PHY 247 Lecture 14 Gary Shiu 10/9/06

Relativistic Kinematics (cont)

Recap:

1. Michelson-Morley expt $\Rightarrow$ no ether
2. Einstein's relativity $\Rightarrow$ modify Galilean transf.

Today:

1. Einstein's postulates
2. Time dilation
3. Length contraction

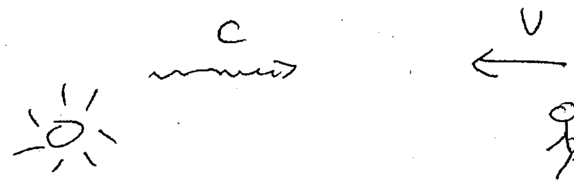
Einstein's Postulates

(1) Absolute uniform motion cannot be detected

(2) Speed of light is independent of the motion of source.

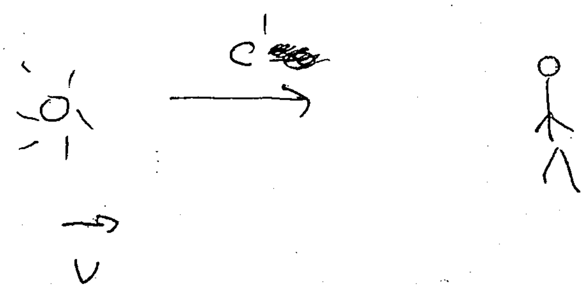
Important consequences

Simple expt:



what's speed of light?

completely equivalent to (by postulate (1))



Postulate (2) ⟹ $\boxed{c' = c}$ same in all inertial frame!

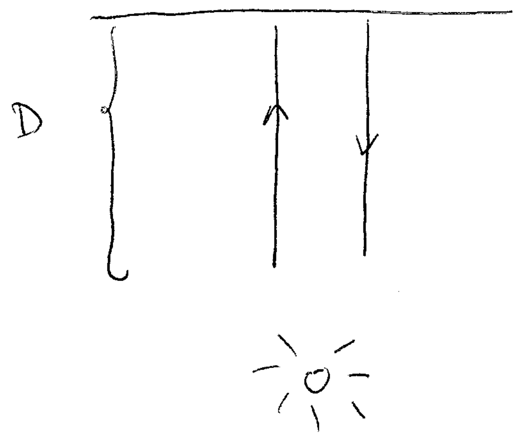
Einstein's [illegible] puzzle..

what do you see if run at $v \sim c$ [illegible]?

[illegible]

(Homework)

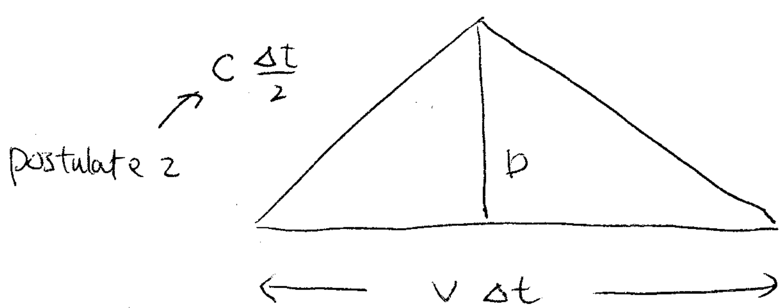
Gedankenexperiment (Thought Expt)



train 's frame

$$\Delta t' = \frac{2D}{c}$$

In lab frame



$$\left(c\frac{\Delta t}{2}\right)^2 = \left(\frac{v\Delta t}{2}\right)^2 + D^2$$

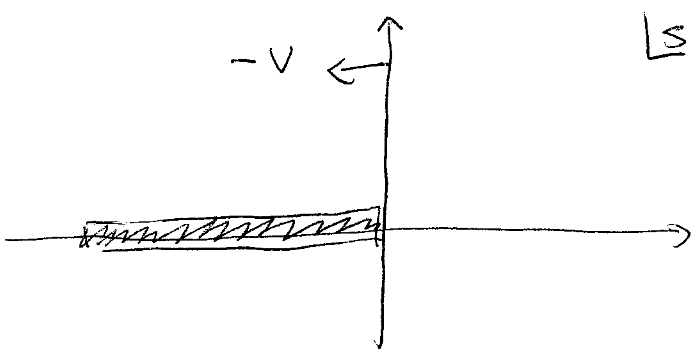
$$\Delta t = \frac{2D}{c\sqrt{1-\frac{v^2}{c^2}}} = \gamma\,\Delta t' \qquad \gamma \equiv \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

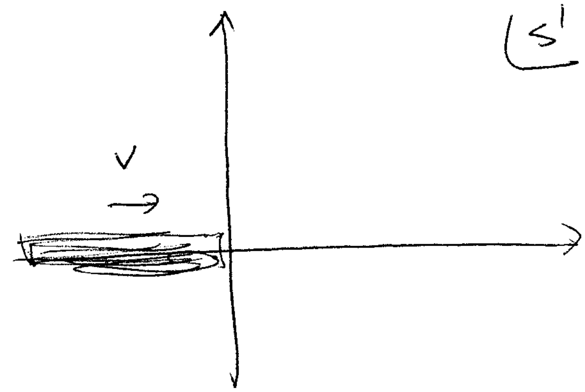
$\Rightarrow$ Time dilation [in lab frame]

Proper time : time measured at the same position in a reference frame [smallest time among all ref frames]

Length contraction

Consider two reference frames:





Meter stick stationary
origin moving at -v

meter stick moving at v
origin stationary

$$L = v\,\Delta t$$

$$L' = v\,\Delta t'$$

↑ proper time (why?)

$$\Rightarrow \boxed{L' = L\,\frac{\Delta t'}{\Delta t} = \frac{L}{\gamma}}$$

Length contraction

<u>Length contraction</u>: moving objects appear shorter than <u>proper length</u>
↓
at rest.

Muon Decay (classic example of relativity)

High Energy Cosmic ray hits earth's atmosphere

→ μ are produced as secondary radiation

μ can reach earth's surface because they

(i) decay relatively slowly (c.f other particles produced)

(ii) interact weakly with other stuff

- How slowly? $\tau \sim 2\mu s$ in μ-frame

What does that mean? $N(t) = N_0 e^{-t/\tau}$ (c.f. terminal velocity)

In $t \sim \tau$ $N \sim N_0 e^{-1}$ ⇒ practically $N \sim 0$ after a few τ

Typical speed $\sim 0.998c$

In $t \sim \tau$ travels only $0.998c \cdot \tau \sim 600m$ only

Naively, takes many τ to reach sea level.

How come we still find significant amount of μ?

→ **Time Dilation & Length Contraction**

Analyze from 2 different ref. frames:

(1) Earth's frame

$$\Delta t = \gamma \tau \quad \sim 15 \times 2\mu s \sim 30 \mu s$$

↑ proper time

Distance $\sim v \Delta t \sim 9000m$

(2) Muon's frame

$$\Delta t' = \tau$$

but length traveled is contracted

$$L' = \frac{9000m}{\gamma} \sim 600m \quad \text{according to } \mu$$

In fact, the fact that we observe significant amount of μ at sea level is a <u>sharp prediction</u> of relativity

$$N(t) \simeq N_0 e^{-t/\tau} \qquad t = \begin{cases} \frac{L}{v} & \gg \tau \quad \text{no relativity} \\ \frac{L}{\gamma v} & \sim \tau \quad \text{relativity} \end{cases}$$

L = distance from atmosphere to sea level