PHYS 2170

General Physics 3 for Majors

Fall 2021

Lecture 2

Time dilation

August 25

1 What are the postulates of Einstein's theory of special relativity?

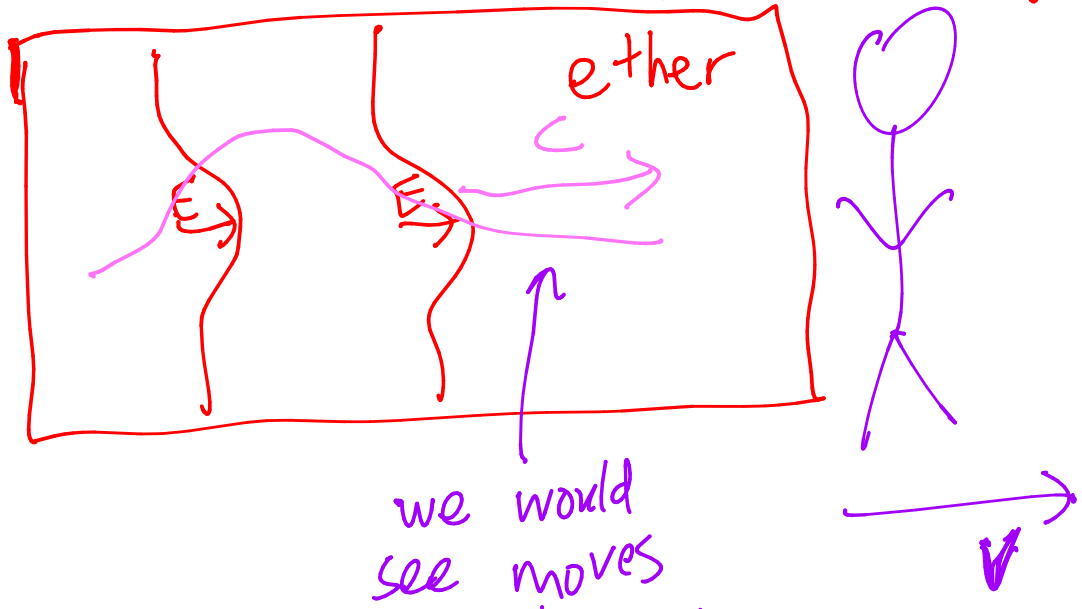
#1: laws of physics same in all inertial ref. frames

conc. of momentum

observer moves @ const. velocity.

#2: speed of light ($c \approx 3 \times 10^8 \frac{m}{s}$) is same in all inertial frames.

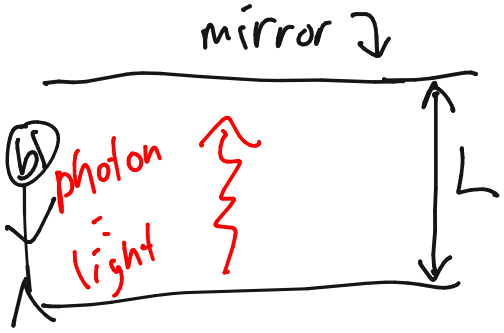
History: 1860s: Maxwell develops E&M: light is EM wave



we would see moves at vel. c-v

1890s: Michelson & Morley: expt'l'y see speed of light c

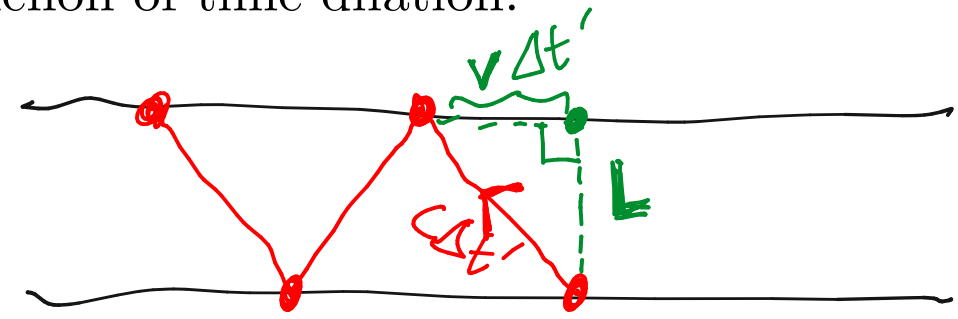
2 Explain the phenomenon of time dilation.

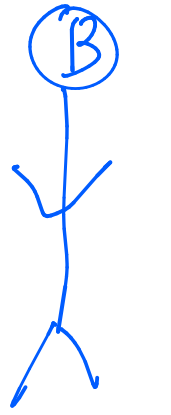


clock tick =
light hit mirror

ticking time $\Delta t = \dfrac{\text{distance}}{\text{speed}}$

$$\Delta t = \frac{L}{c}$$





What is ticking time $\Delta t'$ seen by Blue?

Pythagorean Thm:

$$(c\Delta t')^2 = (v\Delta t')^2 + L^2$$

Solve for $\Delta t'$:

$$\Delta t' = \frac{L}{\sqrt{c^2 - v^2}}$$

$\boxed{\Delta t' > \Delta t}$

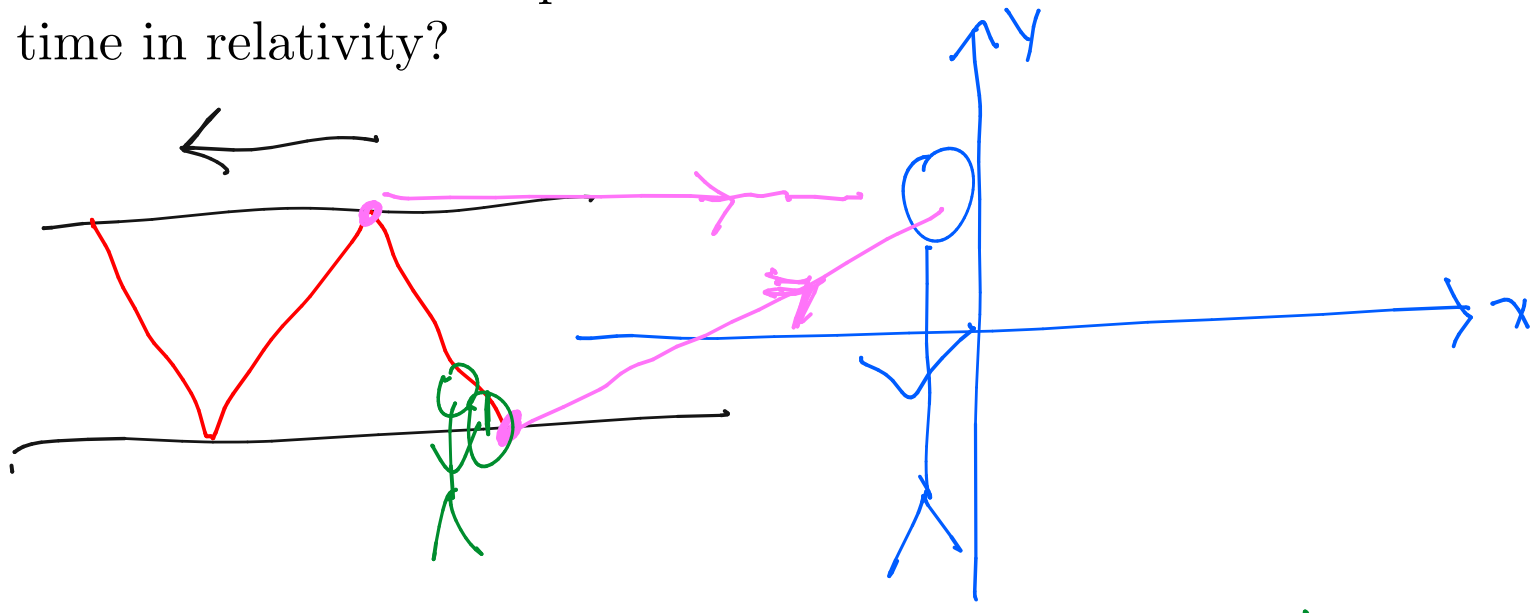
time dilation

$\beta = \dfrac{v}{c}$ $\quad -1 \le \beta \le 1$

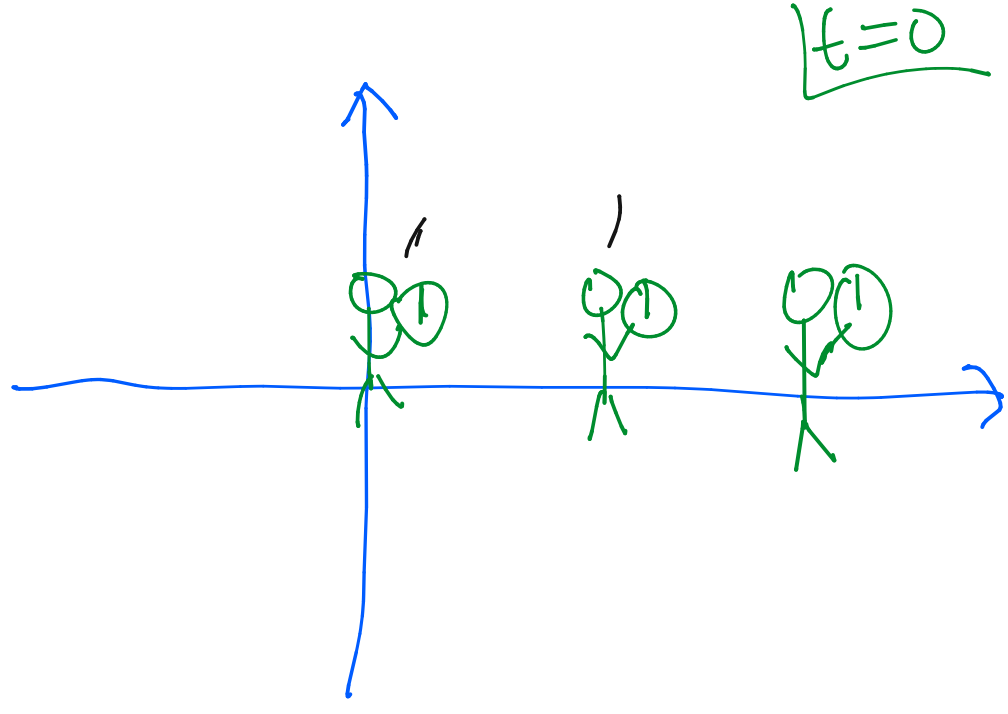
$\gamma = \dfrac{1}{\sqrt{1-\beta^2}}$ $\quad \gamma \ge 1$

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

3 What is the definition of a spacetime event? How should we think about time in relativity?



event: (t, x, y, z)



4 On an airplane, you travel at around 200 m/s. How much slower does someone's watch tick (as "seen" by you, on the ground) when they are on a plane?

plane ↓ $\Delta t'$ / Δt ↑ ground

$$\frac{\Delta t'}{\Delta t} - 1 = \boxed{\gamma - 1} \approx 10^{-13}$$

$$\beta = \frac{2\times10^2}{3\times10^8} = \frac{2}{3}\times10^{-6}$$

Taylor expand!

β small

$$\gamma(\beta) = \frac{1}{\sqrt{1-\beta^2}}$$

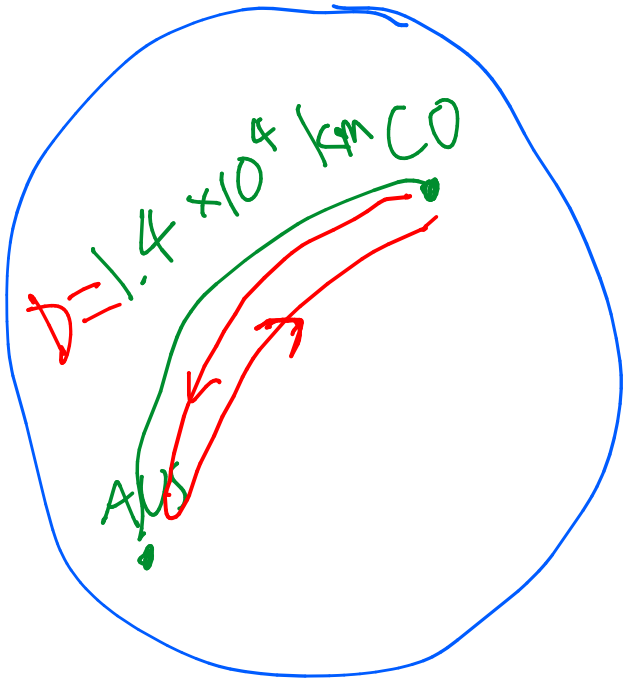
$$= \gamma(0) + \gamma'(0)\beta + \frac{1}{2}\gamma''(0)\beta^2 + \cdots$$

$$\gamma(\beta) = 1 + \frac{1}{2}\beta^2 + \cdots$$

higher order corrections.

$$\gamma - 1 \approx \frac{1}{2}\beta^2 \approx \frac{1}{2}\left(\frac{2}{3}\times10^{-6}\right)^2 = \frac{2}{9}\times10^{-12} \approx 2.2\times10^{-13}$$

5 Australia is about 1.4×10^4 km away from Boulder (as measured along the surface of the Earth). How long does it take to send a signal there and back? (E.g. relevant for online gaming!)



$$\Delta t = \frac{2D}{c}$$

$$= \frac{2.8 \times 10^4 \times 10^3 \text{ m}}{3 \times 10^8 \text{ m/s}}$$

$$= 100 \text{ ms} = 0.1 \text{ s}.$$