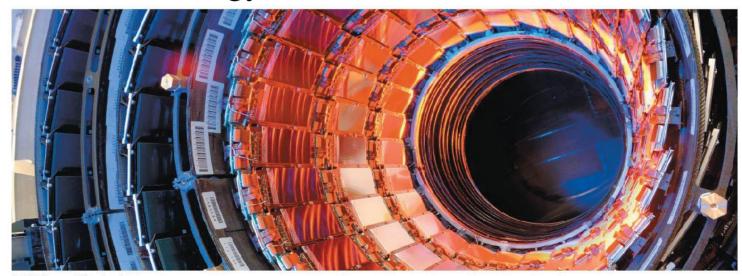
Chapter 36 – Relativity

- Reference frames, events, measurements, space-time diagrams
- Postulates of special relativity, impact on simultaneity
- Time dilation, space contraction, and Lorentz transformations
- Relativistic momentum and energy



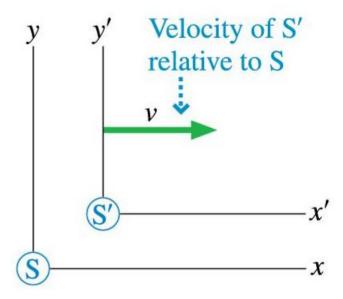
© 2022 Pearson Education, Inc.

What is an inertial reference frame?

Inertial reference frames are reference frames that move relative to each other with constant velocity.

- You'll learn to work with the positions and times of events.
- All the clocks in an inertial reference frame are synchronized.

CLOOKING BACK Section 4.3 Relative motion



The origins of S and S' coincide at t = 0. Alternatively, frame S moves with velocity -v relative to frame S'. © 2022 Pearson Education, Inc. © 2022 Pearson Education, Inc.

Frame S' moves with

velocity v relative to

frame S, parallel to the x- and x'-axes.

The axes of S

and S' have the

same orientation.

at t = 0.

Origins coincide Distances perpendicular to the motion are not affected.

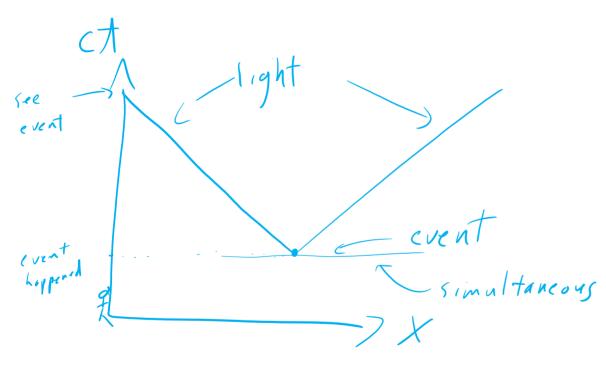
Thus y' = y and z' = z.

At time t, the origin of S' has moved

distance vt to the right. Thus x = x' + vt.

Firecracker

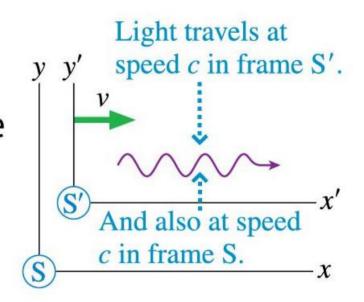
Space-time diagrams



What is relativity about?

Einstein's theory of relativity is based on a simple-sounding principle: The laws of physics are the same in all inertial reference frames. This leads to these conclusions:

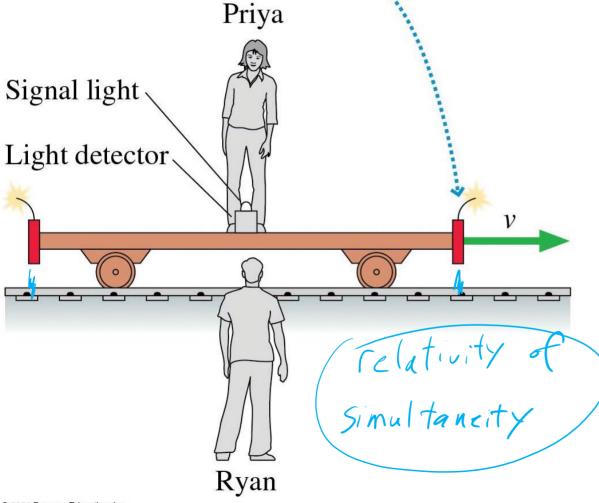
- Light travels at the same speed c in all inertial reference frames.
- No object or information can travel faster than the speed of light.



© 2022 Pearson Education, Inc.

The firecrackers will make burn marks on the ground at the positions where they explode.

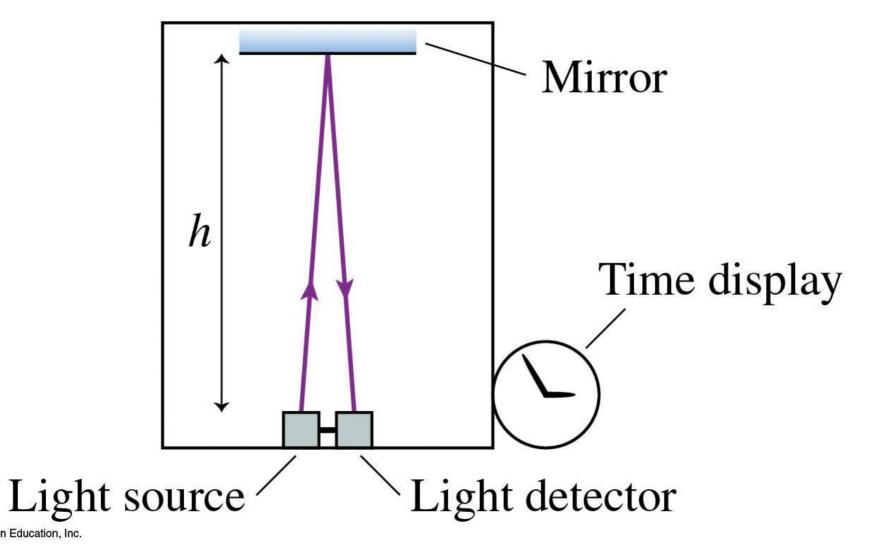
Priya

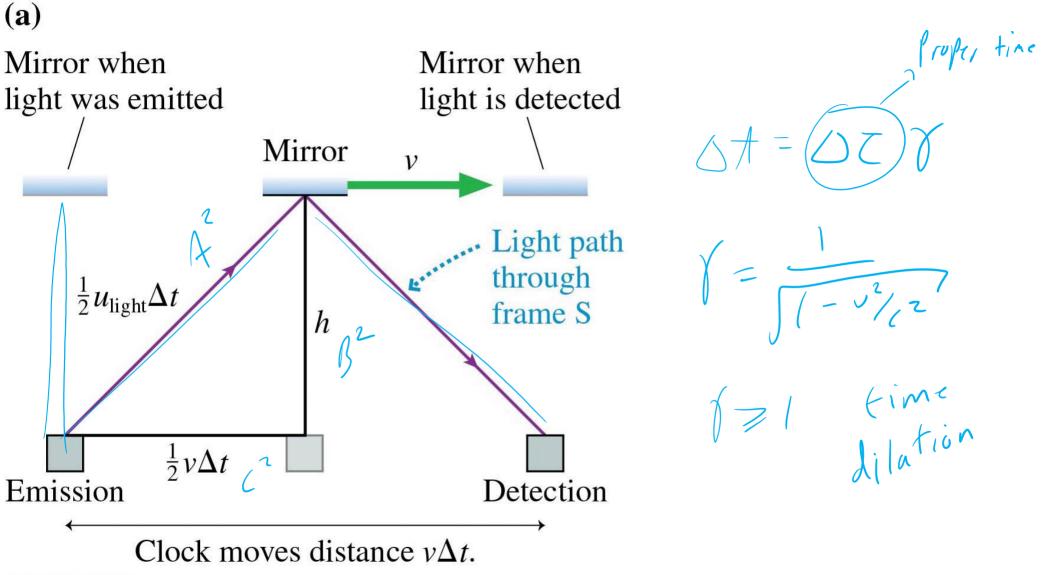


The right wave reaches The left firecracker explodes later. Priya first. The waves reach Ryan simultaneously. The left wave has not reached Priya. © 2022 Pearson Education, Inc.

The right firecracker explodes first.

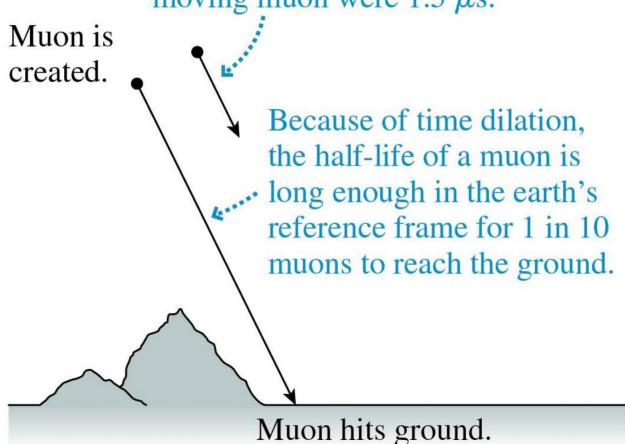
(a) A light clock



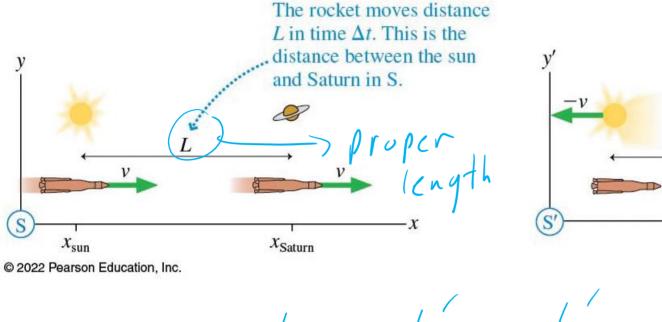


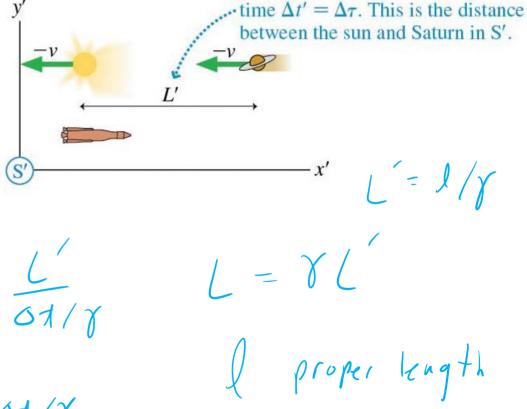
© 2022 Pearson Education, Inc.

A muon travels ≈ 450 m in 1.5 μ s. We would not detect muons at ground level if the half-life of a moving muon were 1.5 μ s.



(a) Reference frame S: The solar system is stationary.





Saturn moves distance L' in

△ T = 0+/7

h is the same in Light path $h^{2} = \left(\frac{1}{2}cdx'\right)^{2} + \left(\frac{1}{2}dx'\right)^{2}$ in S' both frames. Mirror Mirror in S' in S" $= \left(\frac{1}{2} \left(\Delta t'' \right)^2 + \left(\frac{1}{2} \delta x'' \right)^2$ $\frac{1}{2}c\Delta t''$ Light $\frac{1}{2}c\Delta t'$ $ds^2 = c^2 dt^2 - dx^2$ path lh in S" Cinvariant $\frac{1}{2}\Delta x''$ S' detection **Emission** S" detection $\Delta x'$ $\Delta x''$

© 2022 Pearson Education, Inc

The Lorentz transformations transform spacetime coordinates and velocities between reference frames S and S'. $x' \models \gamma (x - vt)$ $x = \gamma (x' + vt')$ (x, t) in S (x', t') in S' z = z'

$$t' = \gamma (t - vx/c^2) \qquad t = \gamma (t' + vx'/c^2)$$

$$u' = \frac{u - v}{1 - uv/c^2} \qquad u = \frac{u' + v}{1 + u'v/c^2}$$

$$ere u \text{ and } u' \text{ are the } x\text{- and } x'\text{-components of an object's velocity.} \qquad (1 = v)$$

where u and u' are the x- and x'-components of an object's velocity. $\beta = v/c$ and $\gamma = 1/\sqrt{1 - v^2/c^2} = 1/\sqrt{1 - \beta^2}$ © 2022 Pearson Education, Inc.

 $\times_{R} - \times_{L} = l = \gamma(x_{R} - v_{A}) - \gamma(x_{L} - v_{A})$

 $J = \chi(x_R - x_L) = \chi L$

 $x_{\rm R}$ $x_{\rm I}$

Because the object is moving in frame S, simultaneous measurements of its ends

 $L' = \ell$

Motion

 $\int u \text{ in } S$ u' in S'

The object is at rest in frame S'.

Its length is $L' = \ell$, which can

be measured at any time.

must be made to find its length L in frame S.

$$\gamma = \int_{1-\sqrt{c}}^{2} = \left(1-\frac{u}{c}\right)^{2}\right)^{-1/2} \text{ Velocity, } u$$

$$\gamma = \int_{1-\sqrt{c}}^{2} = \left(1-\frac{u}{c}\right)^{2}\right)^{-1/2} \text{ Velocity, } u$$

$$\gamma = \int_{1-\sqrt{c}}^{2} = m\frac{dx}{dx} = m\frac{dx}{dx}$$

$$= \gamma m\frac{dx}{dx}$$

$$= \gamma m\frac{dx}{dx}$$

$$= \gamma mu$$

© 2022 Pearson Education, Inc.