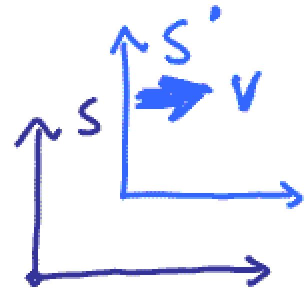
Physics 142 – October 16, 2008

- Presentation groups



Last time

Time dilation

Time is shortest as measured in
Proper frame

Suppose $\gamma = 3$

Biff (in S') burps while looking at his watch. His burp lasts 2 seconds.

Buffy (in S) says his burp lasts how many seconds?

Length contraction

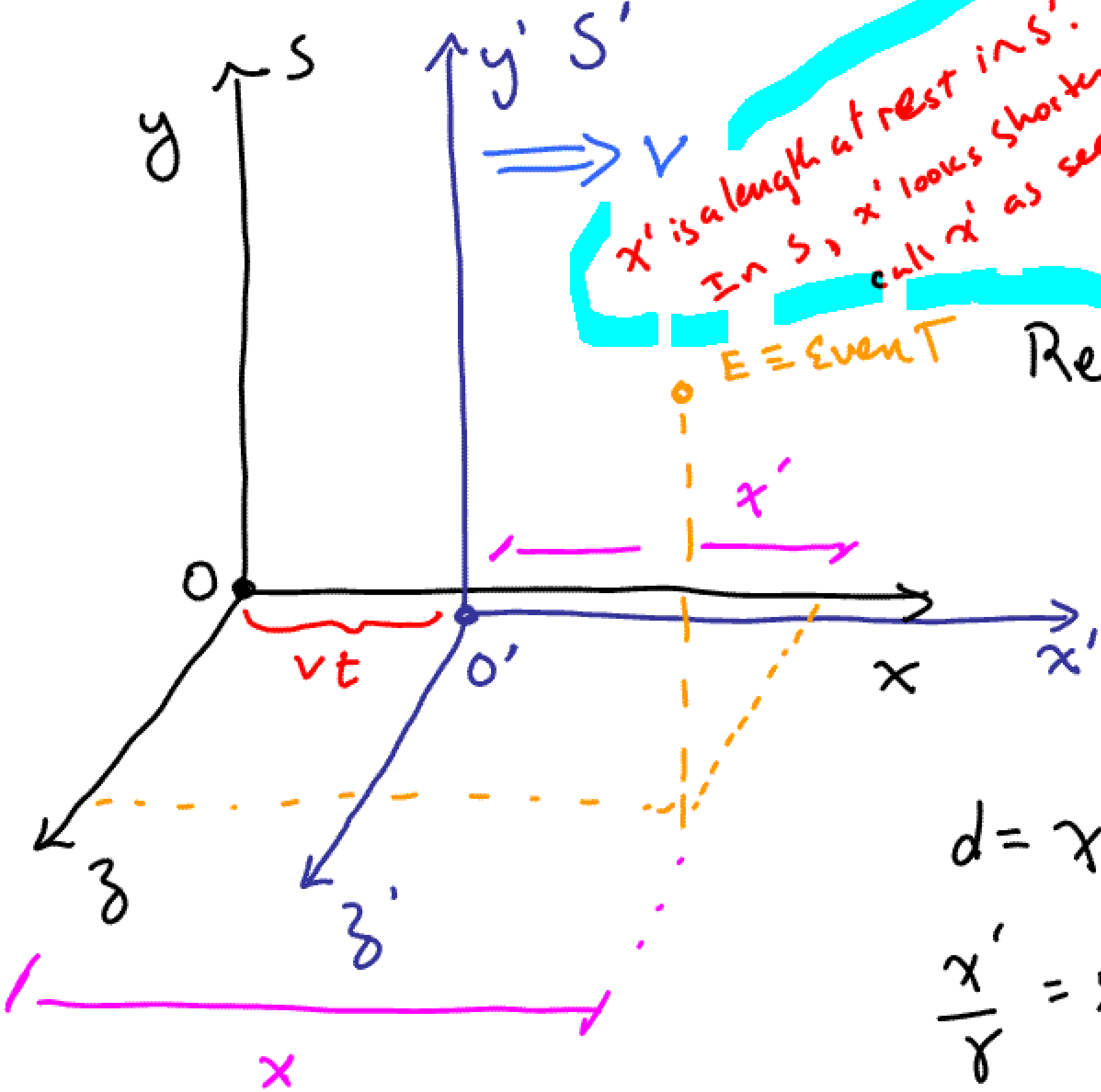
Length is longest as measured in **proper frame**

$$\Delta x = \Delta x'$$

where does γ go?

If S' is proper frame

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



x' is a length at rest in S'. In S, x' looks shorter by $\frac{1}{\gamma}$ call x' as seen in $S \to d$

$d = x'/\gamma$

This is reasoning I didn't recall in class

Relativistic Transformations

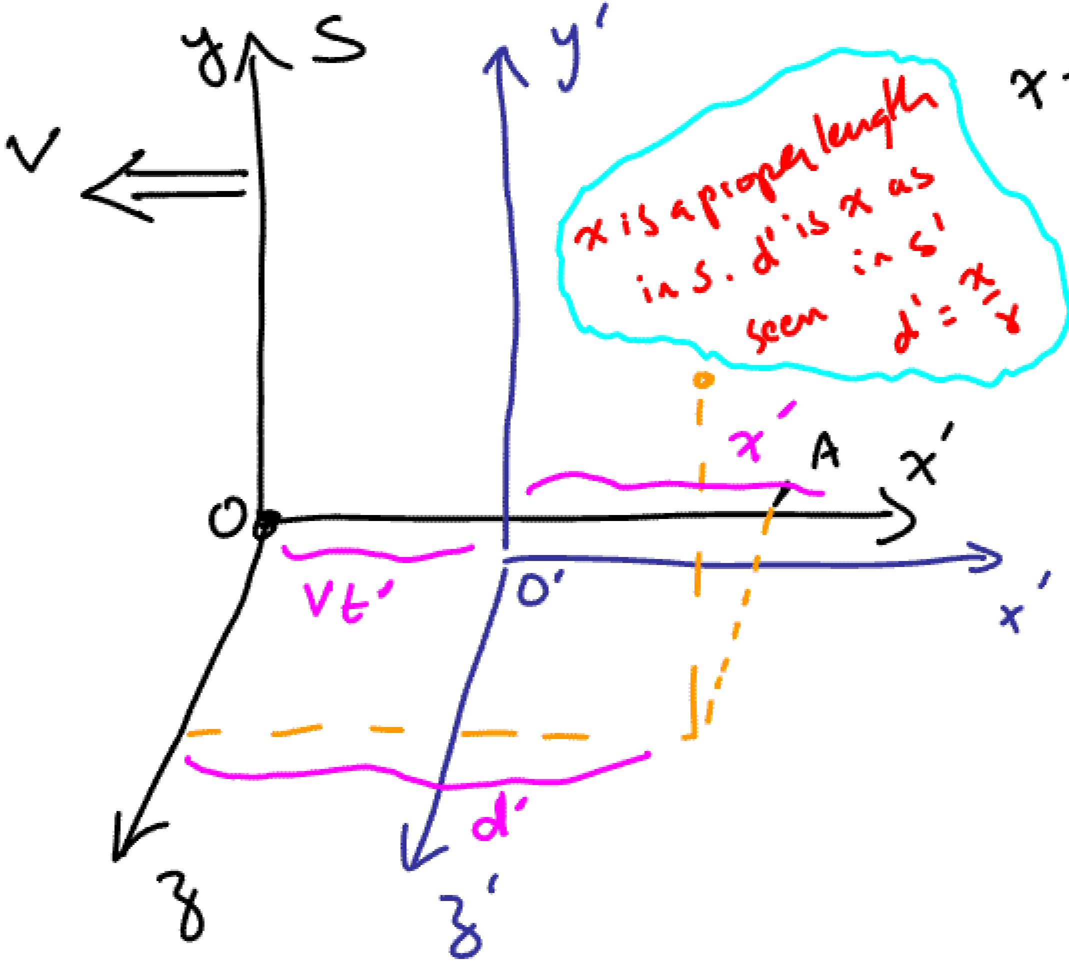
$$d = \frac{x'}{\gamma}$$

$$x' = d\gamma$$

$$d = x - vt$$

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

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



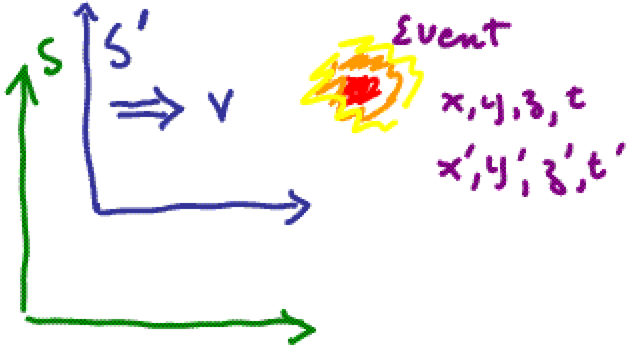
x = dist from O to A in S

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

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

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

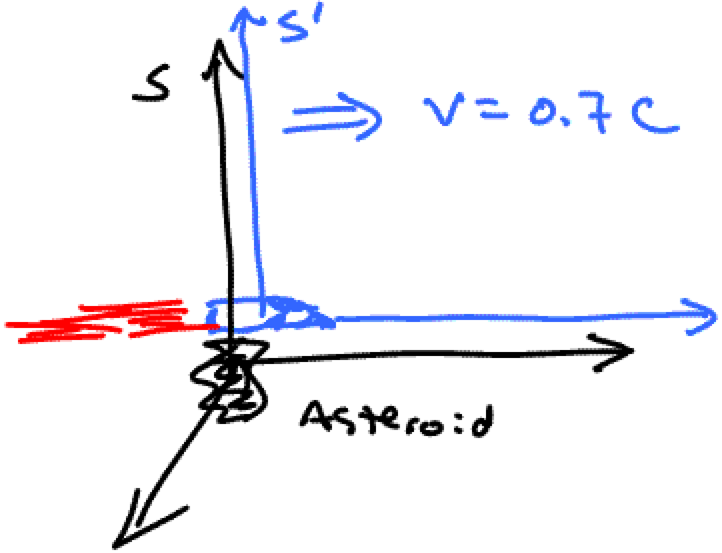
$$x = \gamma(x' + vt')$$



Lorentz Transformations

$$
\begin{cases}
x' = \gamma(x - vt) \\
y' = y \\
z' = z \\
t' = \gamma\left(t - \frac{vx}{c^2}\right)
\end{cases}
$$

$v \to$ small $\Rightarrow \gamma = 1$ $\frac{v}{c} \to 0$ get Gallilean Transformations



$$\gamma = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}} = 1.4$$

Event 1: $t = 0$, $t' = 0$ Rocket passed Asteroid

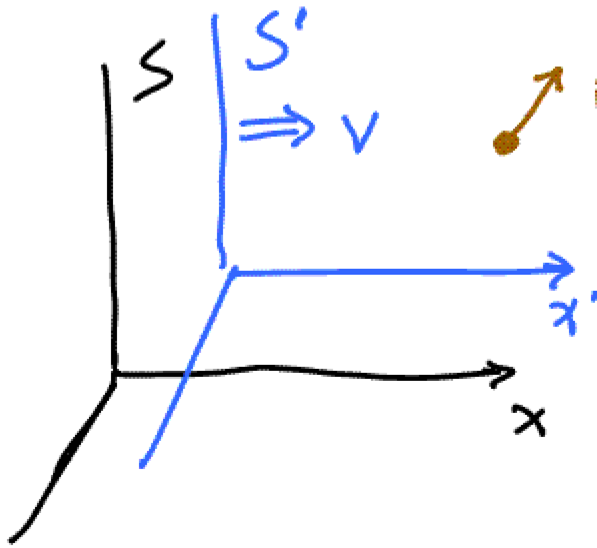
Event 2: Laser flashes at $\underbrace{x = 3\,\text{km},\ t = 5\,\mu s}_{\text{is } S}$

What does event 2 look like in S'?

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

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

Velocity Transformations



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

in S

$$U_x = \frac{dx}{dt}$$

$$U_y = \frac{dy}{dt}$$

$$U_z = dz/dt$$

in S'

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

U_x

U_x

$$\boxed{U_x' = \frac{U_x - V}{1 - \frac{V}{c^2}U_x}}$$

$$u_y' = \frac{dy'}{dt'} = \frac{dy}{\gamma\left(dt - \frac{v}{c^2}\,dx\right)} = \frac{\underbrace{\frac{dy}{dt}}_{u_y}}{\gamma\left(1 - \frac{v}{c^2}\underbrace{\frac{dx}{dt}}_{u_x}\right)}$$

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

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

You flying to LA

Speed is $5/8\,c$ w/ respect to earth

$$\frac{dx}{dt} = v$$

define <u>Proper velocity</u> $\equiv \eta = \dfrac{dx}{d\tau}$

meas on ground

meas on plane

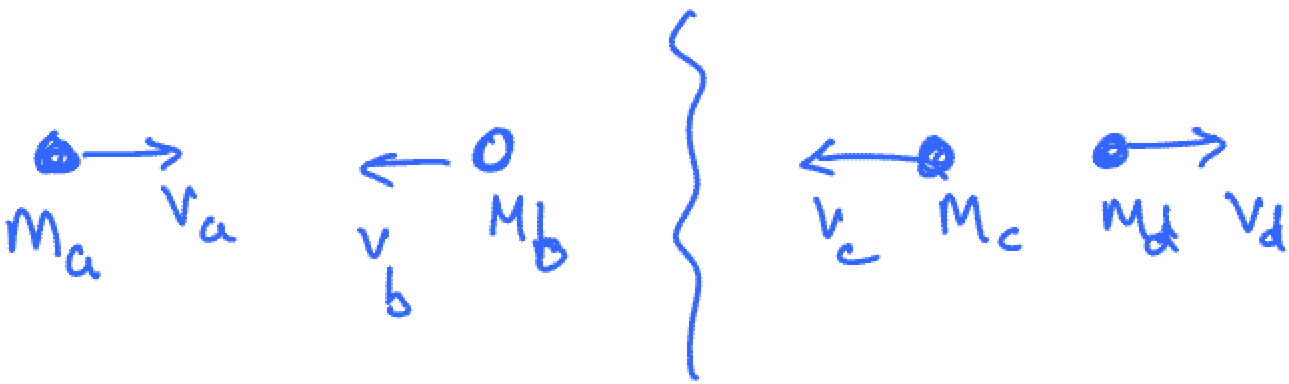
$\tau \equiv$ Proper time

Relevent to decide if you are hungry when you land.

$$\eta_x = \frac{dx}{d\tau}$$ Transforms like x

$$dt = \gamma \, d\tau$$

$$\eta = \frac{dx}{d\tau} = \gamma \frac{dx}{dt} = \gamma v$$



Newton $\quad m_a v_a + m_b v_b = m_c v_c + m_d v_d$

P cons. does not hold!

define $\quad p \equiv m\eta \quad \rightarrow \quad p$ cons. can hold if

4th component = γmc^2

Relativistic Energy

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

Spacetime 4-vector $\vec{x}, t$ is a 4-some (4-vector)

Certain transformation properties

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

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

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

$$\gamma \equiv \left(\frac{v}{c}\right)^2$$

$$E = mc^2 + \frac{1}{2}(mc^2)\left(\frac{v}{c}\right)^2 + \text{higher order term}$$

$$E = \underbrace{mc^2}_{\text{Energy const.}} + \underbrace{\frac{1}{2}mv^2}_{\text{K.E.}} + \text{h.o.t.}$$

Relativistic

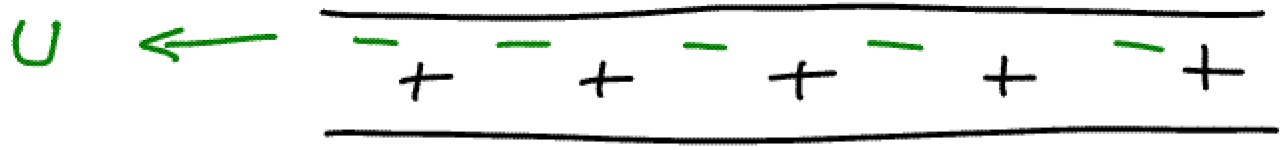
Energy const.

Rest Energy

K.E.

$v=0$

$E = mc^2$

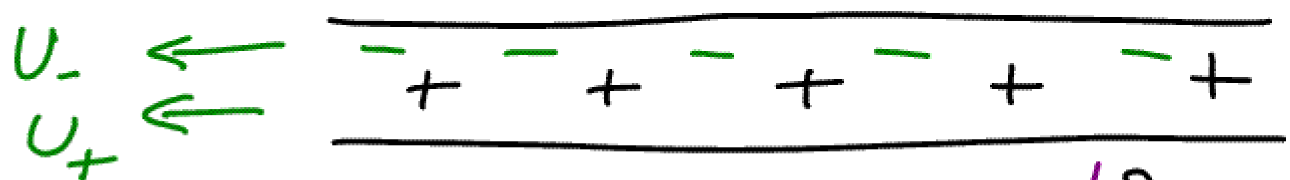


$\lambda_- \approx \lambda_+$

q_0

No Net $\vec{E}$, No force

Look at same situation we move
Right at speed V



$\lambda_- \not\approx \lambda_+$

Have force

Electric ... or Magnetic

$\longleftarrow q_0$

magnetic Field $\equiv \vec{B}$

Lorentz Force Law

$$\boxed{\vec{F} = q\vec{E} + q\vec{V} \times \vec{B}}$$

Einstein's 1905 paper on Special relativity was entitled "On the electrodynamics of Moving Bodies"