Major Concepts in Physics Lecture 24.

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http://physics/courses/PHY102.08Spring

Announcements

- HW6 due in recitation this week
- Final 1 May 5-7:00 pm in Stolkin. Comprehensive. Same style, format to mid terms.
- Review Monday 28th in class. Also this week in recitation

Exam 3

- Mean 32.5 (74%) B-.
- (Rough) threshold for A-: 37
- (Rough) threshold for C: 28
- Slightly harder than exam1,2 and somewhat broader distribution of grades

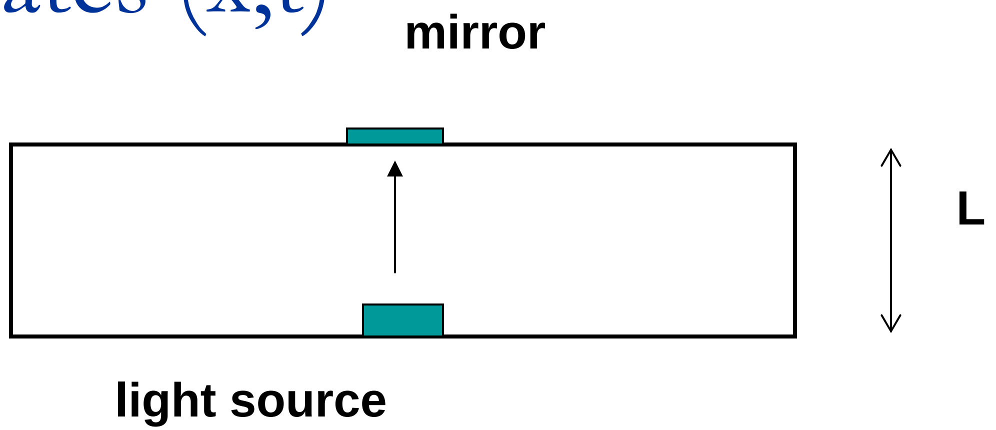
Recap -- space and time a la Newton

- Motion described by giving coordinates (x,t) in some inertial reference frame
- All such frames are equally good to discover Newton's laws of motion (relativity principle)
- All such moving observers agree on a single (absolute) time
- Velocities measured in different moving frames related in simple way

Einstein asserts relativity principle

- Maxwell's equations must make sense in any frame.
- Must be possible to discover correct laws of EM in all such frames – relativity principle.
- Requires speed of light to be same for all observers independent of their relative speed.
- Velocity rule must be wrong … must critically rexamine how time and space related …

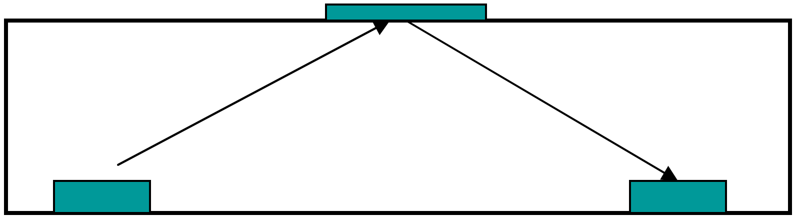
Thought experiment – rocket frame coordinates (x,t)



From rocket frame: light travels to mirror and back in time 2L/c

$$\Delta x=0$$
$$\Delta t=2L/c$$

Earth frame – coordinates (X,T)



In Earth frame light travels a BIGGER distance
If its speed is to the same in Earth frame then
THE TIME INTERVAL in this frame MUST BE BIGGER!

Simple geometry reveals:

$$\Delta T = \Delta t / (1 - v^2/c^2)^{1/2}$$
$$\Delta X = v \Delta T$$

Rexamine

- Time interval between emission and return of light pulse is less in rocket frame than in Earth frame if $v<c$

Time dilation!

Effect is extremely small for everyday speeds

Experimentally verified to high accuracy using high energy particles

Derived using light – but must be true for all phenomena if relativity principle correct …

Example – twins paradox

- Imagine two identical twins. One starts out on a fast spaceship travelling at v=4c/5 while other remains at home.
- At some point one turns around and heads back at speed v again.
- Time experienced by moving twin

  $(\text{time on earth})\text{x}(1\text{-}16/25)^{1/2}$

Higher speed …

- You should see that by making the rocket twin go fast enough you can make him age very slowly with respect to his twin ….
- But where has this asymmetry in ages come from ?
- Surely by relativity I could have imagined that it was the Earth twin that moved and the other was stationary – but that would have implied the opposite conclusion !!

Ex. 26.1-1

Example 26.1

Slowing the Aging Process

A 20.0-yr-old astronaut named Ashlin leaves Earth in a spacecraft moving at 0.80*c*. How old is Ashlin when he returns from a trip to a star 30.0 light-years from Earth, assuming that he moves at 0.80*c* relative to Earth during the entire trip?

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Spacetime interval

- In rocket example. Two frames do not agree on spatial and temporal differences between events
- But can easily show that

$$(\Delta x)^2 - c^2 (\Delta t)^2 = (\Delta X)^2 - c^2 (\Delta T)^2$$

- Spacetime distance same …

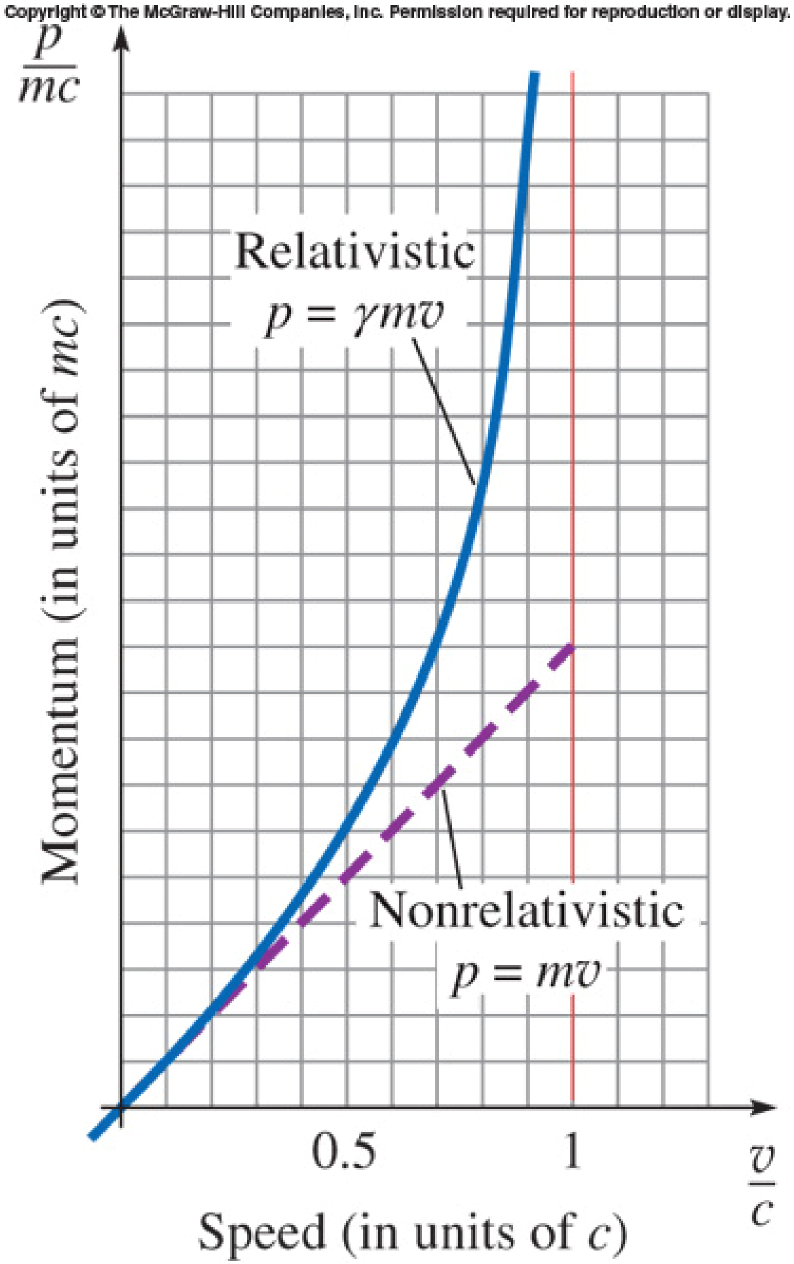
$$(\Delta x)^2 - c^2 (\Delta t)^2 = \Delta s^2$$

Relativistic momentum

- Since time is not an absolute concept in relativity theory any quantity which is defined as a rate like velocity, momentum, kinetic energy must be modified
- Relativistic momentum $p=\gamma mv$

  where $\gamma=1/(1-v^2/c^2)^{1/2}$.
- For small v/c this is close to usual Newtonian expression. What happens as $v \rightarrow c$?

Fig. 26.15



$\frac{p}{mc}$
Momentum (in units of mc)
Relativistic
$p = \gamma m v$
Nonrelativistic
$p = mv$
0.5
1
$\frac{v}{c}$
Speed (in units of c)

Relativistic energy

- Formula for momentum suggests that effective mass depends on velocity

$$m(v)=m_0\gamma$$

- What about kinetic energy $\frac{1}{2} mv^2$?
- Might guess $K=\frac{1}{2}\, m(v)\, v^2$
- Actually relativity tells us that

$$E=m(v)\, c^2$$

- Read as equivalence of mass and energy