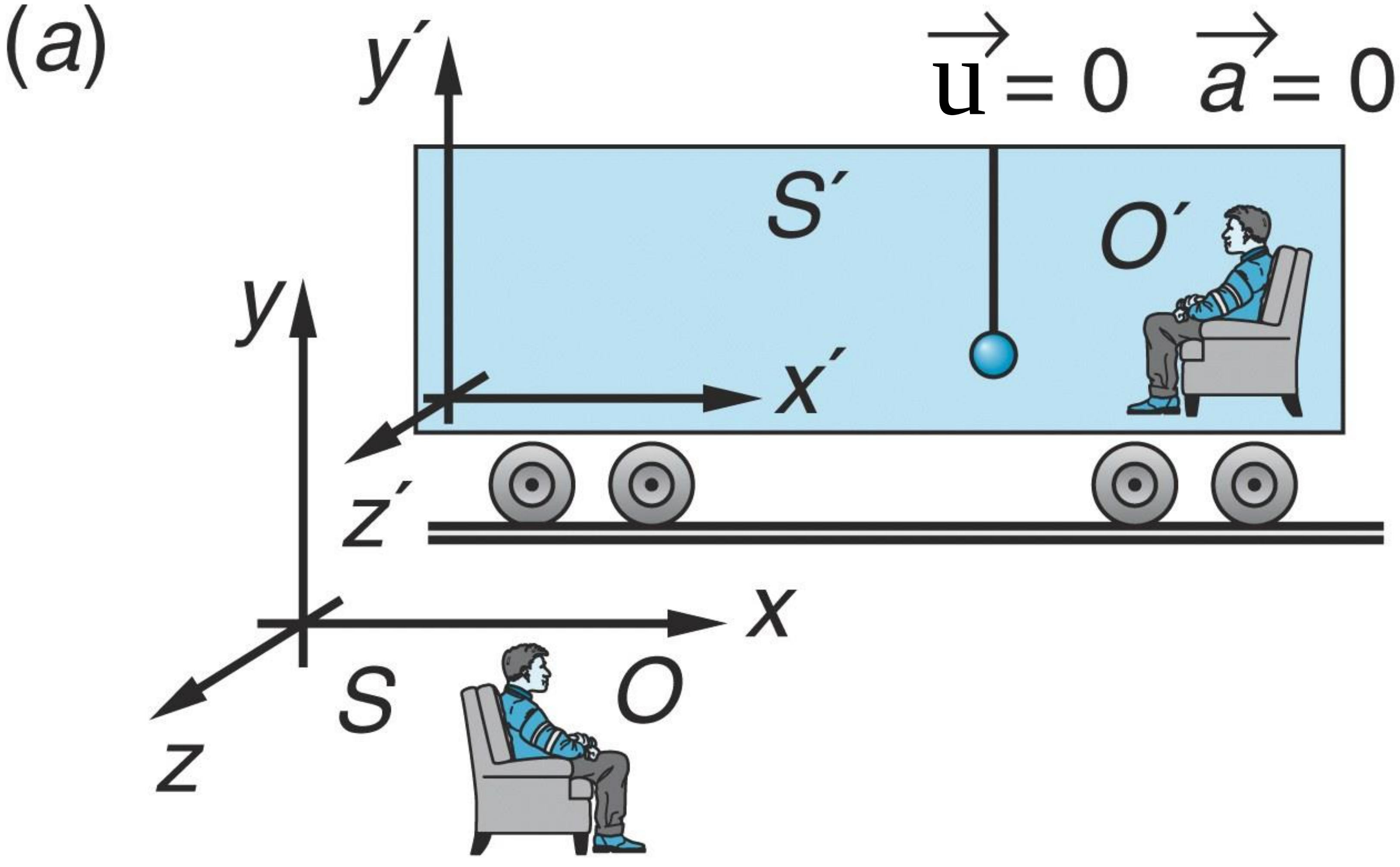
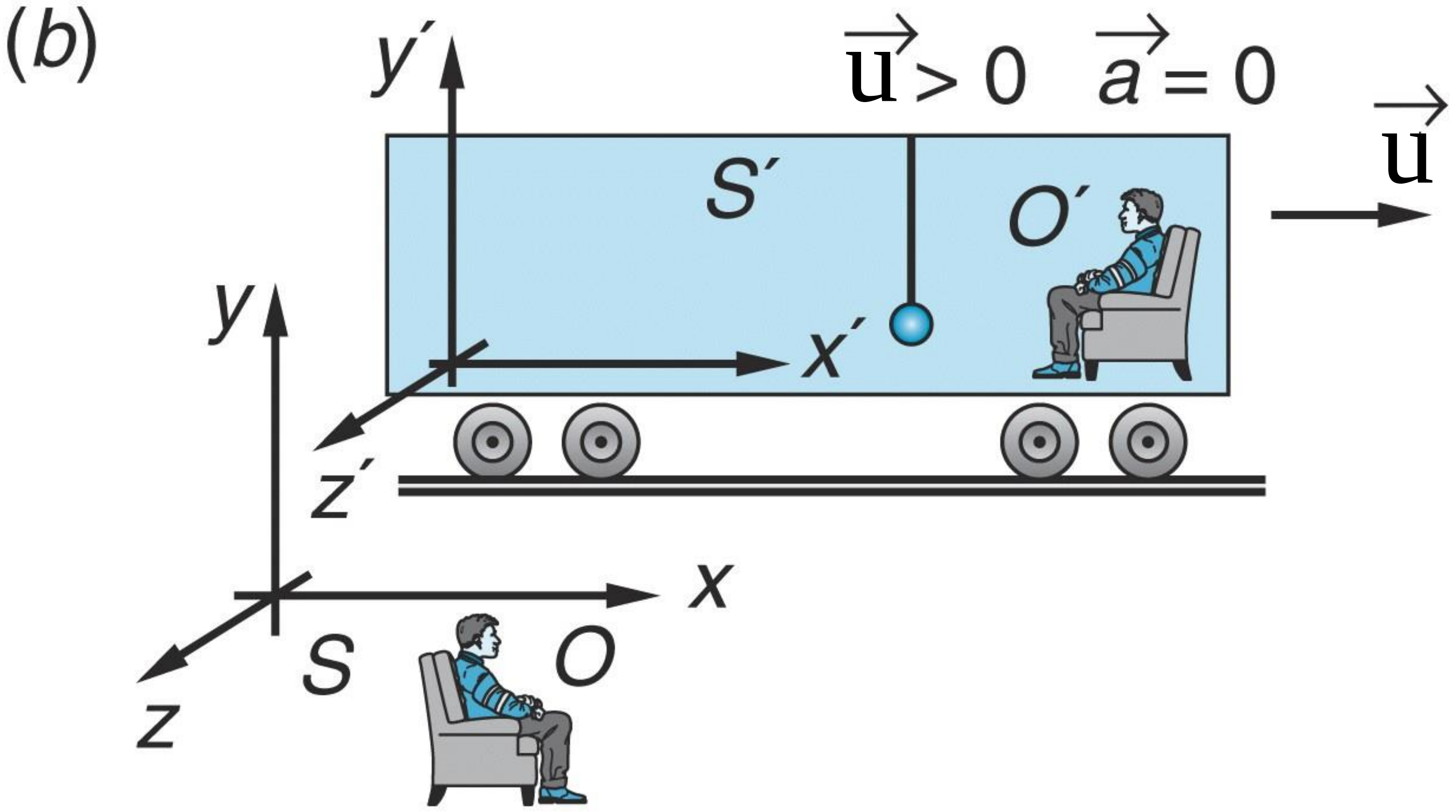
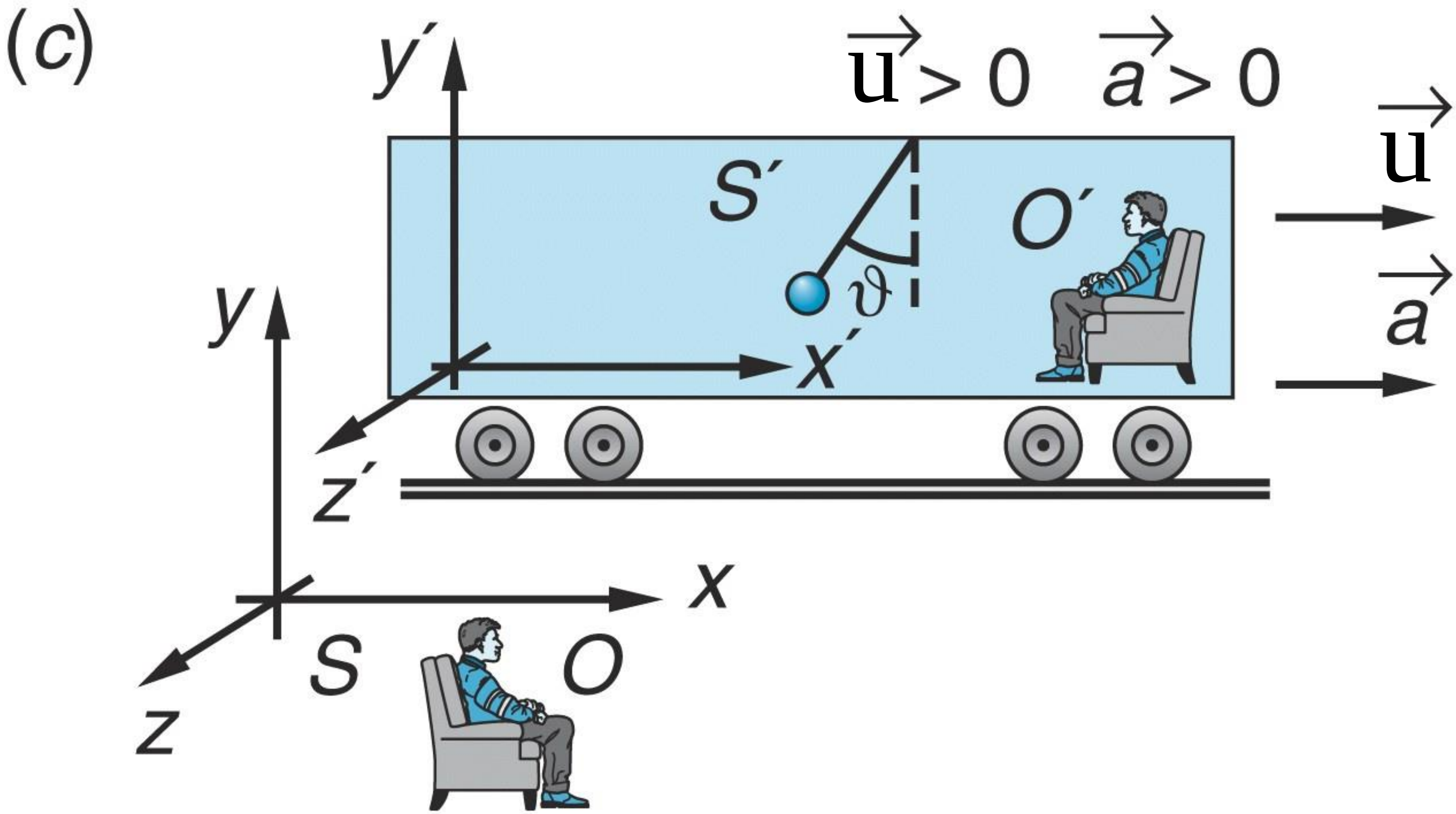
To describe events, you need to specify coordinate system!
The Laws of Physics don't depend on origin of coord sys.



Coordinate systems can be moving at constant velocity
Laws of physics the same in the two inertial frames



Can tell which frame is accelerating
Extra pseudo-forces in accelerating frames (e.g. rotation)



Question #1

You are standing still on the ground with no wind. You measure that a sound wave moves in the +x direction with a speed of 300 m/s. John traveling at 30 m/s in the +x direction relative to you measures the sound speed to be:

(a) 330 m/s.

(b) 300 m/s.

(c) 270 m/s.

Question #2

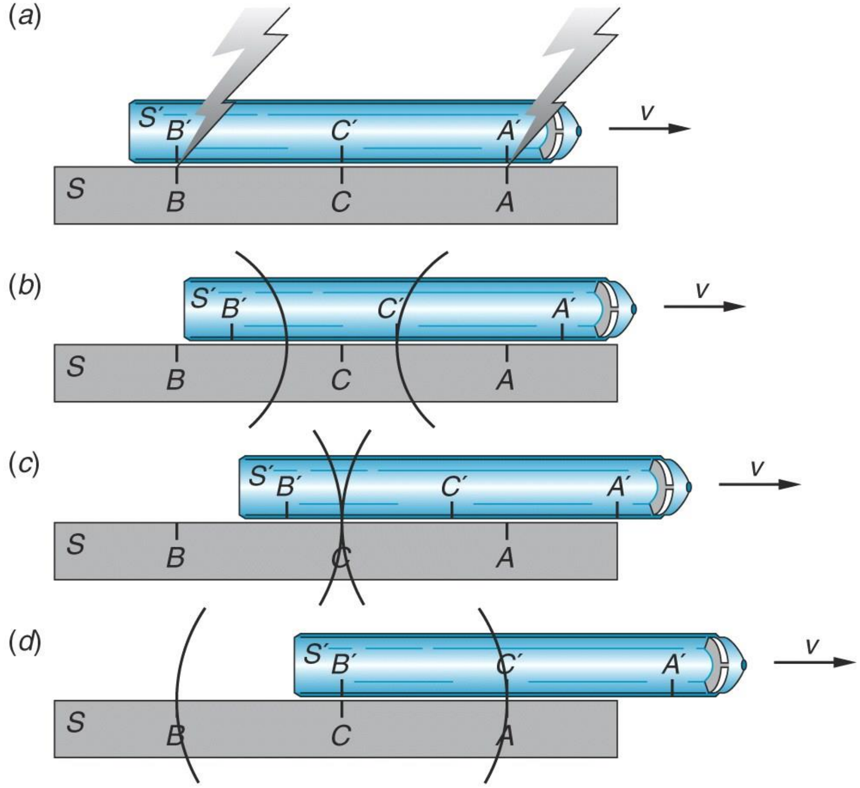
You are standing still in space. You measure that a light wave moves in the +x direction with a speed of 3×10^8 m/s. John traveling at 3×10^7 m/s in the +x direction relative to you measures the speed of the light wave to be:

(a) 3.3×10^8 m/s.

(b) 3.0×10^8 m/s.

(c) 2.7×10^8 m/s.

Simultaneity

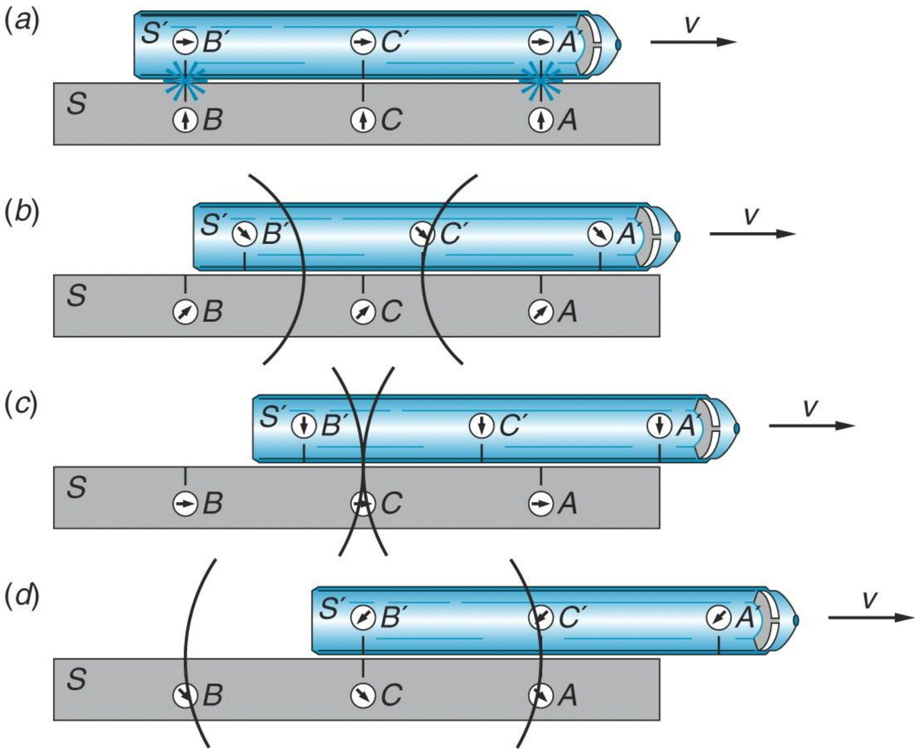


Observer in frame S says lightning strikes at same time

Observer in frame S' says lightning strike at A' before strike at B'

Two events at separate spatial points that are simultaneous in one reference frame are not simultaneous in an inertial frame moving relative to the first (nonzero component of velocity in direction between points).

Synchronize Separated Clocks



The observer at C decides that the clocks at A,A’ and B,B’ are synchronized.

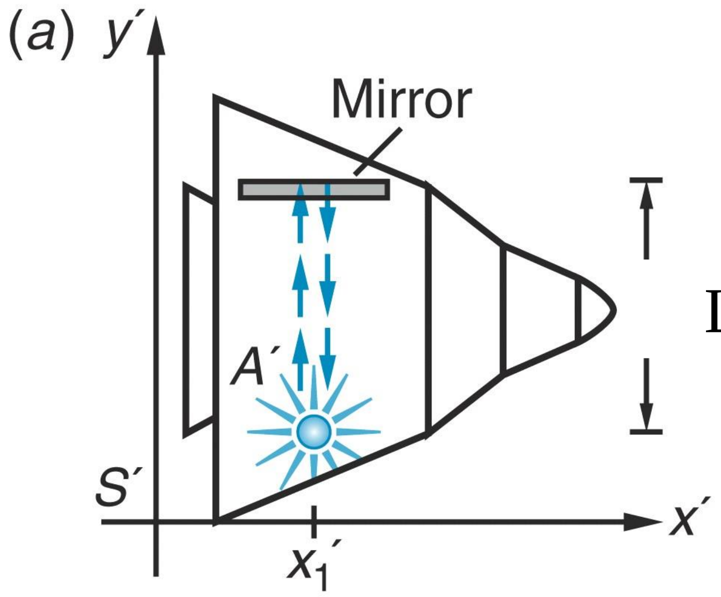
The observer at C’ decides that the clocks at A,A’ and B,B’ are NOT synchronized.

Two observers will disagree on whether separated clocks are synchronized if the observers are moving relative to each other.

Time Dilation

Compare the measured duration between two events that occur at the same place

First look at 1 period of stationary clock

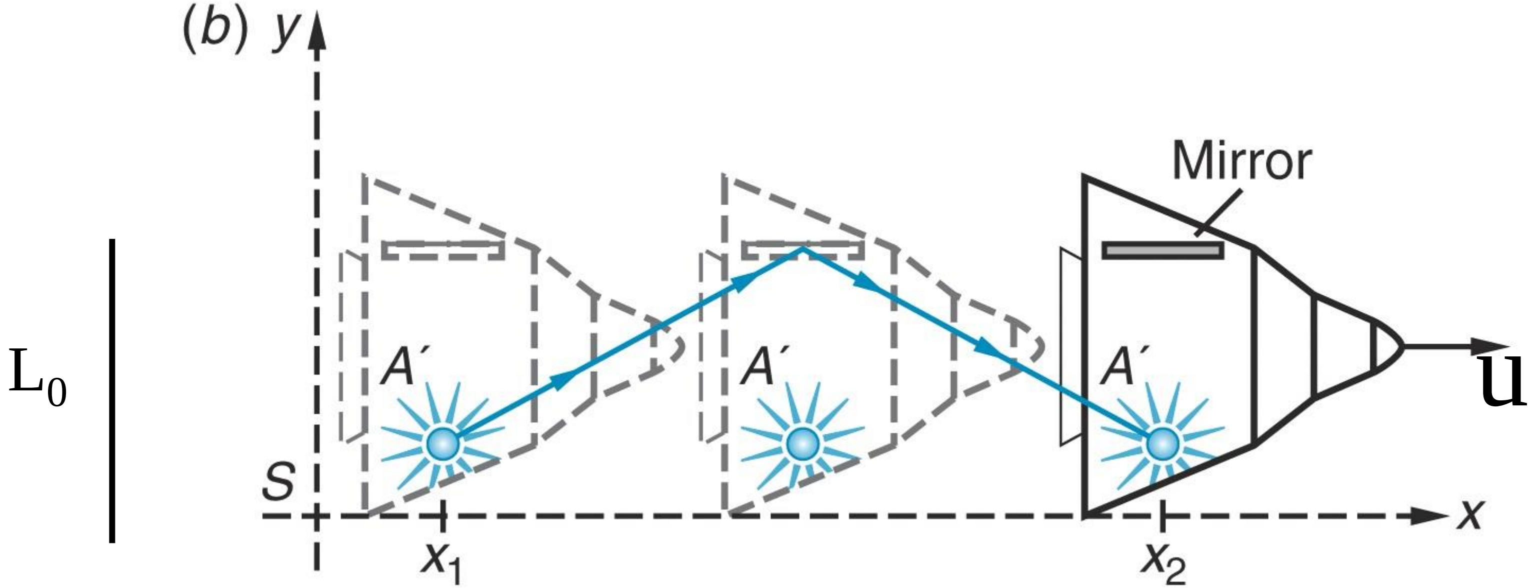


L_0

What is the time for the light to go from A' bounce off of the mirror and return to A'?

$$\Delta t' = \frac{2L_0}{c}$$

Time Measured For Moving Clock, Δt



What is x_2-x_1? $x_2 - x_1 = u\Delta t$

What is path length of the light? $L = c\Delta t$

Common Notation

Proper time interval: time interval measured by clock "at rest"

$\Delta t'$ = proper time interval

τ = proper time interval

$\beta = u/c$ = velocity as fraction of the speed of light

$\gamma = 1/\sqrt{1-\beta^2} \geq 1$ is always larger than 1 for nonzero u

$\Delta t = \gamma\tau$ Implication is that any measured time interval between events at the same place is longer than or equal to the proper time interval

What if $u > c$?

Question #3

Jane shoots by you in a space ship; you measure that it takes 2 seconds as measured by your watch for Jane's watch to increment by 1 second. Jane says it takes x seconds as measured by her watch for your watch to increment by 1 second

(a) x = ½ second

(b) x = 1 second

(c) x = 2 seconds

(d) none of the above.

Common Notation

Proper length: length of object measured "at rest"

Δx = proper length

L_p = proper length

$\beta = u/c$ = velocity as fraction of the speed of light

$\gamma = 1/\sqrt{1 - \beta^2} \geq 1$ is always larger than 1 for nonzero u

$\Delta x' = L_p/\gamma$ Implication is that any measured length of moving object is shorter in direction of motion than the proper length

Question #4

You are traveling in the +x direction at a large fraction of c relative to Percy. Percy holds a meter stick in the +x direction. You can measure the length of the stick to be:

(a) 20 cm

(b) 80 cm

(c) 100 cm

(d) 140 cm

(e) either (a) or (b).

Are you traveling faster if the answer is (a) or if the answer is (b)?

Question #5

You are traveling in the +x direction at a large fraction of c relative to Percy. Percy holds a meter stick in the +y direction. You can measure the length of the stick to be:

(a) 20 cm

(b) 80 cm

(c) 100 cm

(d) 140 cm

(e) either (a) or (b).

Question #6

Frame S' has a speed of ¾ m/s in the +x direction. An observer in frame S' measures a frebble traveling in the +x direction with a speed of ¾ m/s. What is the frebble's speed as measured by an observer in frame S?

(a) v = 0 m/s

(b) v = 3/2 m/s in +x direction

(c) v= ¾ m/s in +x direction

(d) v = 3/2 m/s in –x direction

Question #7

Frame S' has a speed of ¾ c in the +x direction. An observer in frame S' measures a frebble traveling in the +x direction with a speed of ¾ c. What is the frebble's speed as measured by an observer in frame S?

(a) v = 0 c

(b) v = 3/2 c in +x direction

(c) v= 0.96 c in +x direction

(d) v = 3/2 c in –x direction

Vague Question

An observer in Frame S measures that there are two rocket ships traveling directly away from the origin. Ship 1 travels in the +x direction with a speed v_x and Ship 2 travels in the +y direction with a speed v_y. What is the velocity (vector) of ship 2 as measured by ship 1? What is the velocity (vector) of ship 1 as measured by ship 2? Is the velocity vector of Ship 2 as measured by Ship 1 opposite that of Ship 1 measured by Ship 2? Are the speeds the same? Can the relative speed of the two ships ever be larger than c if the individual speeds as measured in Frame S are less than 0?

Detection of exoplanets

The Doppler effect is used to detect exoplanets

https://en.wikipedia.org/wiki/Methods_of_detecting_exoplanets

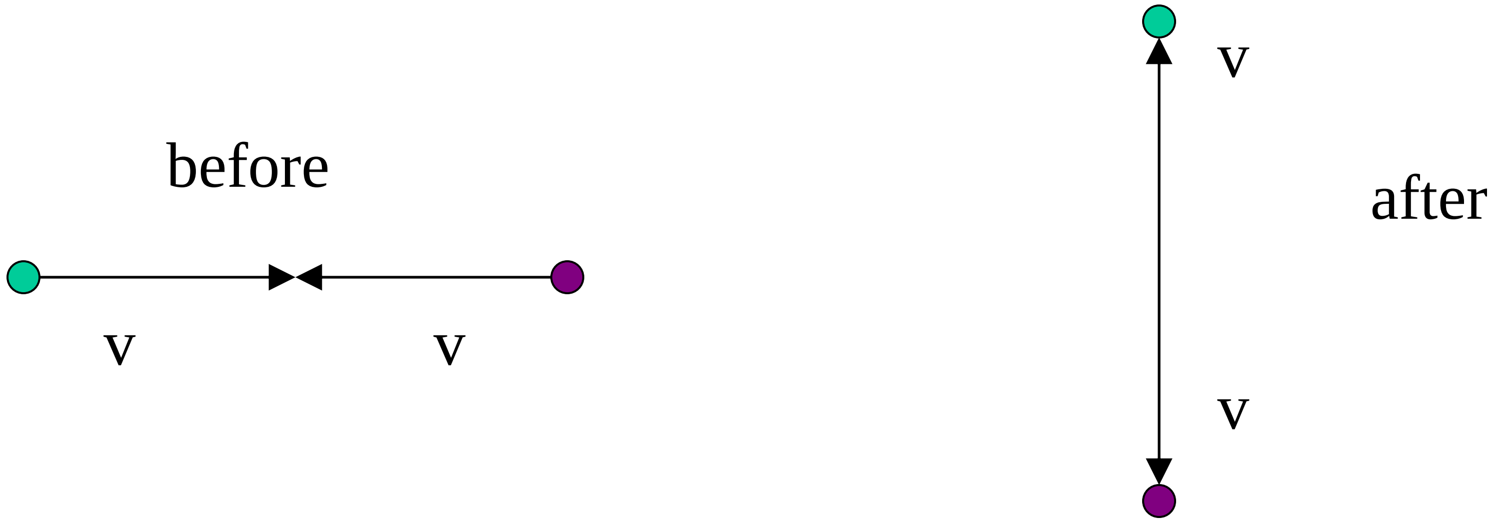
https://en.wikipedia.org/wiki/Doppler_spectroscopy

Red shift of galaxies

The red shift of frequencies shows that galaxies are moving away (most) or toward (a couple) us.

https://en.wikipedia.org/wiki/Redshift

Non-conservation?



Two balls of equal mass and opposite velocity vectors collide elastically.

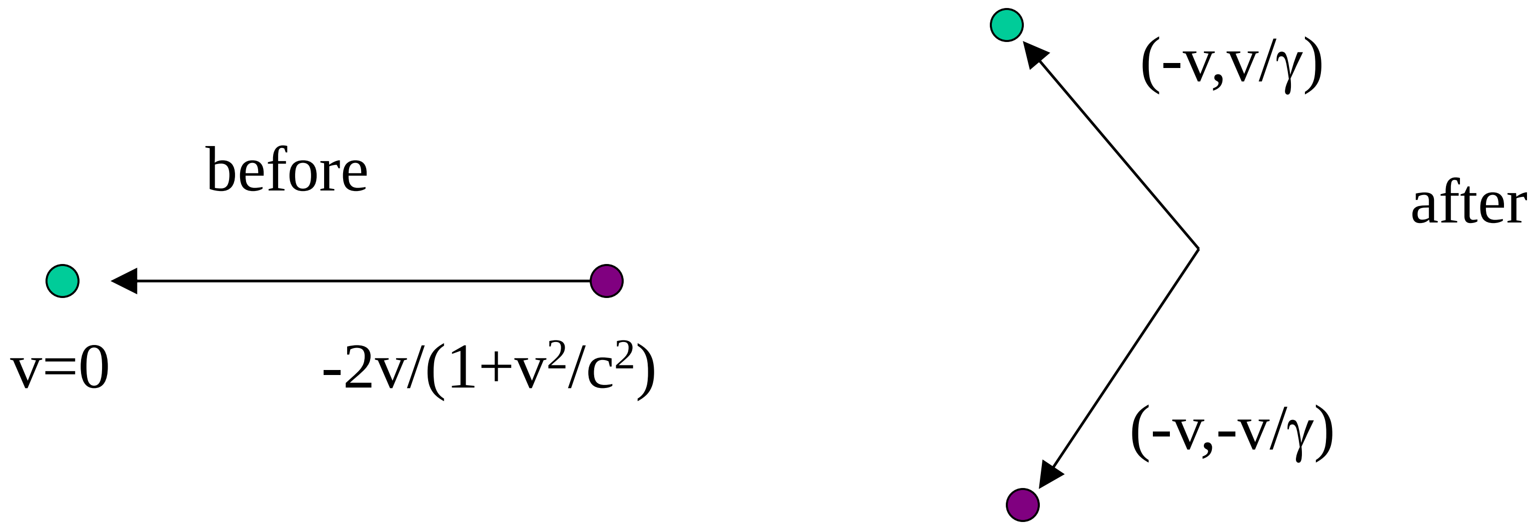
Why must speeds be same before and after?

Is there a restriction on direction after collision?

Non-conservation?

$$v'_x = (v_x - u)/(1 - u\, v_x / c^2) \qquad v_y' = v_y/\gamma\,(1 - u\, v_x / c^2)$$

Frame S' moving to right with respect to S at speed u



Is the x-component of momentum conserved? (Larger or smaller after the collision?)

Is the y-component of momentum conserved?

Question #8

Consider the case of an ideal windup toy with a mass of 0.1 kg. Suppose you wind up the spring so that the potential energy of the spring increases by 1 J. By how much does the mass of the toy increase/decrease?

(a) The mass of the toy does not increase or decrease.

(b) The mass of the toy decreases by roughly 10^{-8} kg.

(c) The mass of the toy decreases by roughly 10^{-17} kg.

(d) The mass of the toy increases by roughly 10^{-8} kg.

(e) The mass of the toy increases by roughly 10^{-17} kg.

Question #9

There are 4 quantities of an object E, p, v, & M (I mean magnitude of p & v). Which statement is most true?

(a) E & M can be used to find p.

(b) E & v can be used to find p.

(c) M & p can be used to find E.

(d) v & p can be used to find E.

(e) Any of the two quantities can be used to find the other two.

Vague Energy Question

Suppose a mass M object splits into two equal mass pieces. The pieces fly out back to back with equal and opposite velocities. Each piece has mass m and speed u. Is m larger or smaller than M/2? Determine m if (A) the speed is not relativistic and if (B) the speed is relativistic.

Constant Force

Initially an object of mass M is at rest. Suppose it is subject to a constant force F. Compute the object's momentum as a function of t. Compute the object's speed as a function of t. Compute the object's position as a function of t. Take the specific example of an electron (M = 9.11E-31 kg) in a 1E6 V/m electric field (F = 1.6E-13 N). How long does it take before the electron has a speed of 0.9 c? How far does it travel while reaching this speed?