

SPECIAL RELATIVITY

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

$$v/c \rightarrow 0 \quad \gamma \rightarrow 1$$

(Newtonian)

$$v/c \rightarrow 1 \quad \gamma \rightarrow \infty$$

(Relativity)

example:

$$M = \gamma m_0$$

rel. mass \uparrow rest mass

$$v \rightarrow c \quad M \rightarrow \infty$$

no more acceleration

$$F = m \cdot a$$

HENCE cannot go faster than c

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photon have zero m_0

"post-Newtonian" approx.

v^2/c^2 is small
but not zero

$$(1+E)^n = 1 + nE + \dots$$

\uparrow something small $E \ll 1$ $\nwarrow \searrow$ negligible

$\Rightarrow (1+E)^n \approx 1 + nE$ if $E \ll 1$.

\uparrow Newtonian \nwarrow "post-Newtonian" approx

Earth's orbit: $v = 3 \times 10^4 \text{ m/s}$
 $c = 3 \times 10^8 \text{ m/s}$

$$\frac{v^2}{c^2} = \left(\frac{3 \times 10^4}{3 \times 10^8} \right)^2 = 10^{-8}$$

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

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

\nwarrow ignore

$$\begin{aligned}
 M &= M_0 \gamma \\
 &= M_0 \left(1 + \frac{1}{2} \frac{v^2}{c^2} \right) \\
 &= M_0 + \underbrace{\frac{1}{2} M_0 v^2}_{\text{Kinetic energy}} \frac{1}{c^2}
 \end{aligned}$$

\uparrow Newtonian

$$M = M_0 + \frac{K.E.}{c^2}$$

$$\boxed{\frac{E}{c^2} = m}$$

\uparrow mass equivalent
kinetic energy

$$\begin{aligned}
 \overline{m = m_0 \gamma} : & \quad \frac{v^2}{c^2} \rightarrow 0 \\
 & \quad \frac{v^2}{c^2} \rightarrow 1 \\
 & \quad \frac{v^2}{c^2} \gg 1
 \end{aligned}$$

Newtonian
 light is
 a speed limit
 $E = mc^2$

What is mass?

$$F = m a$$



higher mass requires
greater force to accelerate

"inertial mass"

$$t = \gamma t_0 \quad \text{time dilation}$$

$$L = \frac{L_0}{\gamma} \quad \text{length contraction}$$

"Lorentz transformations"

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

$$v/c \rightarrow 0 \quad \gamma \rightarrow 1$$

$$M_{\text{energy}} = M_{\text{invariant}}$$

↑
rest mass

$$\frac{1}{(1 - v^2/c^2)^{1/2}}$$

$$\sim 1 + \frac{1}{2} v^2/c^2 + \dots$$

↑
rest mass

↑
kinetic
 $\frac{E}{c^2}$

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force : ability to do work

$$E = mc^2$$

total energy inertial mass kinetic energy

$$m = m_0 + \frac{K.E.}{c^2}$$

rest energy

 c^2

$$E = c^2 m_0 + K.E.$$

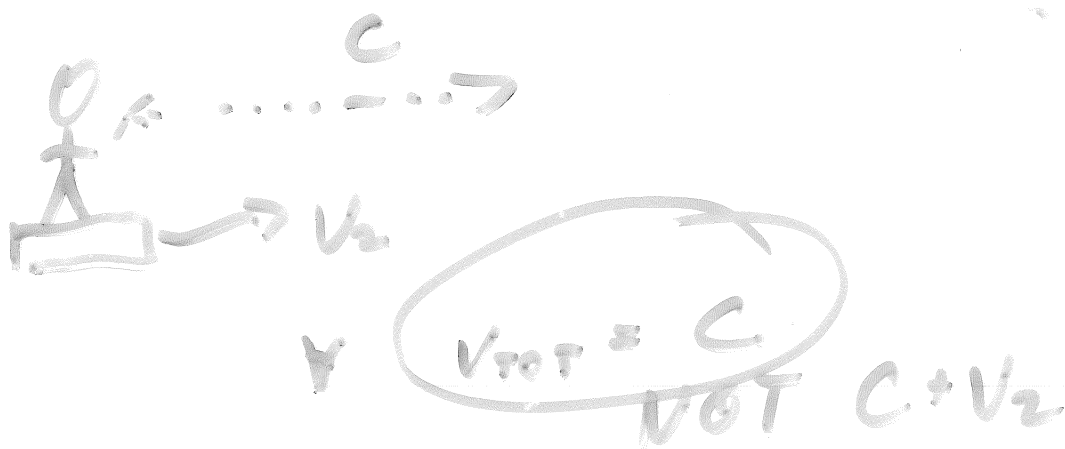
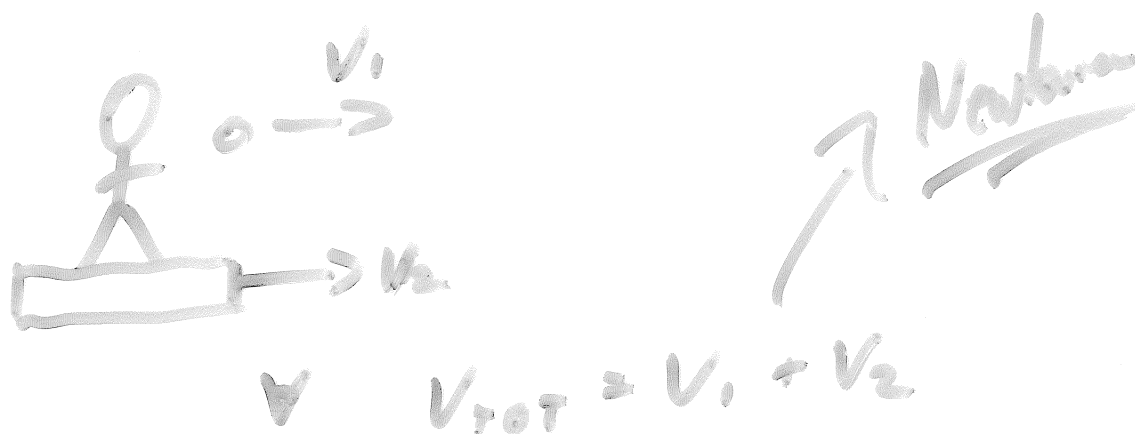
$$t = \gamma t_0$$

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

\Rightarrow imaginary



the speed of light is
same ~~is~~ for all
observers.



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velocity is space
time

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So space and time are messed up
close to c.