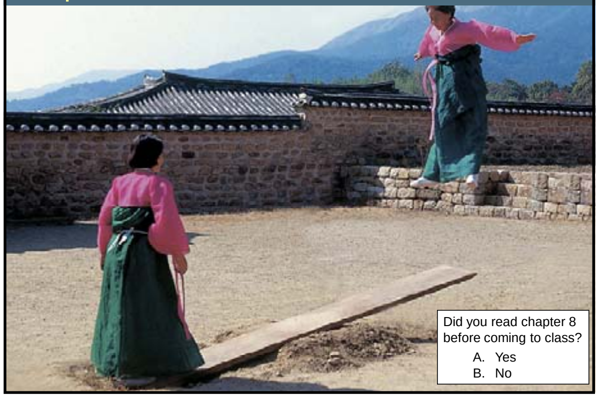
Chapter 8: Conservation Laws



Vocabulary Quiz

- Mostly memorization
- On Blackboard
- You can retake it
- Grade comes from LAST retake
- Score ROUNDED to 4 (3.6 pts = full credit)
- closed book

Exam 1

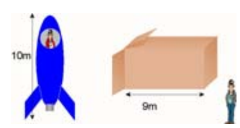
- 30 multiple. choice problems (1 pt. each)
- 1 Essay question (5 pts)
- closed book
- Test your ability to apply science concepts
- Slides available – link from blackboard

Summary of the important concepts of relativity:

- Things that are moving very fast are measured to be shorter along the direction of motion than when at rest.
- Moving clocks are observed to run slow
- Events that are simultaneous in one frame of reference are usually not simultaneous in another.
- Light always travels at the speed of light
- Objects with mass always travel at speeds less than the speed of light (preserves causality)

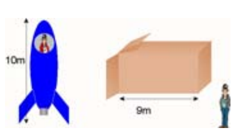
A set of twins decide to mail their rocket to a friend, but when they measure the rocket and box, they discover that the box is too small. One of the twins decide to fly towards the box at a speed close to the speed of light. In the frame of reference where the box is at rest

a) The length of the rocket will be longer than 10m
b) The length of the rocket will be shorter than 10m
c) The length of the rocket will be 10m
d) Not enough info

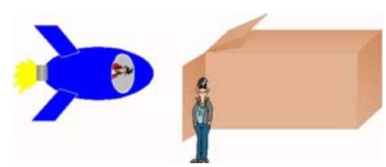


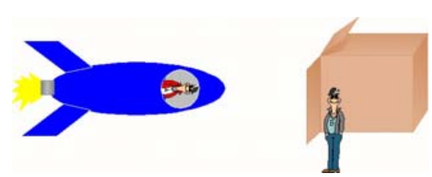
In the frame of reference where the rocket is at rest

a) The length of the box will be longer than 9m
b) The length of the box will be shorter than 9m
c) The length of the box will be 9m
d) Not enough info



So what happens





Conservation Laws

- What does it mean to conserve something?
- A conserved quantity:

_______ can neither be created or destroyed, but can be changed from one form to another or transferred from one object to another.

Conservation of Mass

- Mass is neither created nor destroyed. Mass may change from one form to another, but the total mass after the transformation is always the same as that before.

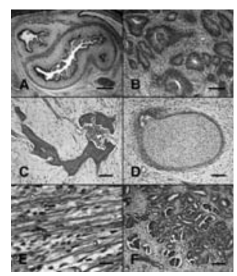
Examples
- gasoline in car
- forest fire
- boiling water

Conservation of total Electric Charge

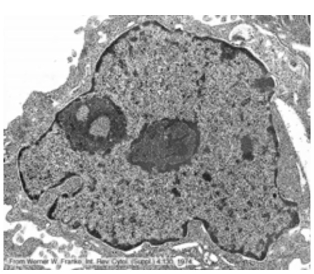
- The difference between the total amount of positive and negative charges does not change.

Examples
- Cat fur and rubber rod
- Batteries
- Power plants

At a fundamental level, what is it that is being conserved?



The limit of optical microscopy.

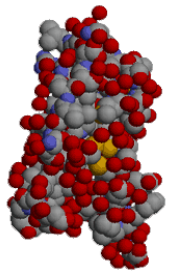


At this point, we've reached the limit of what you can see with light.

- We can use other methods to "see" finer details
- Mostly, we just use hammers to break the particles apart and try to detect the pieces.

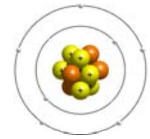
Molecules

- Size ~ 10^{-9} – 10^{-8} meters
- Held together by the electromagnetic force via sharing electrons.



Atoms

- Size ~ 10^{-10} meters. An atom is mostly empty space!
- The only relevant force is the electromagnetic one which holds the electrons to the nucleus.

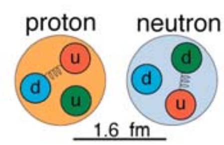


Hans Geiger and Ernest Rutherford

Electrons seem fundamental (we can't break them into pieces), but the nucleus comes apart.

Nucleons have parts (but we never see them separately)

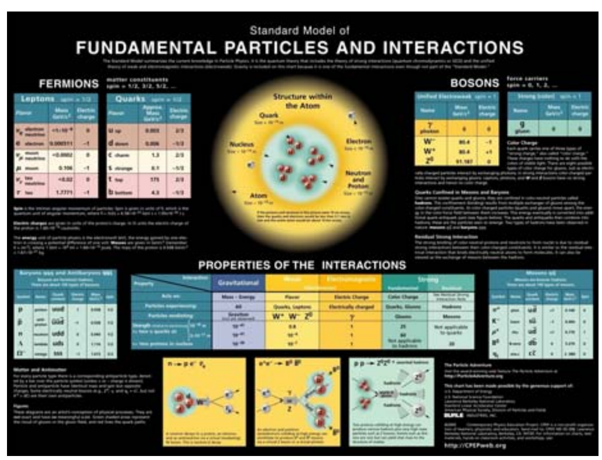
- Size ~ 10 $^{-15}$ meters
- Only 2 nucleons
  - Protons: charge = +1
  - Neutrons: no charge
- Their masses are essentially the same
- They are thought to be composed of simpler entities called *quarks*. *(Nobel Prize in 1990)*



So what are little girls really made of?

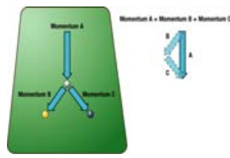
- Electrons
- Quarks

- Mass and charge conservation both relate to the conservation of these fundamental particles.
- There are other fundamental particles too, and in all the processes you experience, fundamental particles are conserved.



Macroscopic properties conserved in motion: Linear Momentum

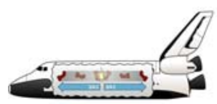
- Momentum is (mass) x (velocity)
- Conserved in the absence of external net force
- For a system with constant mass, this is just of restatement of Newton's First Law
- Examples
  - Collisions
  - Cannon



Momentum is conserved even when the various parts of the system split due to internal forces

Conservation of Linear Momentum at Very High Speeds

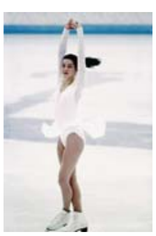
- As an object is accelerated to very high speeds, its resistance to acceleration begins to increase. We classify this increased resistance to acceleration as an increase of mass
- What about conservation of mass?

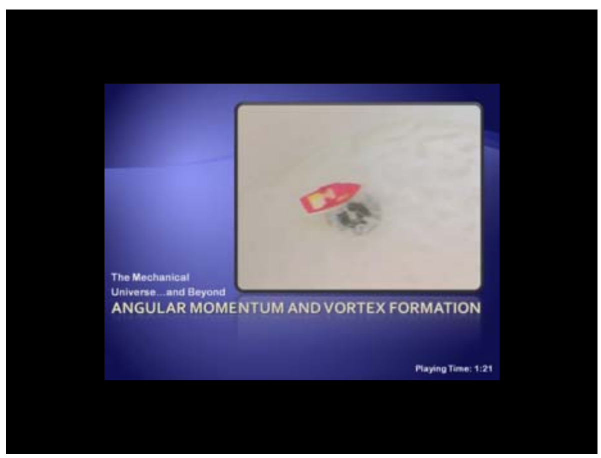


Consequences of relativity: Short, Fat, Slow (like getting old)

Conservation of angular momentum

- Angular momentum is mass x speed x radius
- Examples:
  - Diver
  - Ice skater
  - Riding a bike





Newton's Cradle

- To explain this behavior we need something else to be conserved. This will turn out to be Energy