Physics 201 - Lecture 31

$$\boxed{\text{Relativity, Continued!}}$$

Time Dilation

"Moving clocks run slower"

$$\boxed{t_{\substack{\text{moving}\\ \text{observer}}} = \gamma \, t_{\substack{\text{stationary}\\ \text{observer}}}}$$

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

Example: Let's take a trip to the nearest star, and see if there is any life there!

Proxima Centauri (it has at least one planet, according to recent exoplanet searches!)

How far away is it?

→ 4.4 lightyears

?

what's this.

1 ly ≡ distance traveled by light in one year

$$= v \, t \qquad 365 \times 24 \times 60 \times 60$$

$= (3.0 \times 10^8 \, m/s)(3.15 \times 10^7 s)$

$\boxed{1 \text{ ly} = 9.45 \times 10^{15} \, m}$

$\therefore \boxed{4.4 \text{ ly} = 4.15 \times 10^{16} \, m}$ ✓

How fast can we travel?

Current Best: Parker Solar Probe

(launched in 2018)

Expected final speed in 2024

$= \boxed{430{,}000 \text{ mph}}$

$= 430{,}000 \dfrac{\cancel{\text{miles}}}{\cancel{\text{hour}}} \times \dfrac{1609 \, m}{\cancel{\text{mile}}} \times \dfrac{1 \cancel{\text{hour}}}{3600 \, s}$

$= 1.19 \times 10^5 \, m/s$

$$\boxed{\frac{v}{c}} = \frac{1.19 \times 10^{5}\ \text{m/s}}{3.0 \times 10^{8}\ \text{m/s}} = \underline{0.0004}$$

(i.e. 0.04 % of the speed of light)

How long to Proxima Centauri?

$$t = \frac{d}{v} = \frac{4.15 \times 10^{16}\ \text{m}}{1.19 \times 10^{5}\ \text{m/s}}$$

$$= 3.49 \times 10^{11}\ \text{s}$$

$$= \boxed{11{,}000 \text{ years!!!!!}}$$

9595 AD

$$\boxed{v = 0.5\,c}$$

$d \rightarrow$ m

$d = vt$

$t \to s$

$v \to m/s$

ly fraction of speed of light.

$d = 4.4$ ly

$v = 0.5c$

$t = ?$

$$t = \frac{d}{v} = \frac{4.4 \text{ ly}}{0.5}$$

$t = 8.8$ years.

$\boxed{\text{OK}}$

Relativity:

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

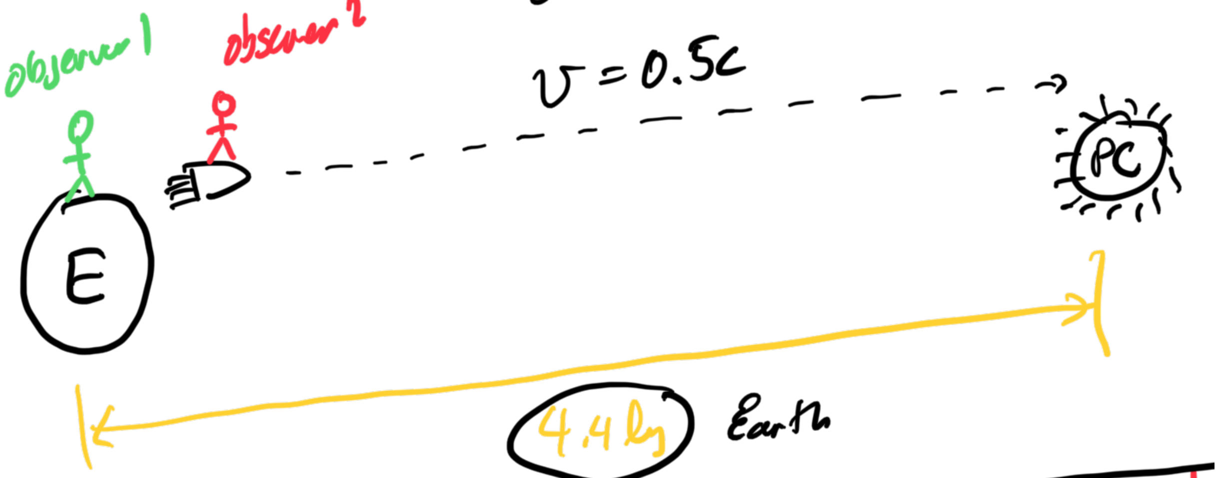
$$= \frac{1}{\sqrt{1-\left(\frac{0.5\cancel{c}}{\cancel{c}}\right)^2}}$$

$$\boxed{\gamma = 1.155}$$

$$t_{\text{moving observer}} = \gamma \, t_{\text{stationary observer}}$$

Earth → moving observer; Spaceship → stationary observer

$t_E = 8.8$ years.



speed!

→ $\boxed{\text{Both observers agree on the spa...}}$

→ spaceship is moving relative to observer 1 !!!

→ spaceship is stationary relative to observer 2.

$$t_{Earth} = \gamma\, t_{spaceship}$$

$$\boxed{8.8 \text{ years}} = (1.155)\, t_{spaceship}$$

$$t_{spaceship} = \frac{8.8 \text{ years}}{1.155}$$

$$t_{spaceship} = \boxed{7.6 \text{ years.}}$$

$$\boxed{v = 0.99\,c}$$

$$\gamma = \frac{}{\sqrt{1-\frac{v^2}{c^2}}} = 707$$

$$t_{earth} = \gamma\, t_{spaceship}$$

$$(8.8 \text{ years}) = 707\, t_{spaceship}$$

$$t_{spaceship} = 0.012 \text{ years}$$

$$= 0.15 \text{ months}$$

$$\boxed{t_{spaceship} = 4.5 \text{ days.}}$$

Spaceship

$$v = 0.5c$$

$$t_s = 7.62 \text{ years}$$

$$d_s = v \cdot t_s$$

$$= (0.5c)(7.62 \text{ years})$$

$$= \boxed{3.81 \text{ ly.}} \quad !!$$

~~wrong~~ ?

Earth

$$v = 0.5c$$

$$t_E = 8.8 \text{ years.}$$

$$d_E = v \cdot t_E$$

$$= (0.5c)(8.8 \text{ years})$$

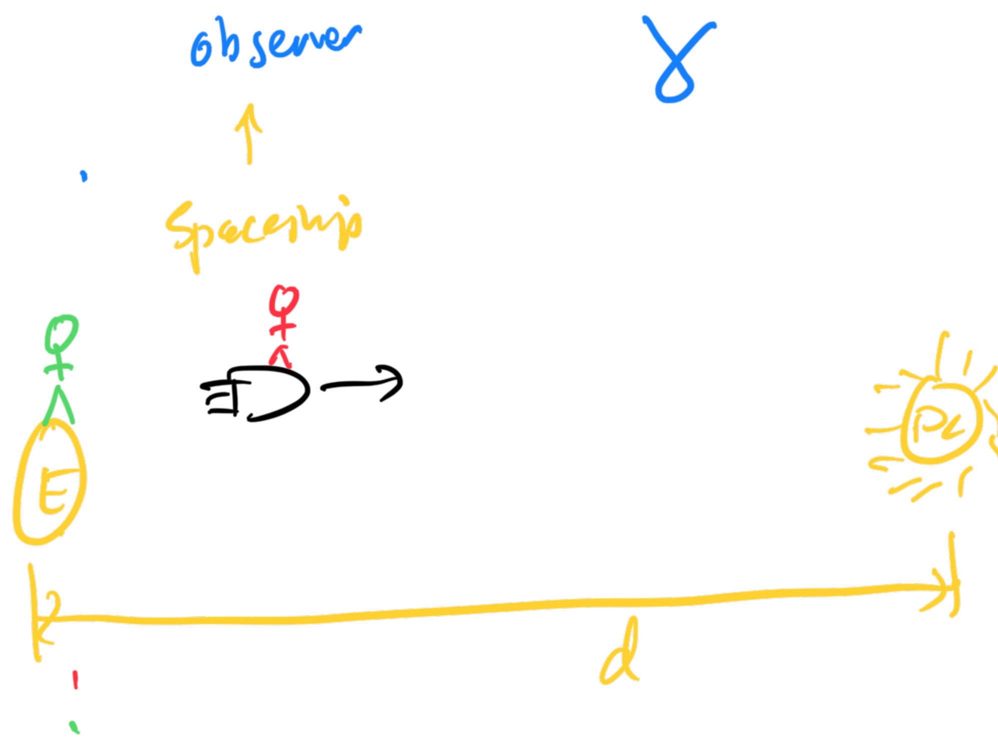
$$= \boxed{4.4 \text{ ly.}} \quad !!$$

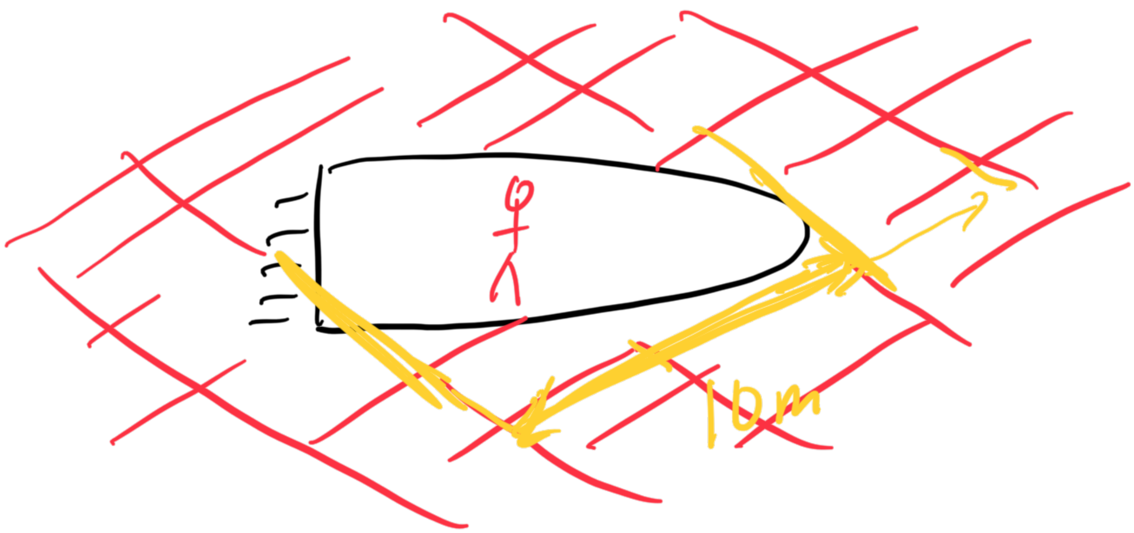
It's not just *time* that is relative, *distance* is as well!

Length Contraction:

$$d_{moving} = \frac{d_{\substack{\text{stationary} \\ \text{observer}}}}{}$$

earth





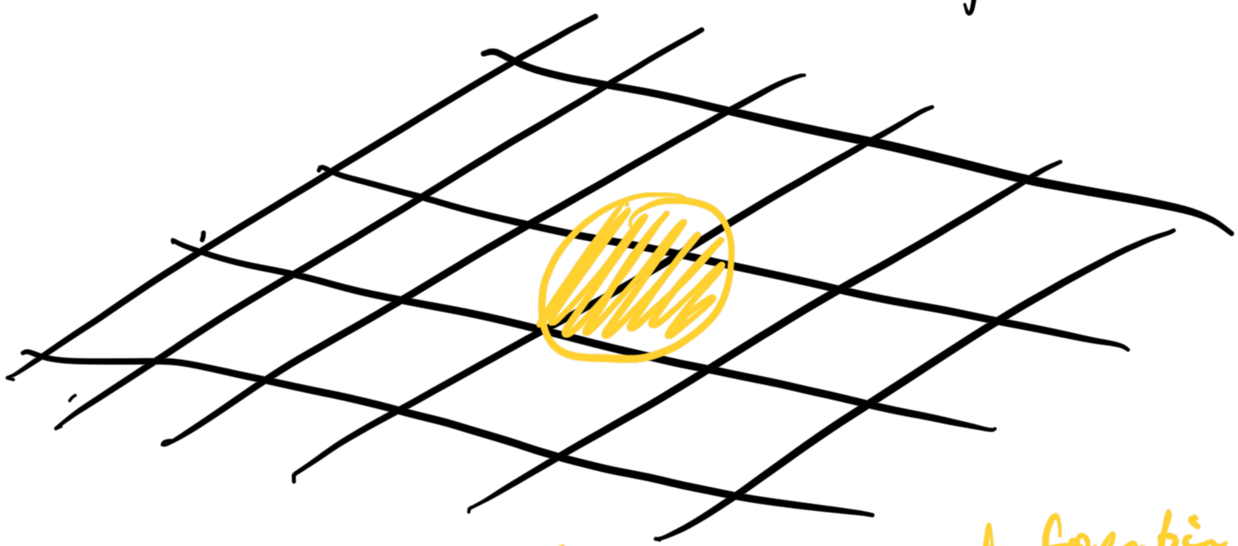
Space is like a ruler

$\boxed{\text{Gravity}}$

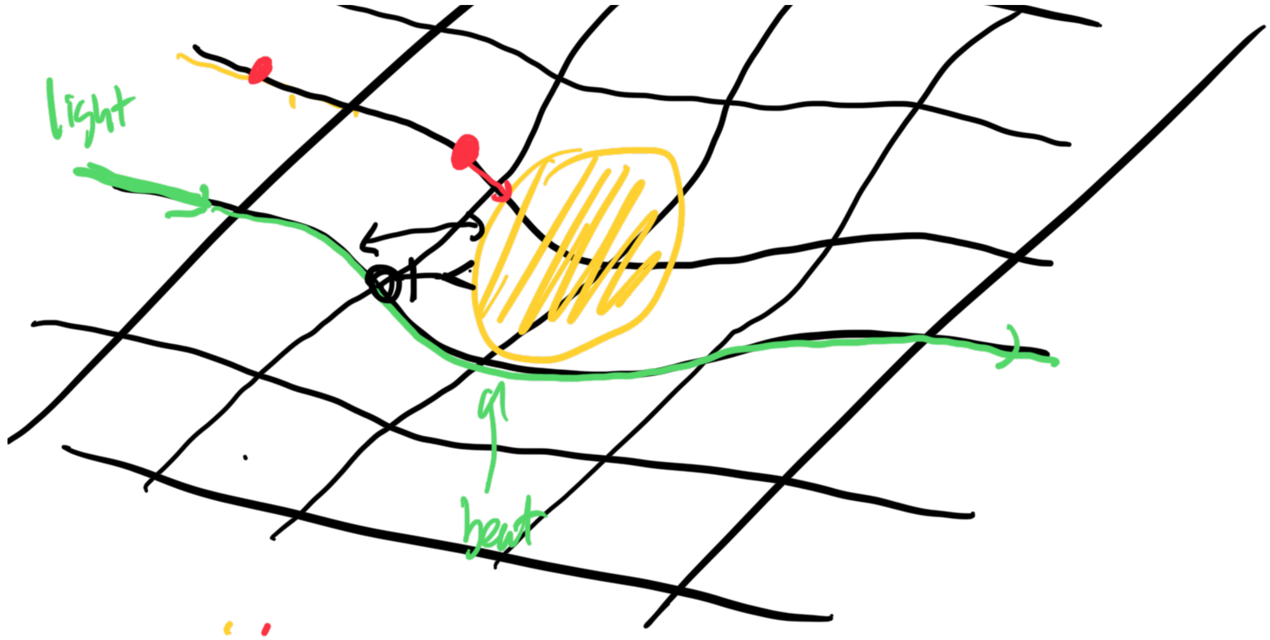
Newton → How.

Einstein → Relativity → Why

space.



gravity → deformation of the lines of space



gravitational lensing.