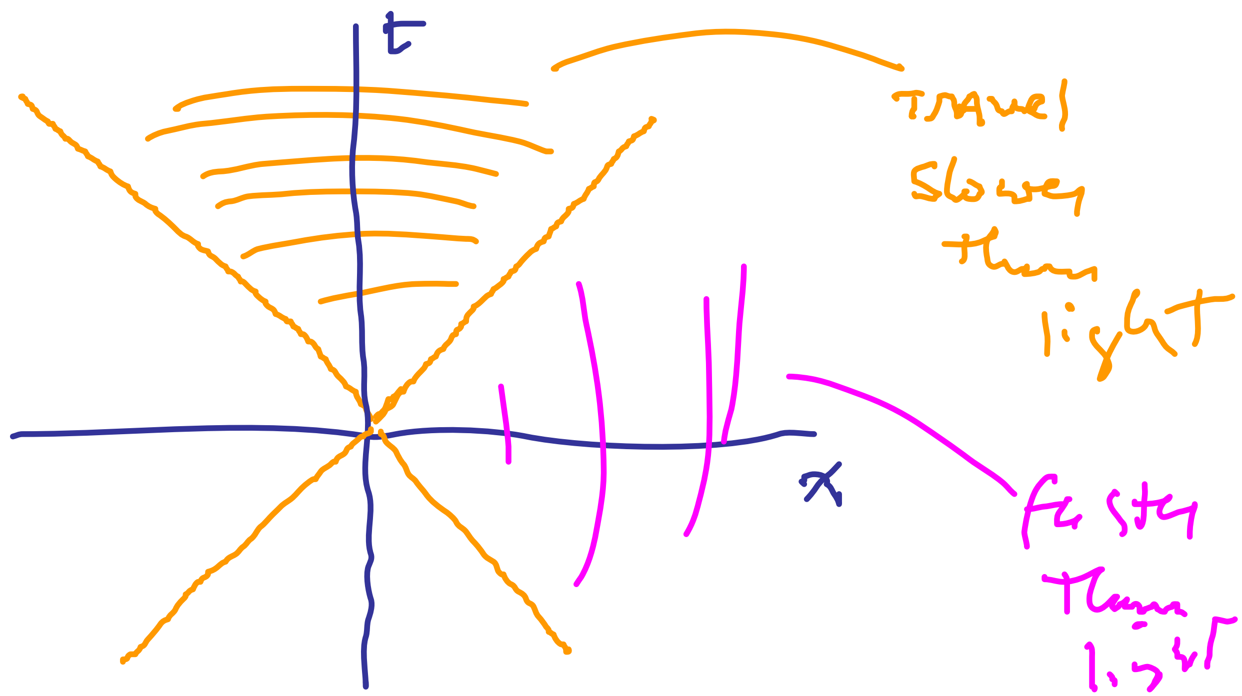
Event 2 ≡ light beacon flashes at

$$\underbrace{x = 3\text{ km}, \; t = 5\,\mu s}_{\text{in } S}$$

what does event 2 look like in S'

$$x_2' = \gamma(x_2 - v t_2) = 1.4\left[3 - (.7)(3\times10^5)(5\times10^{-6})\right]$$
$$= 2.73 \text{ km}$$

$$t_2' = \gamma\left(t_2 - \frac{v}{c^2}x_2\right) = 1.4\left[5\times10^{-6} - \frac{(.7)(3)}{3\times10^{-5}}\right]$$
$$= -2.8\ \mu s$$



Define Proper velocity

$$\eta = \frac{dx}{d\tau}$$

$\tau \equiv$ proper time

Flight to LA

$$\frac{dx}{d\tau}$$

dx ← measured ground

$d\tau$ ← Time on plane

$$\eta_x = \frac{dx}{d\tau}$$

transform like x

$$dt = \gamma \underbrace{d\tau}_{\text{proper}}$$

$$\eta_x = \frac{dx}{d\tau} = \gamma \frac{dx}{dt} = \gamma v_x$$

$P \equiv m\eta \rightsquigarrow$ P conservation holds

define $4^{\underline{th}}$ component

$$\underline{\underline{\gamma m c^2}} \equiv \text{Relativistic Energy}$$

$$m_a \eta_a + m_b \eta_b = m_c \eta_c + m_d \eta_d$$

$(\vec{X}, t)$ spacetime 4 vector

$(\vec{\eta}, E)$ Energy-Momentum 4 vector

$$E = \frac{mc^2}{\sqrt{1-\left(\frac{v}{c}\right)^2}} = mc^2 \underbrace{\left(1-\left(\frac{v}{c}\right)^2\right)^{-1/2}}_{\text{Taylor expand}}$$

$$(1+x)^{-1/2} = 1 - \frac{1}{2}x + \frac{3}{8}x^2 + \cdots$$

$$E = mc^2 + \frac{mc^2}{2}\left(\frac{v}{c}\right)^2 + \text{h.o.T.}$$

$$E = \underbrace{mc^2}_{\text{Rest energy}} + \underbrace{\frac{1}{2}mv^2}_{\text{K.E.}} + \cdots$$