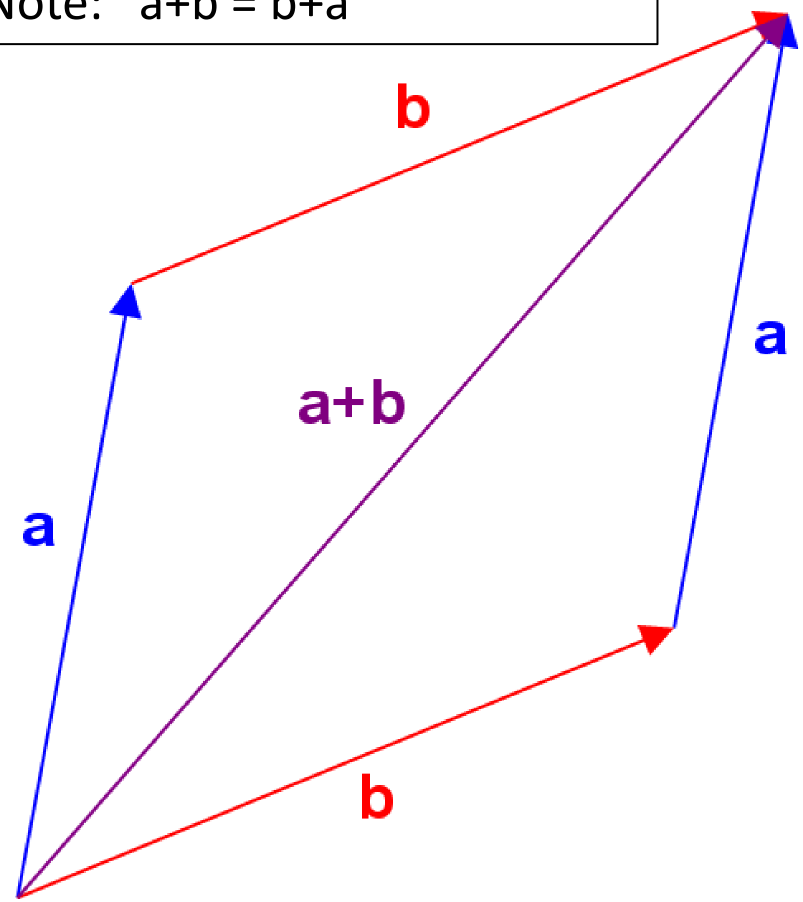
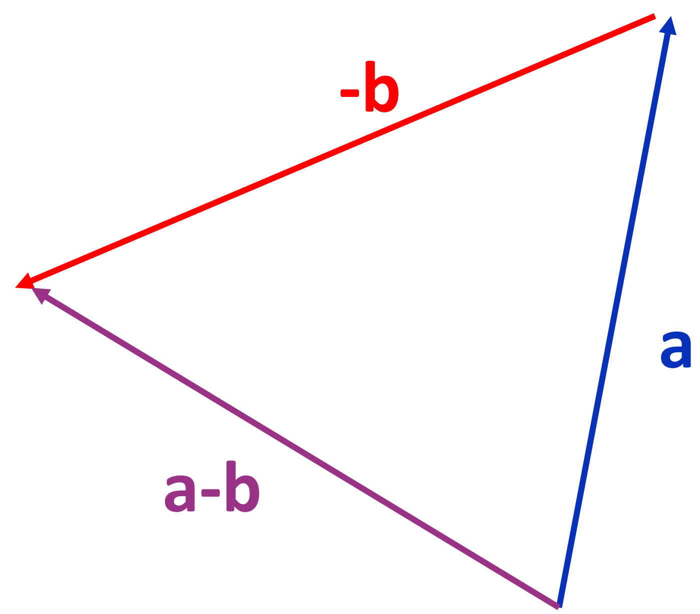
Review of Forces and Conservation of Momentum

Vector Addition and Subtraction

Vectors are added head to tail
Note: a+b = b+a



Vectors are subtracted by added –b to vector a
Note: a-b does not equal b-a
(a-b) = -(b-a)



The Vectors of Kinematics

- Position: $\vec{r}$
- Velocity: $\vec{v}_{ins} = \frac{d\vec{r}}{dt}$
- Acceleration: $\vec{a}_{ins} = \frac{d\vec{v}}{dt}$
- Momentum: $\vec{p} = m\vec{v}$
- Force: $\vec{F}_{A\ on\ B}$

Newton's Laws of Motion

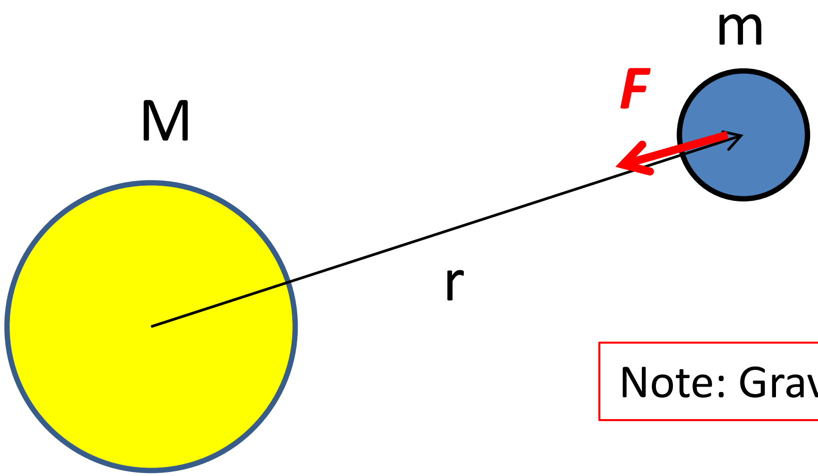
- **1st Law**: The velocity of an object will not change unless acted upon by a force
- **2nd Law**: The net force on an object is equal to the rate of change of momentum
- **3rd Law**: For every force there is an equal but opposite force

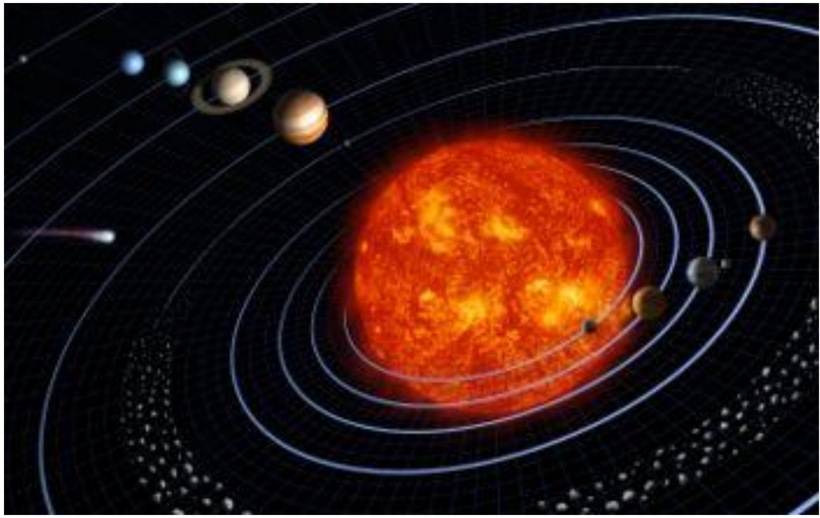
Types of Force

- Contact forces: Require physical contact between two objects (action and reaction)
  - Friction force: Acts parallel to contact surface
  - Normal force: Acts perpendicular to contact surface
- Long-range forces: Require presence of a field between two objects (action at a distance)
  - Gravitational force: Exerted by one massive object on another massive object
  - Electrostatic force: Exerted by one charged object on another charged object

Long Range Force -- $F_g = Gm_1m_2/r^2$ – Gravitational

$$\vec{F}_G = -G\frac{mM}{r^2}\hat{r}$$



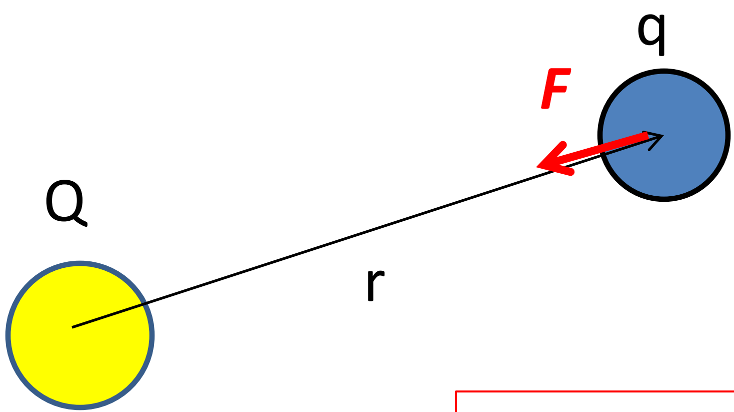


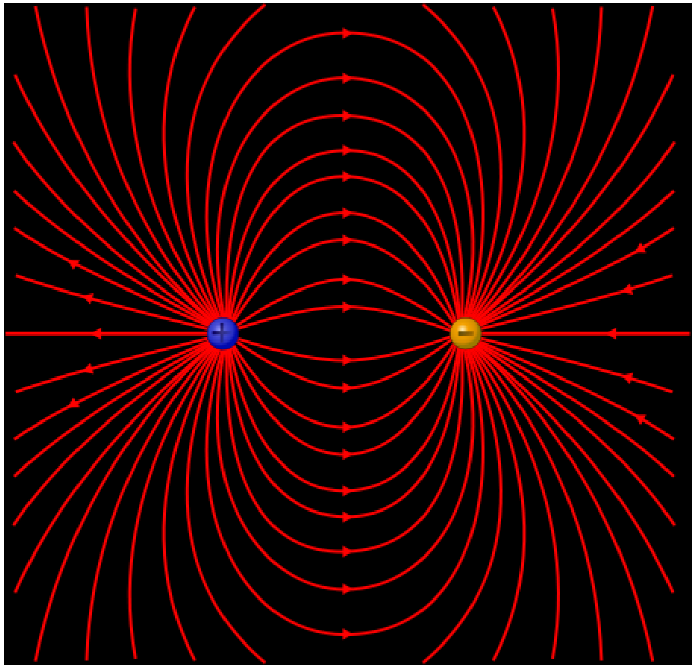
Note: Gravity is always attractive

G = 6.67 X 10^{-11} Nm^2/kg^2 "universal gravitational constant"
M = mass of the object which creates the field
m = mass of the object which experiences the field
r = distance between m and M (pointing from M to m)

Long Range Force -- $F_e = kq_1q_2/r^2$ -- Electromagnetic

$$\vec{F}_E = k\frac{qQ}{r^2}\hat{r}$$





Note: Opposites attract, like signs repel

k = 9.0 x 10^9 Nm^2/C^2 "universal electric constant"

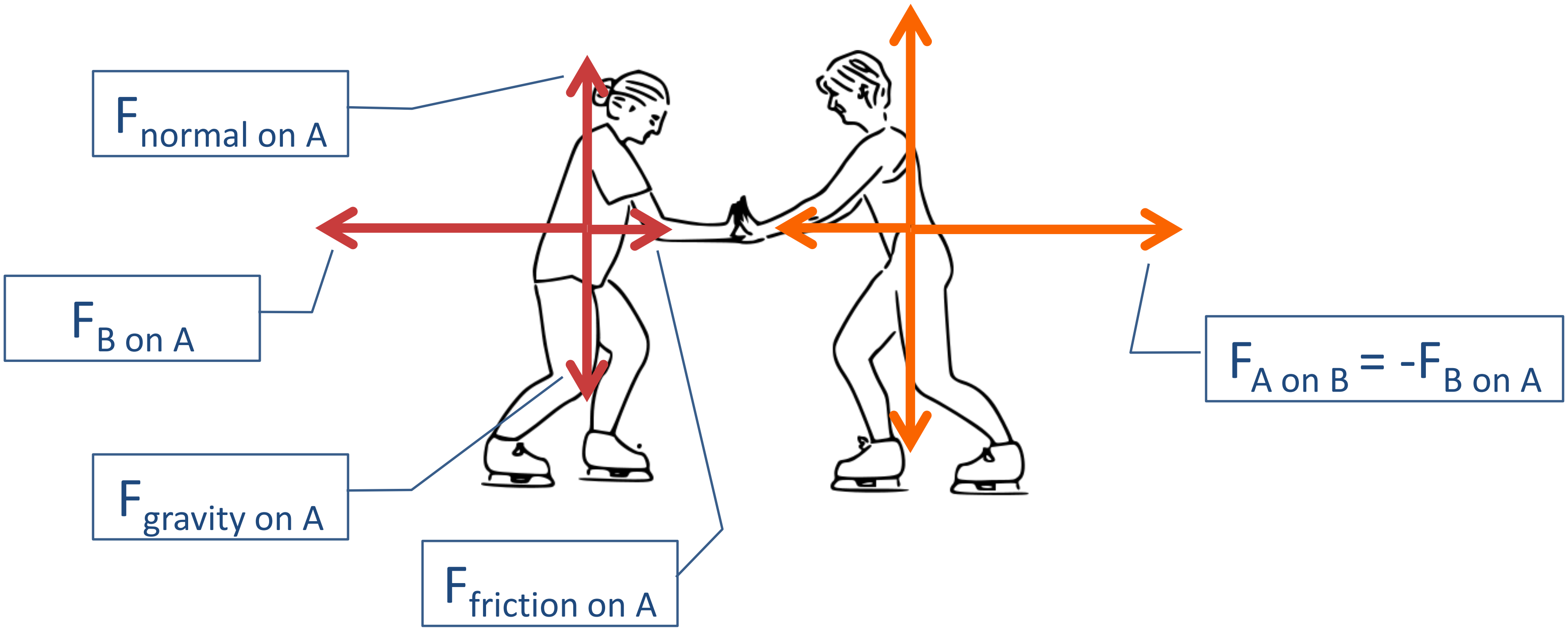
Q = charge of the object which creates the field

q = charge of the object which experiences the field

r = distance between q and Q

Force Diagram

- What are the forces on Alice?
- What are the forces on Bob?



Definition of Momentum
Definition of Impulse
Net force and Net Impulse
Momentum of a system of particles
Momentum Conservation
Collisions
- Elastic
- Newton's 3rd Law
- Inelastic

Relationships
Representations
Introduction of Angular Momentum

Demos:
Cart track
Water Rockets
Cart with fan
Ball on a string
Hockey pucks
Rubber Ball/Clay Ball
Newton's Cradle

The Definition of Momentum

Previously we considered forces. Newton's first law or Gallileo's law of inertia states that in the absence of external forces, a body at rest will stay at rest and a body in motion will continue to move with the same inertia.

Here will define the unchanged quantity to be the *momentum* (***p***), where

Note that ***p*** is a vector with three components.

$$\vec{p} = m\vec{v}$$

Demo: Air puck

Recall that *energy* = $(1/2)mv^2$

The Definition of Impulse

Recall that *work* was resulted in a change in *energy, where work is*

$$W = \int_{x_i}^{x_f} \vec{F}(x) \bullet d\vec{x} = E_f - E_i = \Delta E$$

We can similarly define a quantity called the *impulse*, which is the time integral o f the applied force

$$\vec{J} = \int_{t_i}^{t_f} \vec{F}(t) dt = \vec{p}_f - \vec{p}_i = \Delta\vec{p}$$

J is a vector quantity, which is applied to the vector ***p***.

Demo: Air puck

Conservation of Momentum

$$Net\vec{J}_{ext} = \Sigma\vec{J}_{ext} = \int \Sigma\vec{F}_{ext}(t)dt = \vec{p}_f - \vec{p}_i = \Delta\vec{p}_{system}$$

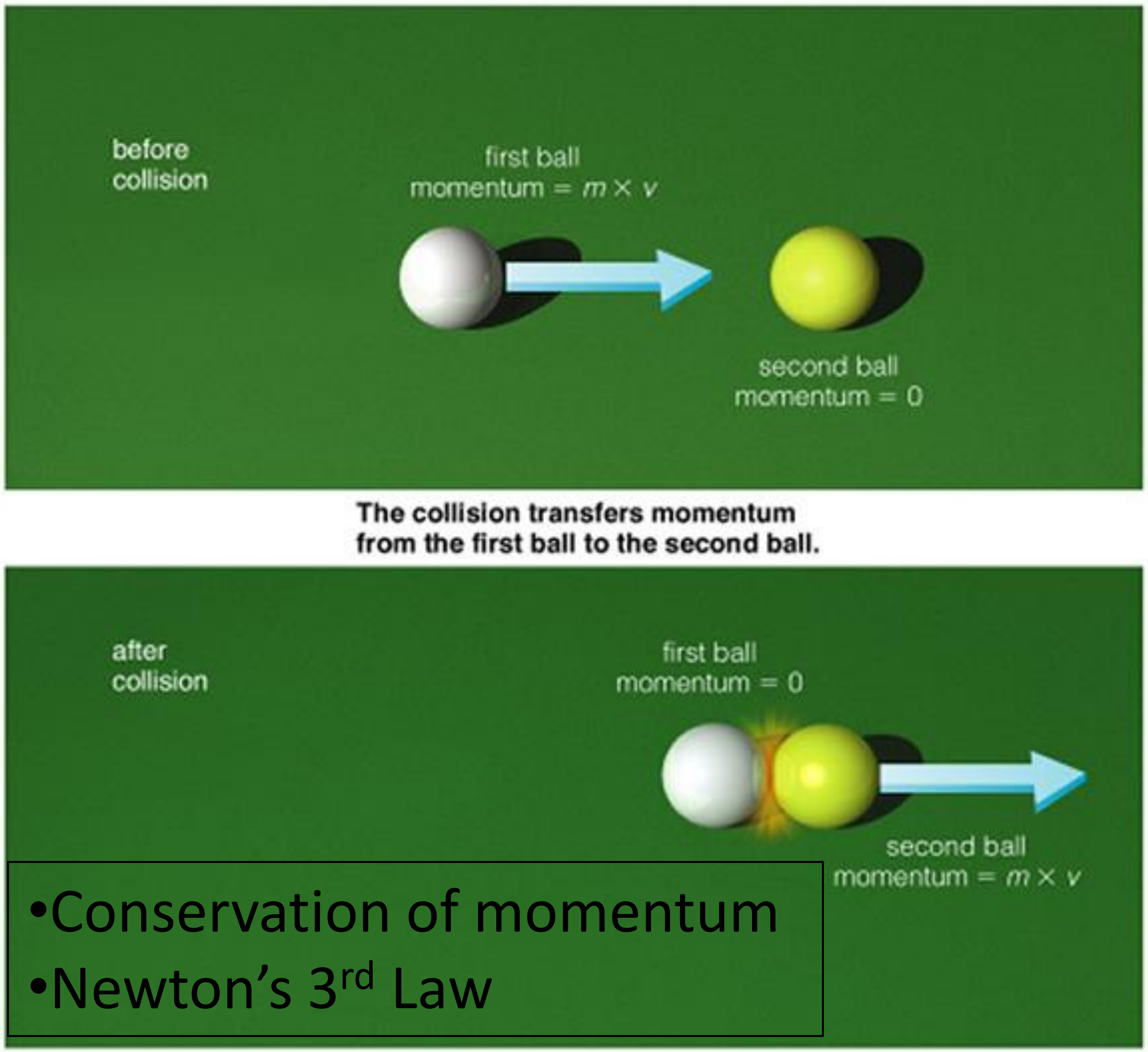
If the net external impulse in a given direction acting on the system is zero, then there is no change in the linear momentum of the system in that direction; Otherwise there is a change in the momentum equal to the net external impulse.

Conservation of Momentum!

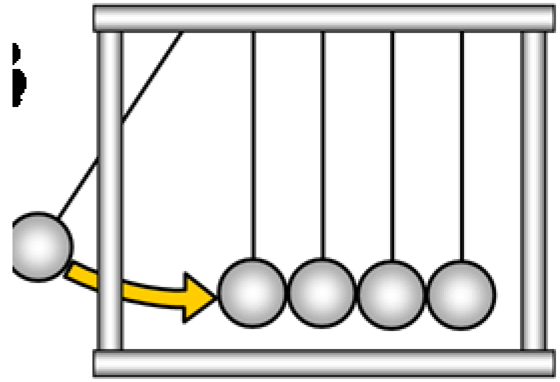
Compare to conservation of Energy

Demo: Cart with sail

The Newton's Cradle



- Conservation of momentum
- Newton's 3rd Law



Rockets

How does a rocket exhibit conservation of momentum?

No external forces – shouldn't $\Delta \boldsymbol{p} = 0$?

The rocket expels propellant at a high velocity backwards.

Net forward ***p*** of the rocket must equal the net backward ***p*** of the propellant.

- Discuss pressure
- Bernoulli's principle
- Add water to rocket

Demo: Rockets

Collisions

A ***collision*** occurs when two free bodies make contact. The contact results in a repulsive normal force. The magnitude of the force and the duration of the contact will determine the resulting impulse. Newton's 3rd law indicates that each of the two participating bodies will experience an equal but opposite impulse.

All collisions conserve both energy and momentum, however we classify collisions as being either ***elastic*** on ***inelastic*** based upon whether kinetic energy is conserved.

Elastic collisions conserve both momentum and kinetic energy.

In an ***inelastic*** collision some of the energy of the collisions is dissipated as internal energy within the bodies.

In a ***completely inelastic*** collision, the two bodies stick together and there is only center of mass motion remaining after the collision

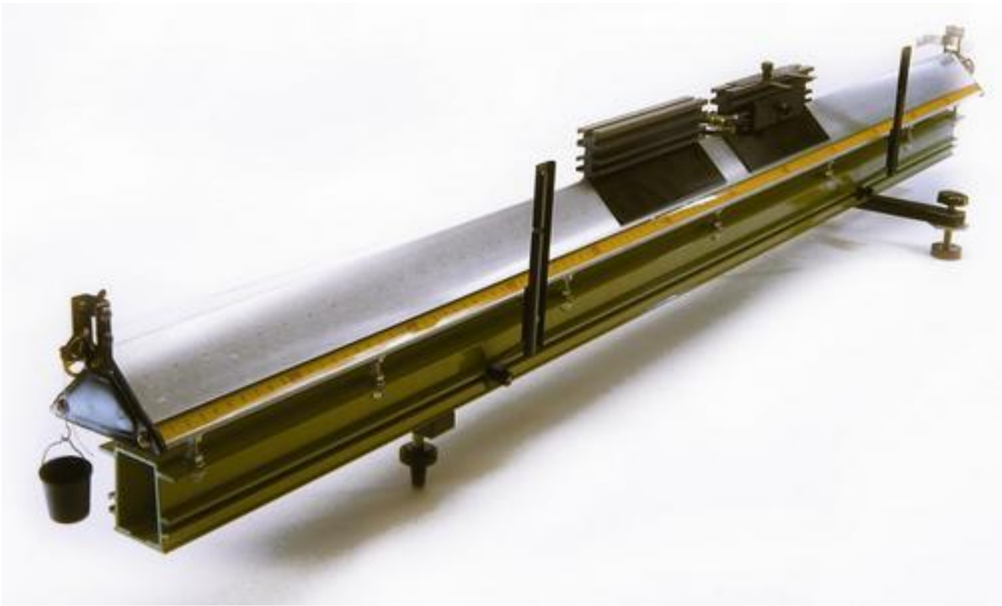
Demo: Rubber Ball and Clay Ball

1D Elastic Collisions

Elastic Collisions:

$$KE_i = KE_f$$

$$\vec{p}_{tot,i} = \vec{p}_{tot,f}$$



Try cases of:
Equal masses
- M1>m2
- m1<M2
- v1>v2
- v1<v2

Demo: collision table

The Definition of Momentum

Inelastic Collisions:

$$KE_i \neq KE_f$$

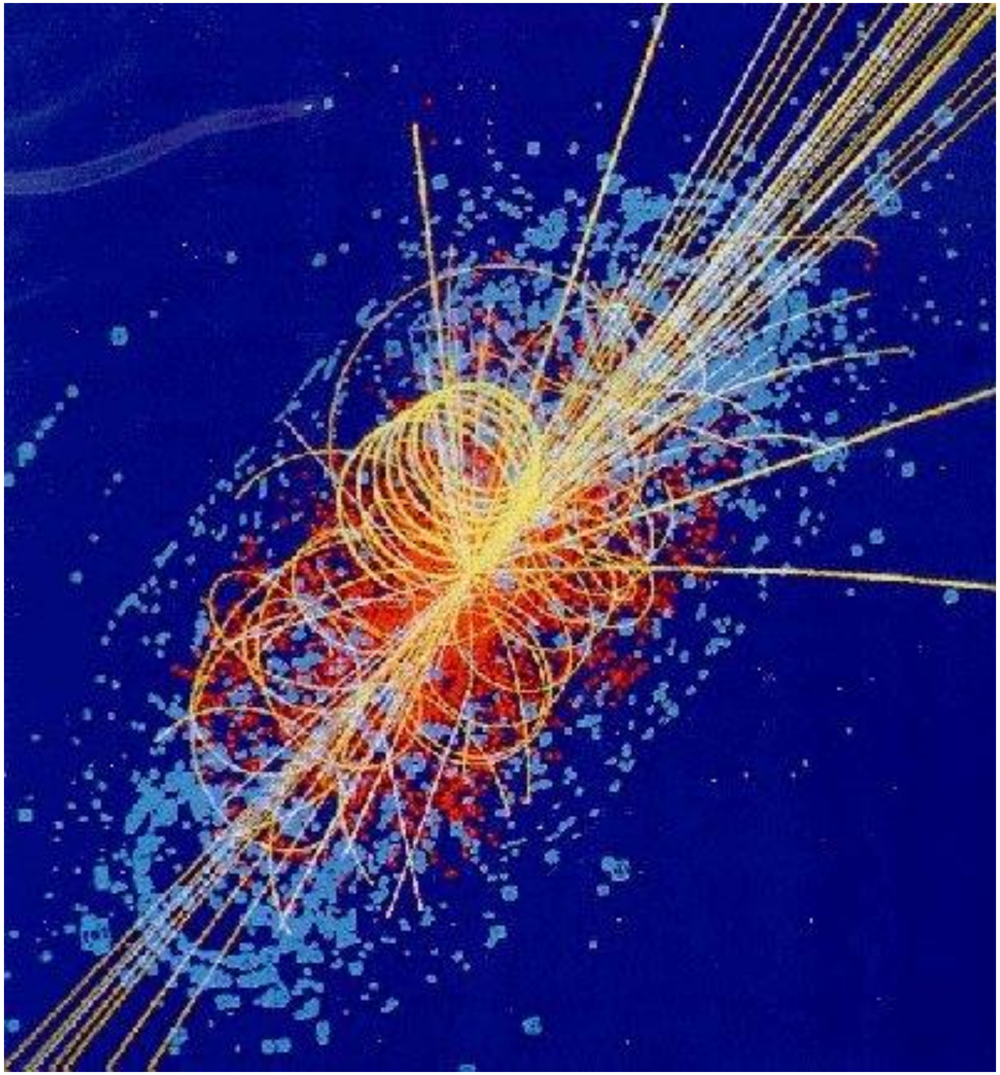
$$\vec{p}_{tot,i} = \vec{p}_{tot,f}$$

Try cases of:

Equal masses

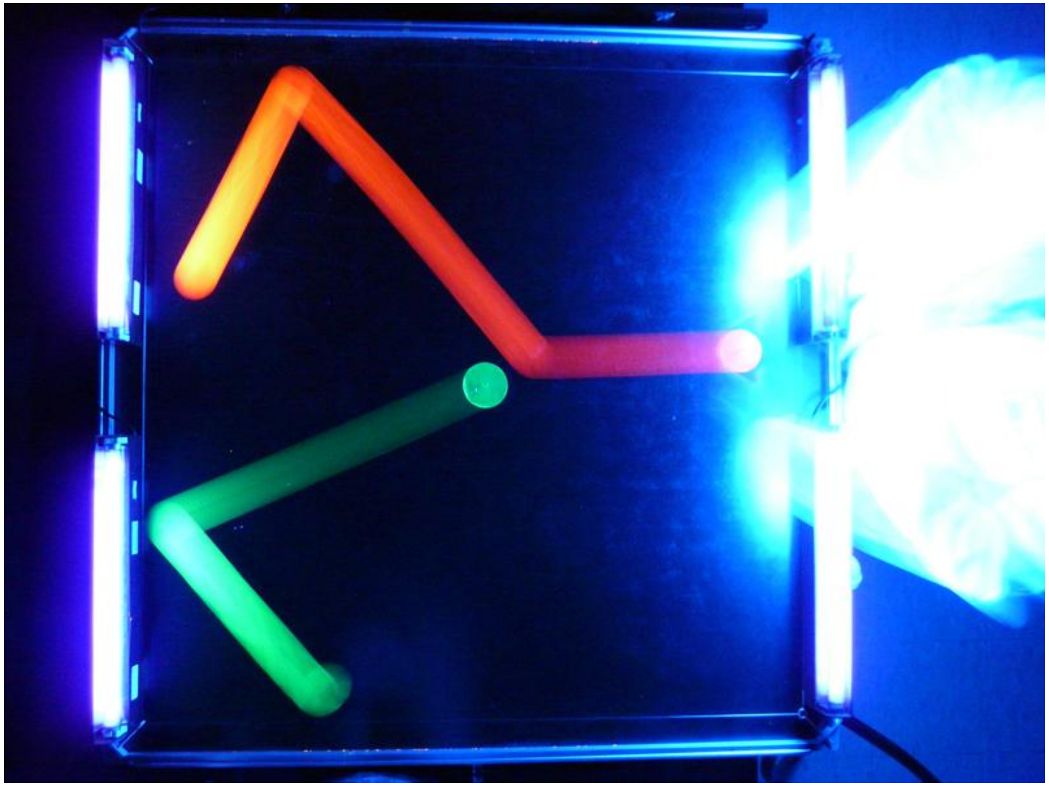
- M1>m2
- m1<M2
- v1>v2
- v1<v2

Demo: collision table



Inelastic Collisions

2D Collisions

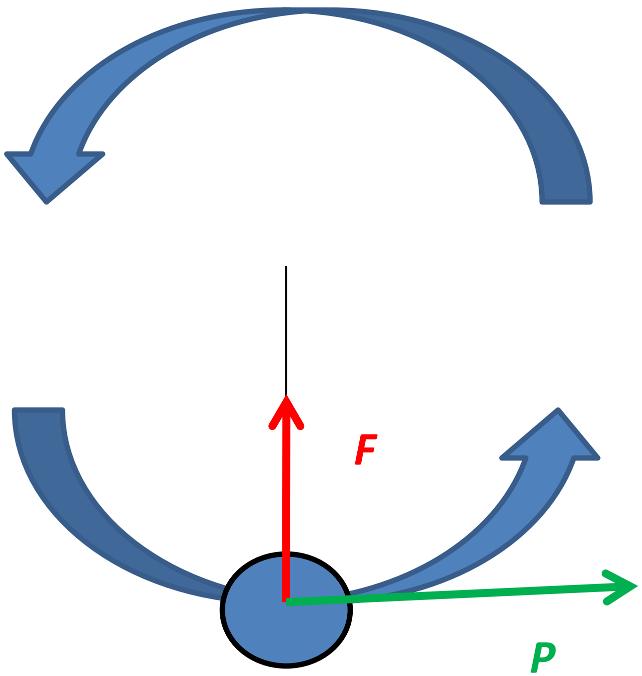


Demo: Air puck

Many Body Problem

Angular Momentum

$F_c = mv^2/r$



Spin the ball, then let it go. Due to conservation of momentum, it must go in the straight line

Demo: Ball on a string

Announcements

President's day Holiday - Monday

DL Sections

Winter 2010 7B-1 (A/B) D/L Assignments & Job Responsibilities

1	WF	10:30-12:50	2317 EPS	Marcus Afshar
2	MW	2:10-4:30	2317 EPS	Aaron Hernley
3	MW	4:40-7:00	2317 EPS	Rylan Conway
4	MW	7:10-9:30	2317 EPS	Rylan Conway
5	MR	8:00-10:20	2317 EPS	Robert Lynch
6	TR	10:30-12:50	2317 EPS	Aaron Hernley
7	R	2:10-4:30	2317 EPS	Justin Dhooghe
7	M	10:30-12:50	2317 EPS	Justin Dhooghe
8	TR	4:40-7:00	2317 EPS	Britney Rutherford
9	TR	7:10-9:30	2317 EPS	Britney Rutherford
10	TF	8:00-10:20	2317 EPS	Emily Ricks
11	TF	2:10-4:30	2317 EPS	Justin Dhooghe