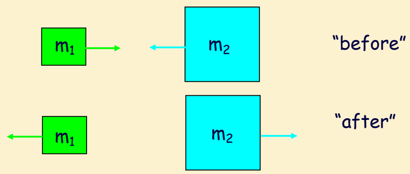
Physics 101: Lecture 12
Collisions and Explosions

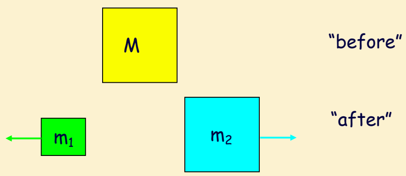
Overview of Semester

- Kinematics: 3 Eqns describing motion under cst *a*
- Newton's Laws
  - $\mathbf{F_{Net} = m\, a}$ = Δ(mv)/Δt = Δp/Δt
- Work-Energy
  - F_{Net} = m *a*   multiply both sides by d
  - $\mathbf{W_{Net} = \Delta K}$ **Work-Kinetic Energy Theorem**
  - $\mathbf{W_{nc}=\Delta E=\Delta(K+U)}$ **Work by NC forces is ΔE**
  - Useful when know Work done by forces
- Momentum
  - $\mathbf{F_{Net}\Delta t= \Delta p}$ If and only if F_{Net} Δt = I = 0 the next line holds
  - F_{Net} Δt = I = 0 => Δp = 0 Momentum is "conserved"
  - Both ideas apply in each direction independently

Collisions



Explosions



General Plan

- Draw "before", "after"
- Define system so that $F_{ext} = 0$ and momentum is conserved (i.e., no external impulse)
- Set up coordinate axes
- Compute P_{total} "before"
- Compute P_{total} "after"
- Set them equal to each other

- Handy relationship:

$KE = \frac{1}{2}mv^2 = \frac{1}{2}mmv^2/m = \frac{1}{2}m^2v^2/m$

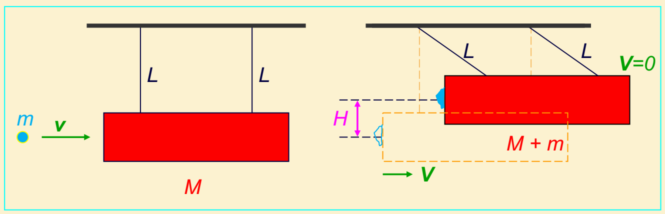
$= p^2/2m$

Useful for when two bodies have same momentum

Elastic Collisions with Gliders

- If **one cart is moving** and the **other cart is stationary**, and **<u>the two have an elastic collision</u>** where both momentum and kinetic energy are conserved, then from the prelecture you learned that:
- $V_{A,Final} = V_{A,Initial}\left(\frac{M_A - M_B}{M_A + M_B}\right)$
- $V_{B,Final} = V_{A,Initial}\left(\frac{2M_A}{M_A + M_B}\right)$
- Demo

Ballistic Pendulum



A projectile of mass *m* moving horizontally with speed *v* strikes a stationary mass *M* suspended by strings of length *L*. Subsequently, *m + M* rise to a height of *H*.

Given *H*, M and m what is the initial speed *v* of the projectile?

Collision Conserves Momentum

0+m v = (M+m) V

After, Conserve Energy

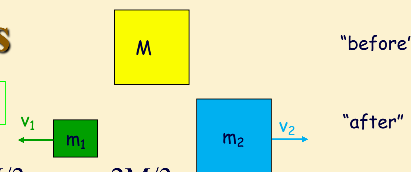
½ (M+m) V²+0 = 0+(M+m) g H

V = sqrt(2 g H)

Combine: $v = \frac{M+m}{m}\sqrt{2gH}$

demo

Explosions



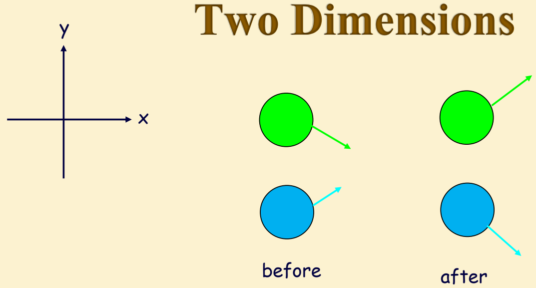
A=1, B=2, C=same

- Example: $m_1 = M/3$ $m_2 = 2M/3$
- Which block has larger |momentum|?
  - * Each has same |momentum|
- Which block has larger speed?
  - * mv same for each ⇒ smaller mass has larger speed
- Which block has larger kinetic energy?
  - * $KE = mv^2/2 = m^2v^2/2m = p^2/2m$
  - * ⇒ smaller mass has larger KE
- Is kinetic energy conserved?
  - A) Yes B) No

$0 = p_1 + p_2$

$p_1 = -p_2$

Collisions or Explosions in Two Dimensions



- $P_{total,x}$ and $P_{total,y}$ independently conserved

  $P_{total,x,before} = P_{total,x,after}$

  $P_{total,y,before} = P_{total,y,after}$

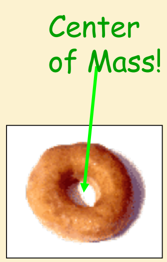
Center of Mass

$$\vec{r}_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2}{\sum m_i}$$ Center of Mass = Balance point

In practice do the above in x and y directions separately

$$x_{cm} = \frac{m_1x_1 + m_2x_{2+} \ldots}{\sum m_i} \qquad y_{cm} = \frac{m_1y_1 + m_2y_{2+} \ldots}{\sum m_i}$$

Shown is a yummy doughnut. Where would you expect the center of mass of this breakfast of champions to be located?



Center of Mass

$P_{tot} = M_{tot}V_{cm}$

$(P_{tot})/M_{tot} = V_{cm}$ $\qquad F_{ext}\Delta t = \Delta P_{tot} = M_{tot}\Delta V_{cm}$

So if $F_{ext} = 0$ then V_{cm} is constant

Also: $F_{ext} = M_{tot}a_{cm}$

Center of Mass of a system behaves in a SIMPLE way
- moves like a point particle!
- velocity of CM is unaffected by collision if $F_{ext} = 0$

(pork chop demo)

Summary

- Collisions and Explosions
  - •Draw "before", "after"
  - •Define system so that $F_{ext} = 0$
  - •Set up axes
  - •Compute P_{total} "before"
  - •Compute P_{total} "after"
  - •Set them equal to each other
- If external force results in impulse, then $I = \Delta P$
- Center of Mass (Balance Point)

$$\vec{r}_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2}{\sum m_i}$$

- V_{cm} does not change in collisions