Physics 2D Lecture Slides
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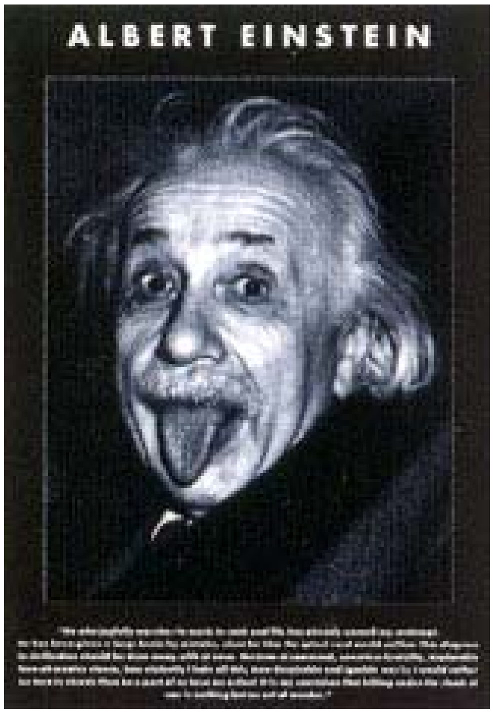
Waves/Interference/Diffraction Refresher

- Brian Wecht's streaming video and lecture notes available
  - http://tijuana.ucsd.edu/sharma/review
- Your will need Quicktime 6 player (MPEG 4) to view it
  - Should "just work" at UCSD computers (CLICS/GIESEL etc)
  - For Cable Modem/DSL Users => Sitting behind a firewall?
    - Need to get in DMZ zone to prevent UDP port blocking
    - Or see Quicktime Website for UDP ports needed for streaming
- Email problems / feedback to 2dvideo@physics.ucsd.edu
  - This gets forwarded also to our technical staff conducting the experiment
  - Feedback greatly appreciated !

Einstein's Theory of Relativity



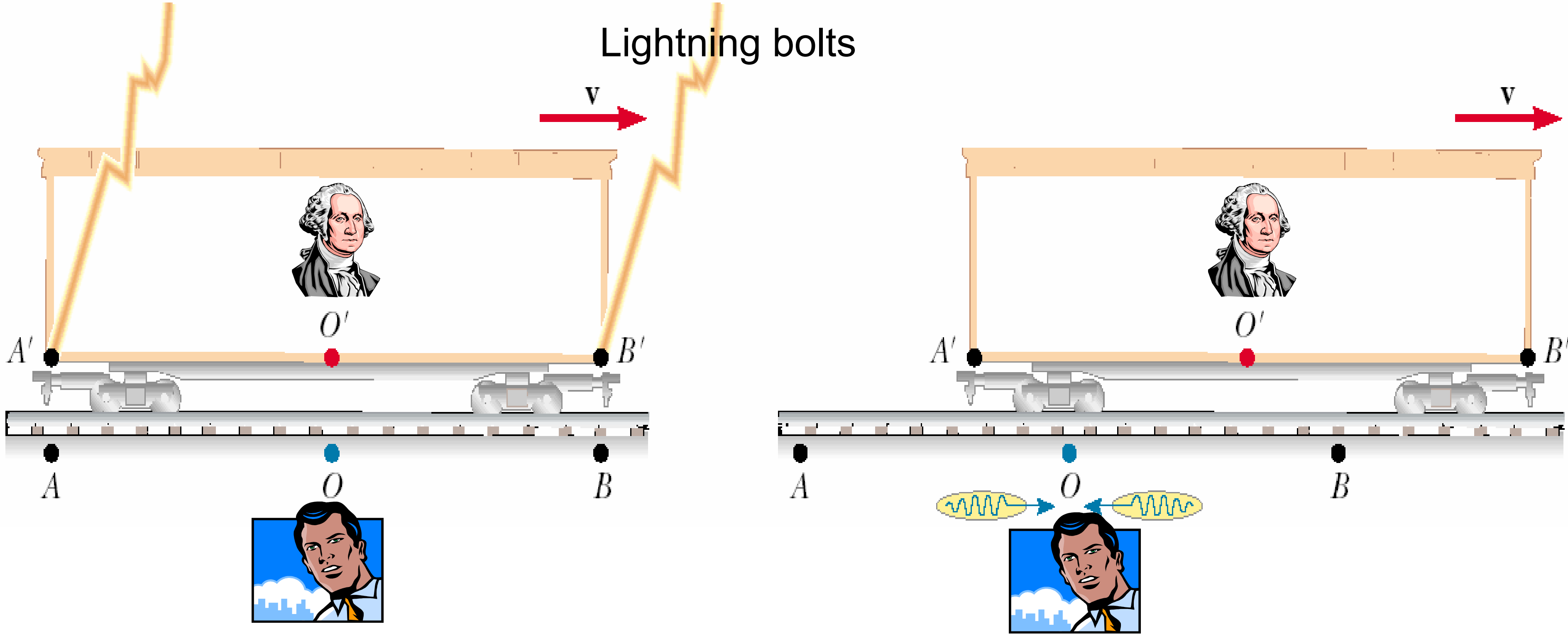
??

- Einstein's Postulates of SR
  - The laws of physics must be the same in all inertial reference frames
  - The speed of light in vacuum has the same value, in all inertial frames, regardless of the velocity of the observer or the velocity of the source emitting the light.

$$c = 3.0 \times 10^8 \text{ m/s}$$

Consequences of Special Relativity

Simultaneity: When two events occur at same time, held absolute for Classical Phys

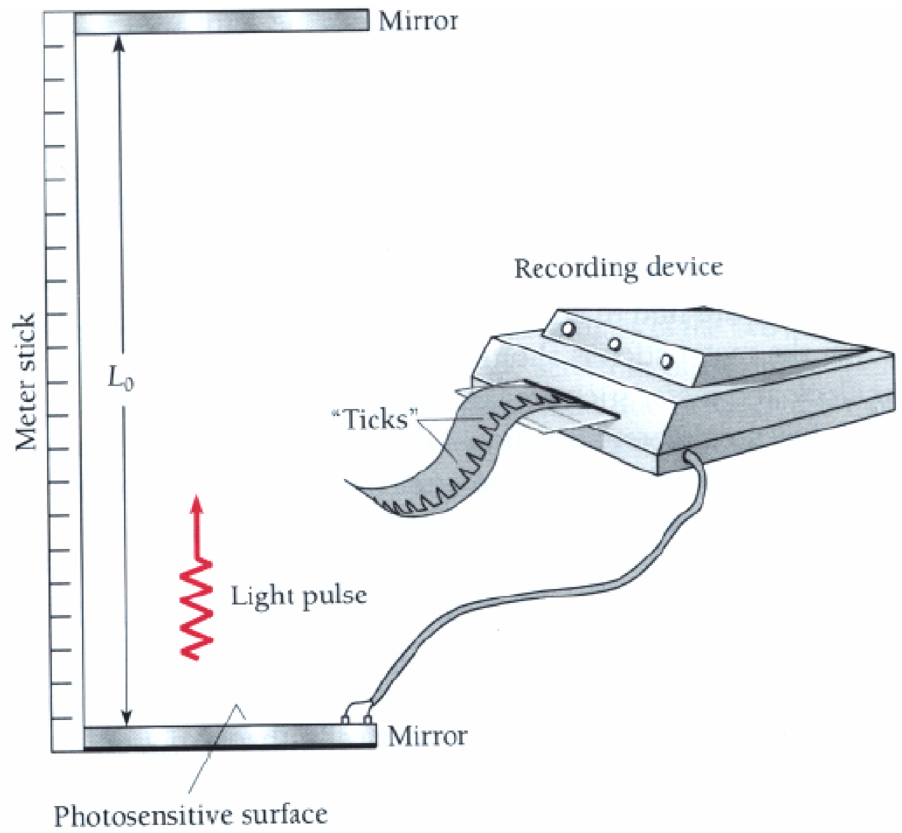


Events that are simultaneous for one Observer are not simultaneous for another Observer in relative motion

Simultaneity is not absolute !!

Time interval depends on the Reference frame it is measured in

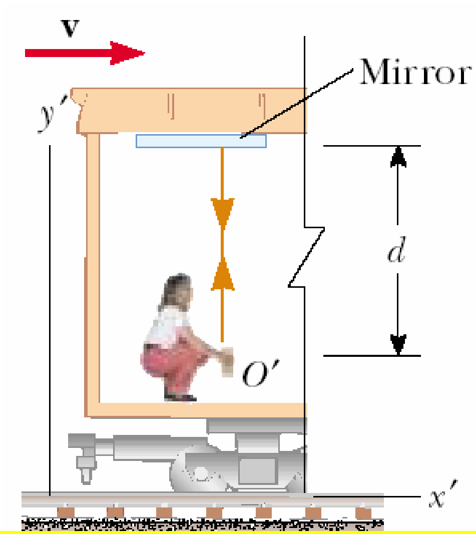
A Simple Clock Measuring a Time Interval

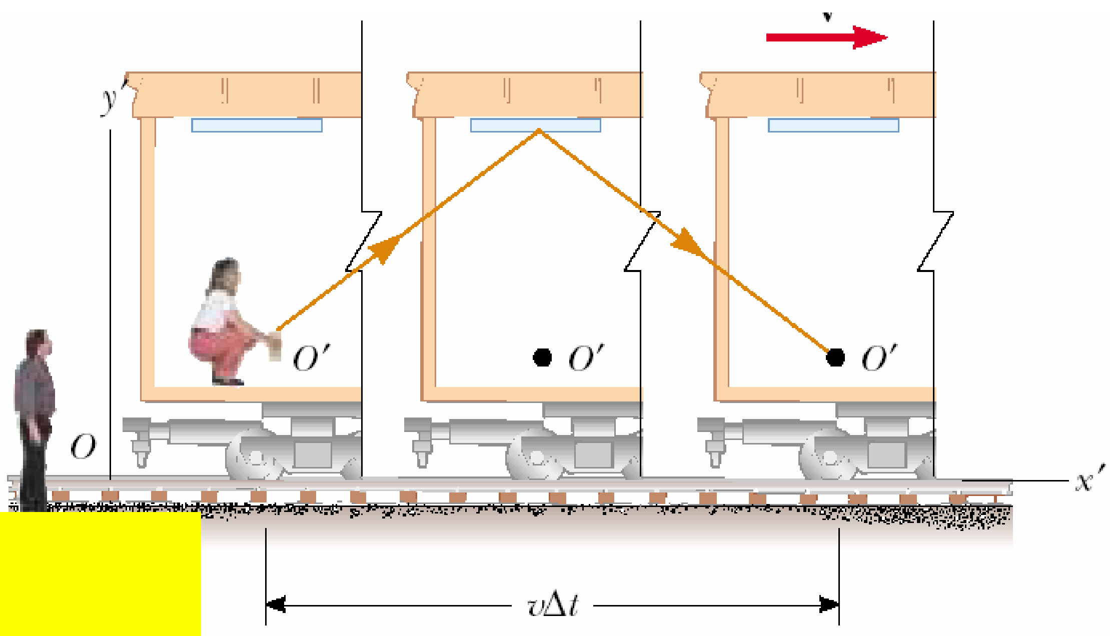


$$t = \int \Delta t$$

Time Dilation and Proper Time

Watching a time interval with a simple clock





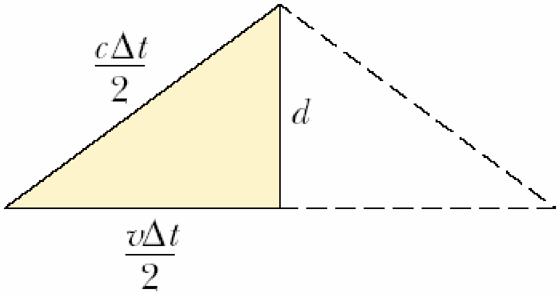
Observer O' : $\Delta t' = \dfrac{2d}{c}$

Observer O : Apply Pythogoras Theorem

$$\left(\frac{c\Delta t}{2}\right)^2 = (d)^2 + \left(\frac{v\Delta t}{2}\right)^2, \text{ but } d = \left(\frac{c\Delta t'}{2}\right)$$

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

$$\therefore \quad \Delta t = \frac{\Delta t'}{\sqrt{1-\left(\frac{v}{c}\right)^2}} = \gamma\,\Delta t', \ \Delta t > \Delta t'$$

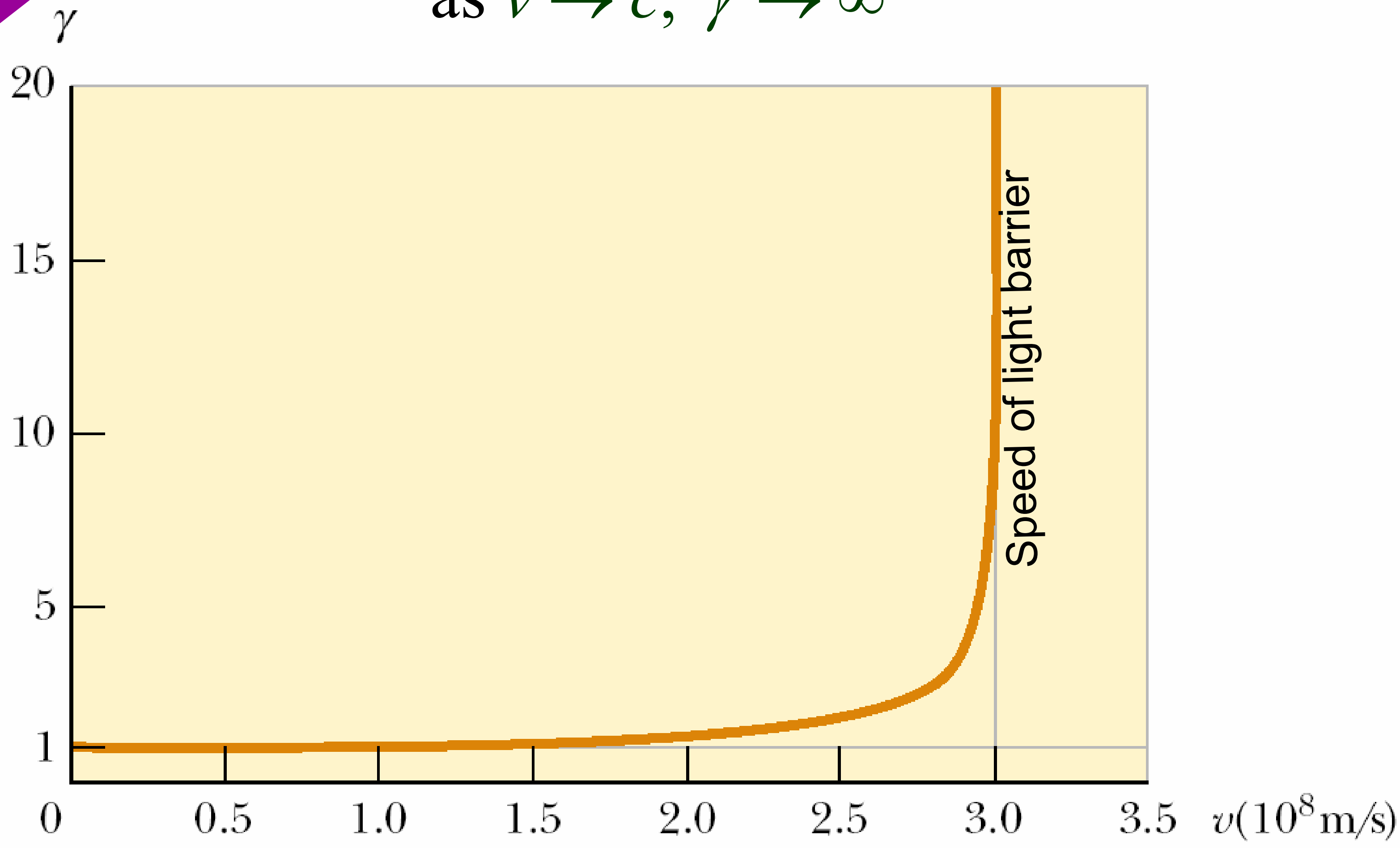


The γ factor

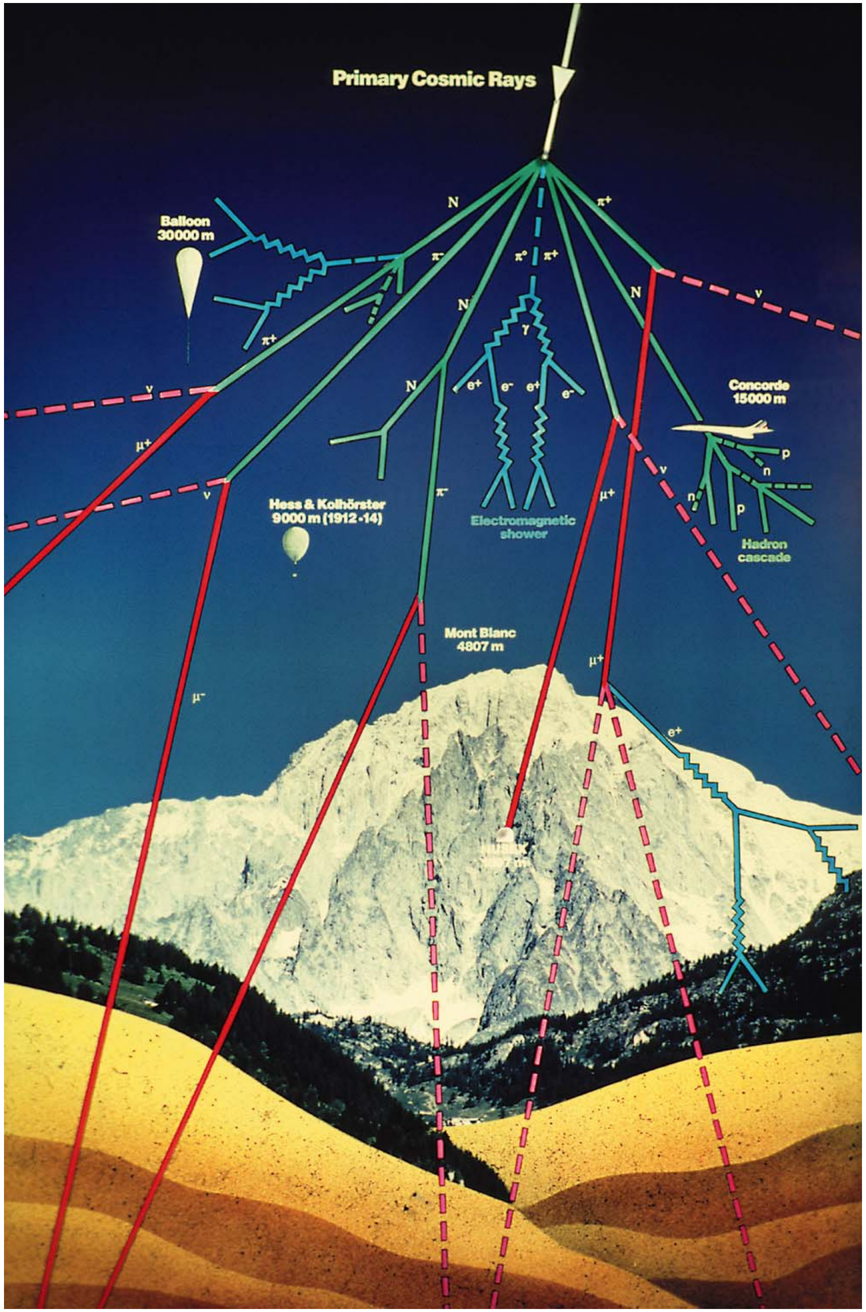
$$\gamma = \frac{1}{\sqrt{1 - v^2 / c^2}}$$

as $v \to 0, \ \gamma \to 1$

as $v \to c, \ \gamma \to \infty$



Time Dilation e.g: Cosmic Rays Bombarding Earth



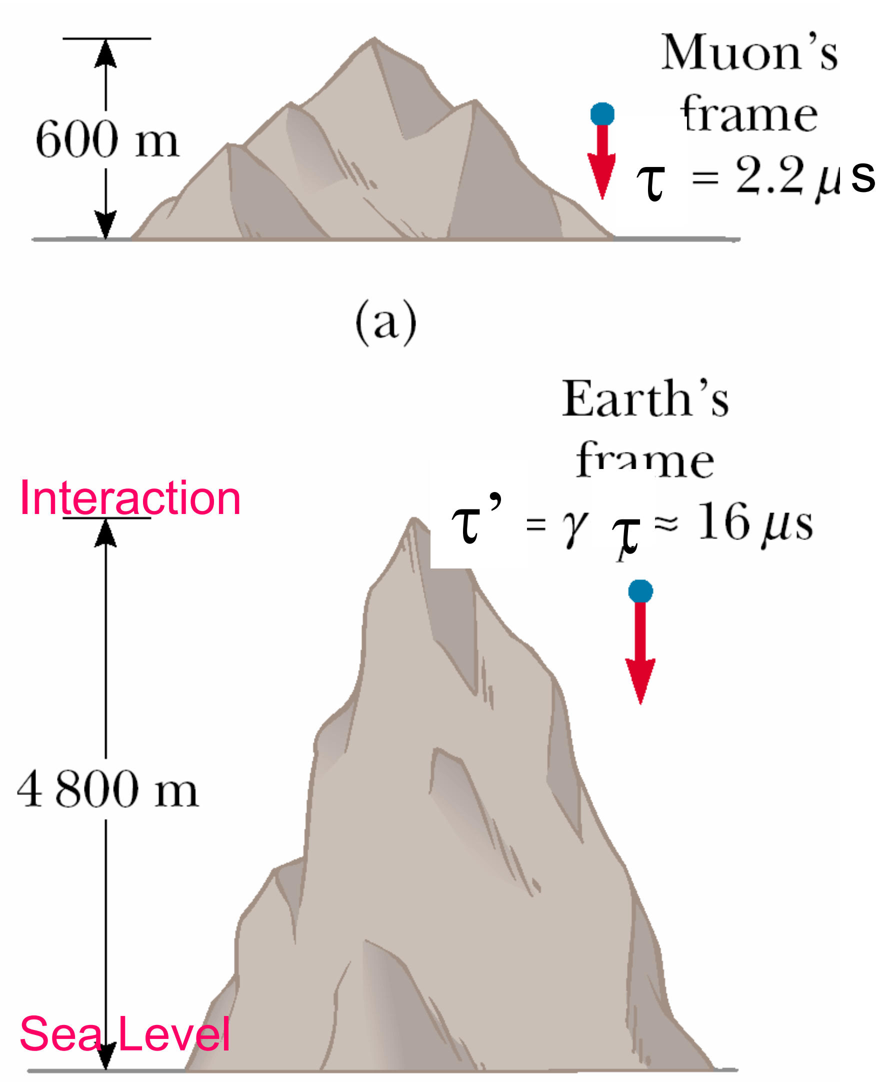
- Cosmic rays are messengers from space
- **Produced in violent collisions in the cosmos**
- **Typical Kinetic energy ~ 100 GeV**
- **Smash into Earth's outer atmosphere**
  - **4700 m from sea level**
- **Sometimes produce short lived Muons**

- **Muon is electron like charged particle**
  - **~ 200 times heavier , same charge**
  - **Lifetime $\tau = 2.2\mu s = 2.2 \times 10^{-6}$ s**
  - **Produced with speed $v \equiv c$**
  - **Distance traveled in its lifetime**

$$d = c\tau = 650m$$

  - **Yet they seem to reach the surface!!**
    - **Why => Time Dilation**
    - **Must pay attention to frames of references involved**

Cosmic Rays Are Falling On Earth : Example of Time Dilation



- Two frames of references
  1. Riding on the Muon
  2. On surface of earth

– Muon Rider has "Proper Time"
  – Time measured by observer moving along with clock
  □ $\Delta t' = \tau = 2.2\ \mu S$
  – $D' = v\ \Delta t' = 650m$

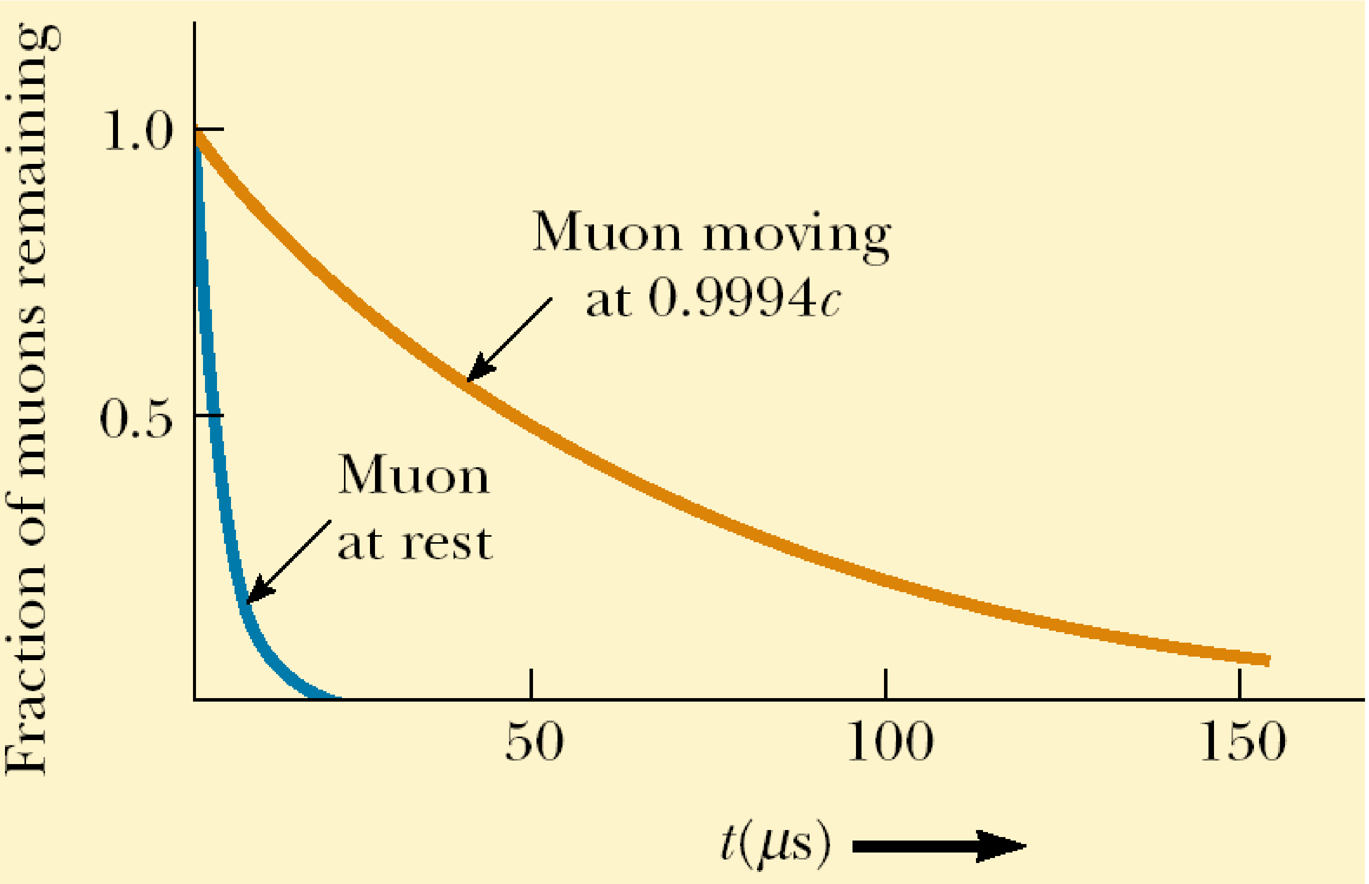
– Earthling watches a moving clock (muon's) run slower
  □ $\Delta t = \gamma\ \tau$
    – $v = 0.99c, \Rightarrow \gamma = 7.1$
    – $D = v\ \Delta t = 4700m$

Muon Decay Distance Distribution

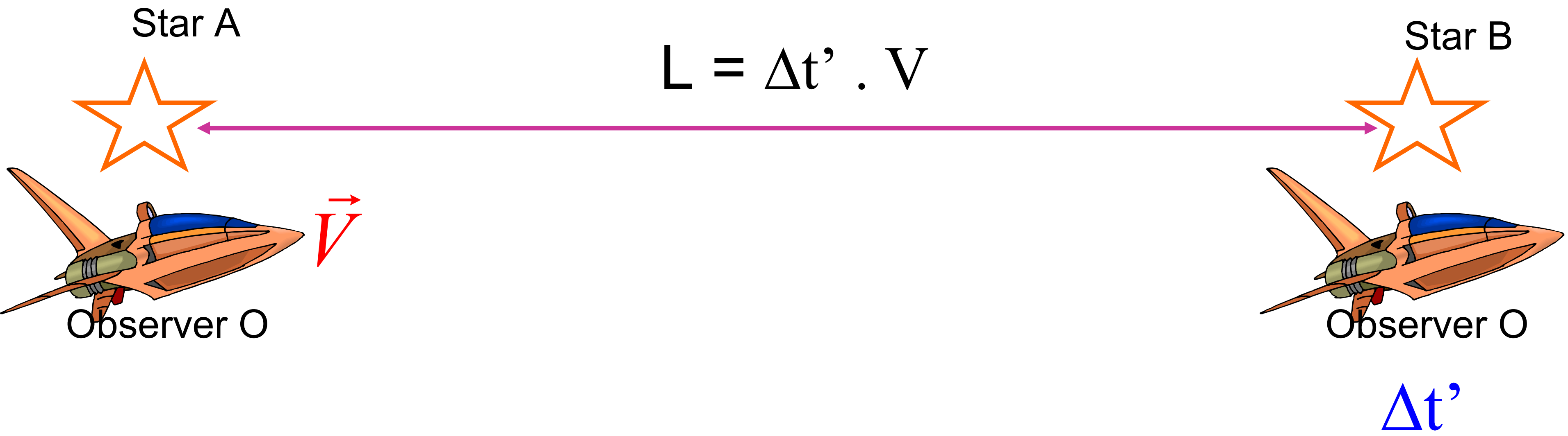
Relative to Observer on Earth Muons have a lifetime

$$t = \gamma\tau = 7.1\ \tau$$

Exponential Decay time Distribution : As in Radioactivity



Offsetting Penalty : Length Contraction



$$\Delta t = L'/V$$

Observer O'
At rest w.r.t stars A & B
Watches rocketship cross from
Star A to Star B in time Δt

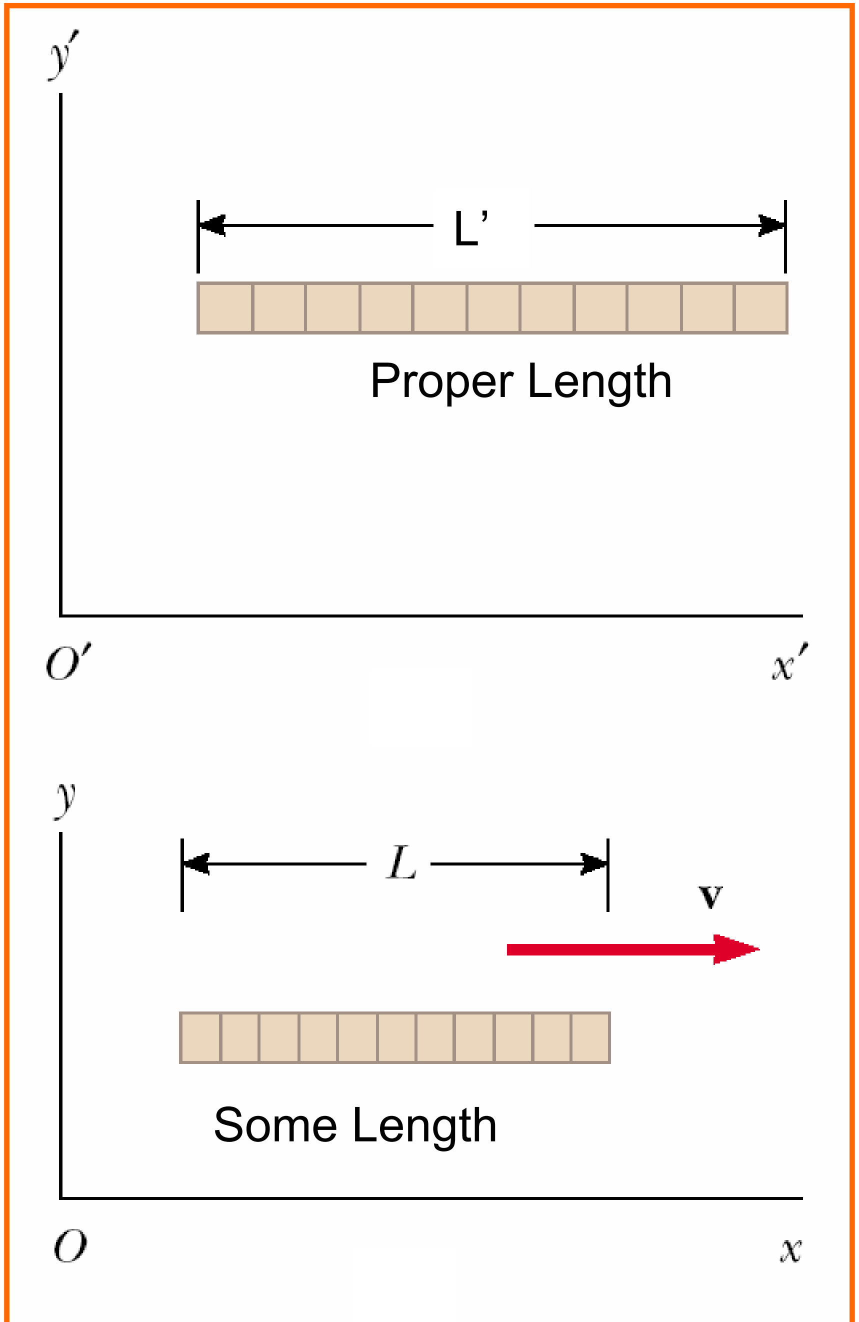
Rocketman Vs The Earthling

- Earth Observer saw rocketman take time $\Delta t = (L' / V)$
- Rocketman says he is at rest, Star B moving towards him with speed V from right passed him by in time $\Delta t'$, so
  - $L = \Delta t' . V$
  - But $\Delta t' = \Delta t / \gamma$ (time dilation)
  - $\Rightarrow L = V. (\Delta t / \gamma)$
    $= L'/\gamma$

$$L = L' . \sqrt{1 - \frac{V^2}{c^2}}$$

$$L \leq L'$$

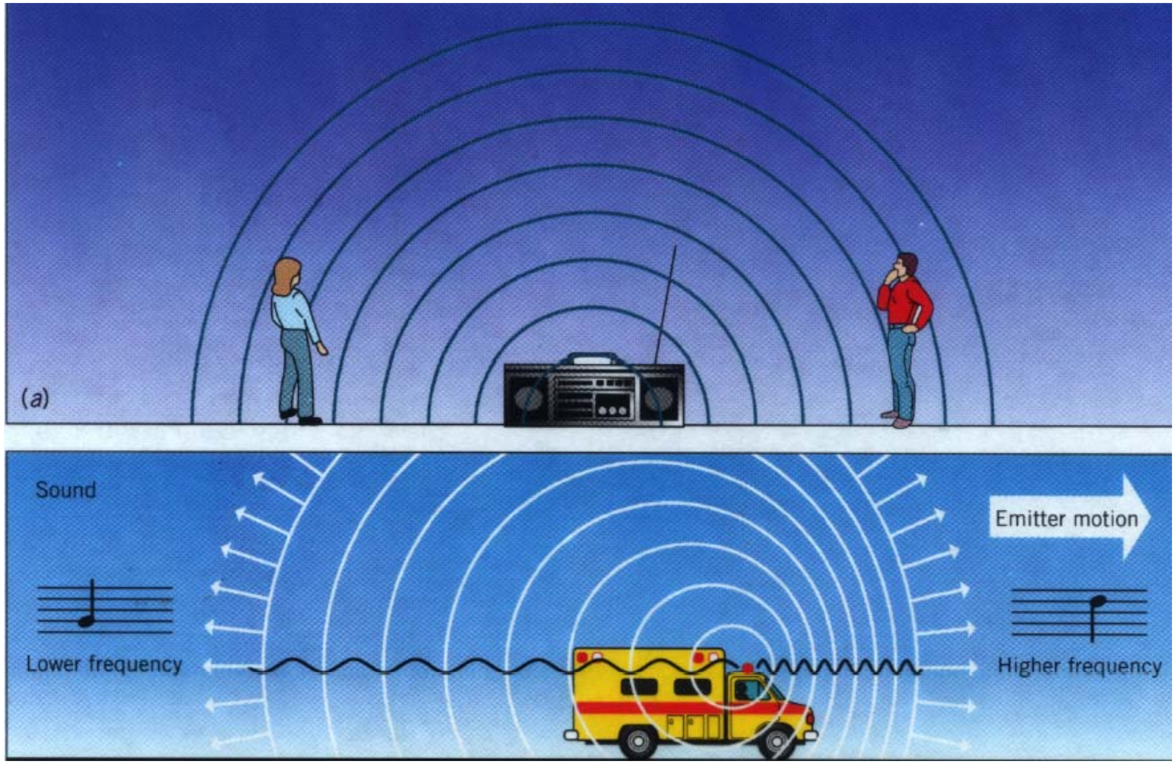
Moving Rods Contract in direction
Of relative motion



Immediate Consequences of Einstein's Postulates: Recap

- Events that are simultaneous for one Observer are not simultaneous for another Observer in relative motion
- Time Dilation : Clocks in motion relative to an Observer appear to slow down by factor γ
- Length Contraction : Lengths of Objects in motion appear to be contracted in the direction of motion by factor γ^{-1}
- New Definitions :
  - Proper Time (who measures this ?)
  - Proper Length (who measures this ?)
  - Different clocks for different folks !

Doppler Effect In Sound : reminder from 2A

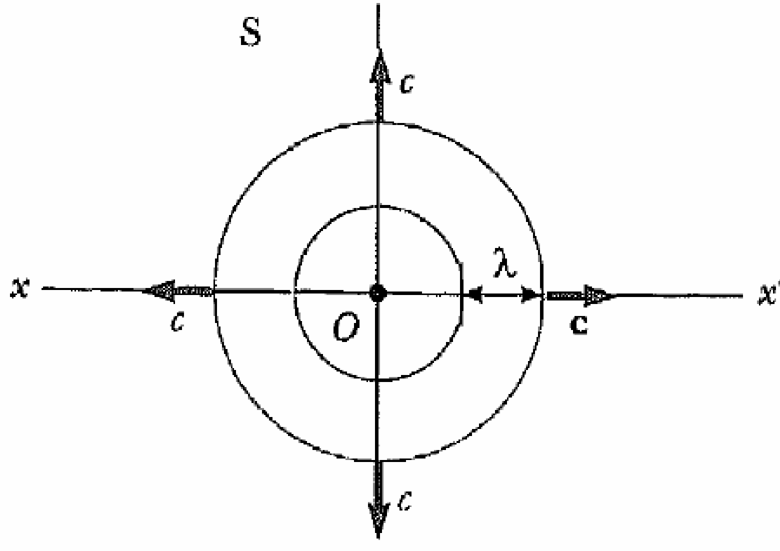


Observed Frequency of sound INCREASES if emitter moves towards the Observer
Observed Wavelength of sound DECREASES if emitter moves towards the Observer

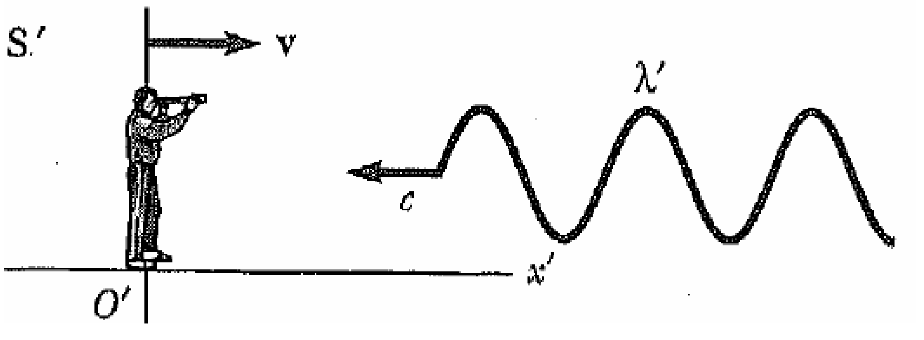
$$v = f \lambda$$

Time Dilation Example: Relativistic Doppler Shift

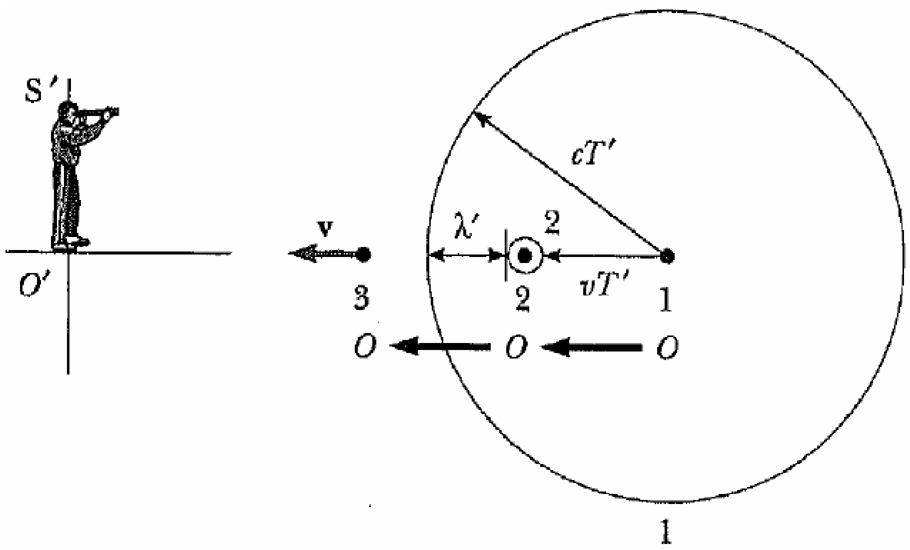
- Light : velocity c = f λ, f=1/T
- A source of light S at rest
- Observer S'approches S with velocity v
- S' measures f'or λ', c = f'λ'
- Expect f' > f since more wave crests are being crossed by Observer S'due to its approach direction than if it were at rest w.r.t source S



(a)



Relativistic Doppler Shift



Examine two successive wavefronts emitted by S at location 1 and 2

In S' frame, T' = time between two wavefronts

In time T', the Source moves by cT' w.r.t 1

Meanwhile Light Source moves a distance vT'

Distance between successive wavefront

$$\lambda' = cT' - vT'$$

$\lambda' = cT' - vT'$, use $f = c/\lambda$

$$f' = \frac{c}{(c-v)T'}, \quad T' = \frac{T}{\sqrt{1-(v/c)^2}}$$

Substituting for T', use f=1/T

$$\Rightarrow f' = \frac{\sqrt{1-(v/c)^2}}{1-(v/c)}$$

$$\Rightarrow f' = \frac{\sqrt{1+(v/c)}}{\sqrt{1-(v/c)}}\, f$$

better remembered as:

$$f_{obs} = \frac{\sqrt{1+(v/c)}}{\sqrt{1-(v/c)}}\, f_{source}$$

f_{obs} = Freq measured by observer approching light source