

LECTURE 23 & 24 : **Special Relativity**

At the end of these lectures you should:

- Understand “*frame of reference*” and “*inertial frame of reference*”.
- Know that the velocity of light is invariant.
- State Einstein’s postulates on which Special Relativity is based.
- Understand “*time dilation*” and be able to perform simple calculations.
- Understand “*length contraction*” and be able to perform simple calculations.
- Understand Einstein’s equation $E = mc^2$ and be able to perform calculations using this equation.
- Understand and use relativistic equations for total energy and kinetic energy.

Special Relativity

- Einstein
- Challenged and changed our concepts of space and time
- Experimentally proven



Frame of reference

A place with respect to which measurements are made eg

Inertial frame of reference

One in which Newton's Laws hold

How would you know if you were in a frame of reference which is accelerating with respect to an inertial frame?

Classical Relativity

Consider someone on a train throwing a ball :

a) horizontally

b) vertically upwards

as measured by an observer in the train and an observer at the station

Ball thrown horizontally

What the observer on the train sees:

He/she sees the ball moving horizontally at v_{bt}
(the speed relative to the train).

What the observer at the station sees:

He/she sees the ball moving horizontally at

$$v_{bs} = v_{bt} + v_{ts}$$

where v_{ts} is the speed of train relative to station

Ball thrown vertically

What the observer on the train sees:

He/she sees the ball moving vertically up and down

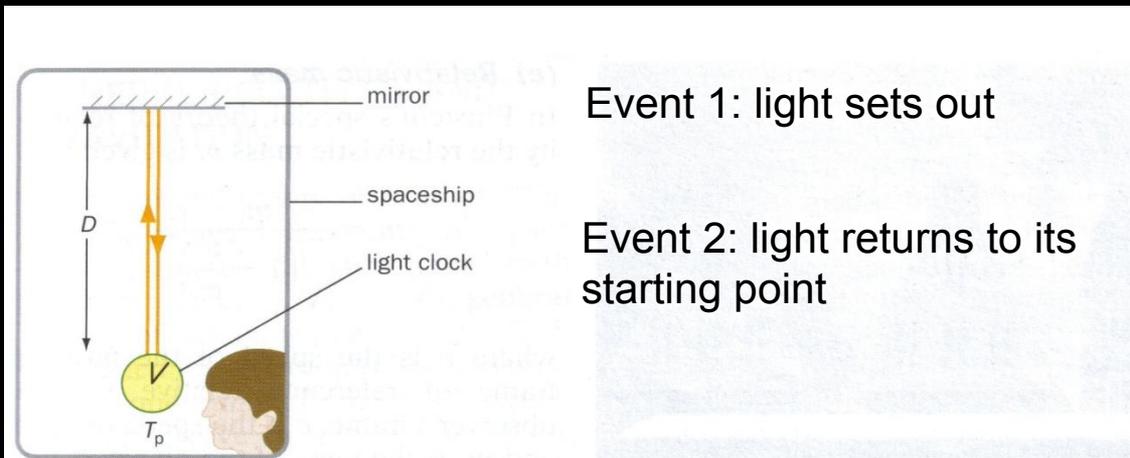
What the observer at the station sees:

He/she sees the ball moving in a parabola. The horizontal speed is v_{ts} . The vertical motion is just motion under gravity.

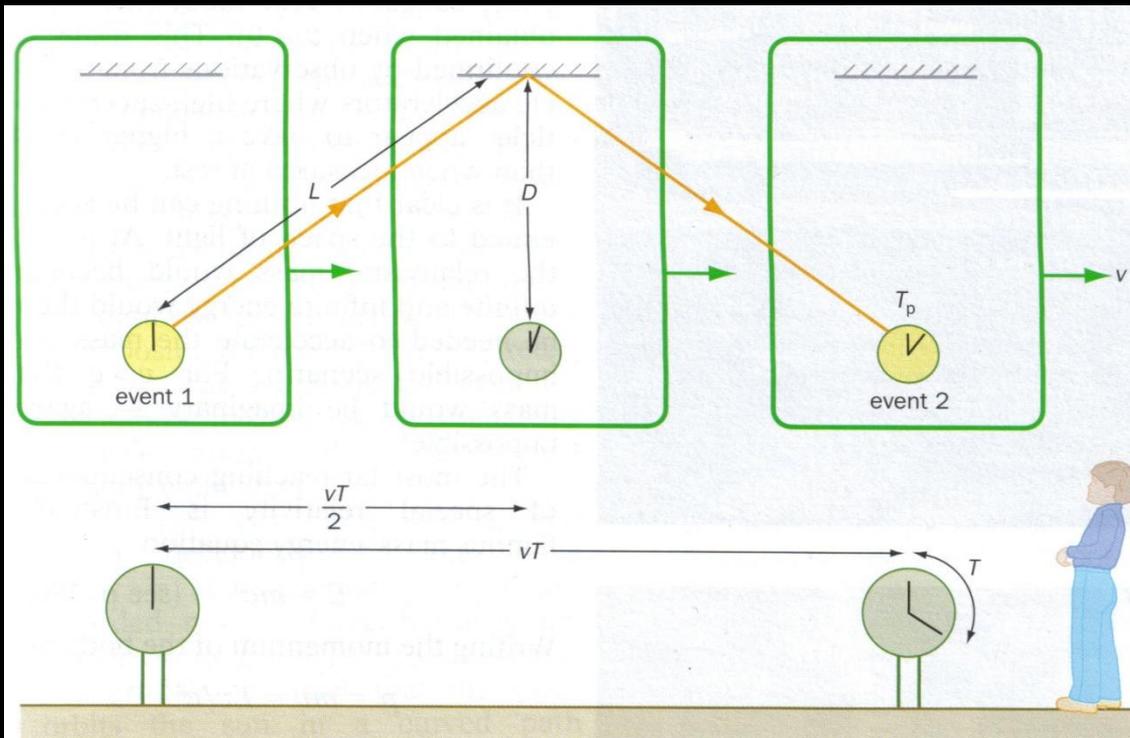
What are
Einstein's
postulates?

Einstein's postulates

- 1 The laws of physics are the same for all observers in all inertial frames of reference.
- 2 The velocity of light (in a vacuum) is the same in all frames of reference and is thus independent of the motion of the light source or the observer.



Zoe in the spaceship measures time between 2 events in the spaceship



Adam on the Earth measures time between same 2 events

Zoe: Proper Time

(Events in same place)

Adam: Measures time interval between events in different places. (Measures time intervals between events on a moving frame of reference).

Time Dilation

- **Proper time** This is when only one clock is required to measure the time interval between two events that occur at the same place in that frame of reference (Zoe's frame)
- Time measured by Adam is “slower” or “dilated” compared with time measured in a frame of reference (Zoe's) which is moving with respect to Adam's frame of reference.

Time dilation

The time interval between two events is shortest in a frame of reference in which the events occur at the same place.

Example 1

A spaceship completes a one-way journey that takes 25 years according to observers on Earth. If the spaceship travels at $0.95c$ relative to Earth, how long does an astronaut on board the spaceship consider the journey to take?

Example 2

A stationary muon decays in $2.2 \mu\text{s}$.
What is its lifetime as observed from a laboratory on Earth if the muon is moving at $0.97c$ relative to Earth?
How far does it travel in this time?
(This situation provides experimental evidence for time dilation).

LECTURE : CHECK LIST

READING Adams and Allday: 8.23, 3.19, 8.24,8.25

At the end of these lectures you should

- Understand the concepts of *frame of reference* and *inertial frame of reference*.
- Know that the velocity of light is invariant.
- State Einstein's postulates on which Special Relativity is based
- Understand what is meant by *time dilation* and be able to perform simple calculations.
- Understand what is meant by *length contraction* and be able to perform simple calculations.
- Understand Einstein's equation $E = mc^2$ and be able to perform calculations using this equation.
- Understand and use relativistic equations for total energy and kinetic energy.

Additional Materials

- Check out the websites at:
- http://www.phys.unsw.edu.au/einsteinlight/jw/module4_time_dilation.htm
- http://www.youtube.com/watch?v=xNB7KEg9siM&feature=results_video&playnext=1&list=PLC560B8892351ACAF
- http://www.squidoo.com/relativity_explanation
- http://www.youtube.com/watch?v=ev9zrt_llec