Physics 101: Lecture 12
Collisions and Explosions

Overview of Semester

- Kinematics: 3 Eqns describing motion under const. *a*
- Newton's Laws
  - ➔ $\mathbf{F_{Net} = m\, \boldsymbol{a}} = \Delta(mv)/\Delta t = \Delta p/\Delta t$
- 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 $F_{Net}\,\Delta t = I = 0$ the next line holds
  - ➔ $F_{Net}\,\Delta t = I = 0 \Rightarrow \Delta p = 0$ Momentum is "conserved"
  - ➔ Both ideas apply in each direction independently

Clicker Question

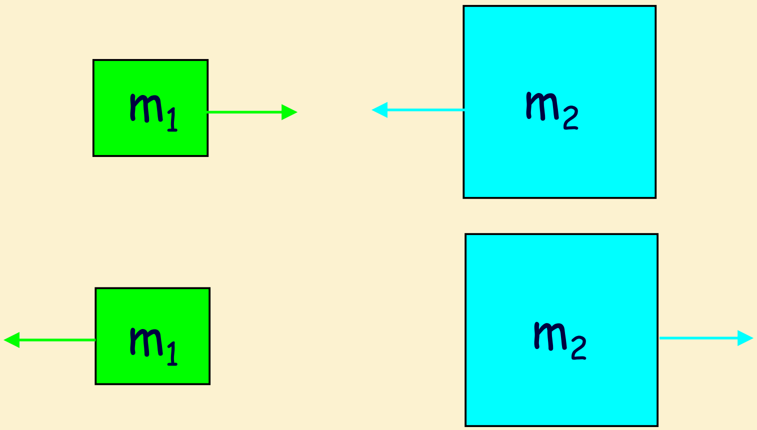
Which of the two balls will exert a larger force on the wooden block and hence have a better chance of knocking it over?

A) The putty, which goes “thud” and does not bounce back

B) The ball, which bounces back

Hint: Think of which one delivers the larger impulse to the block, and since impulse is $F\Delta t=\Delta p$, which ball has a larger Δp? Since Δt is about the same in both collisions, larger impulse means larger force.

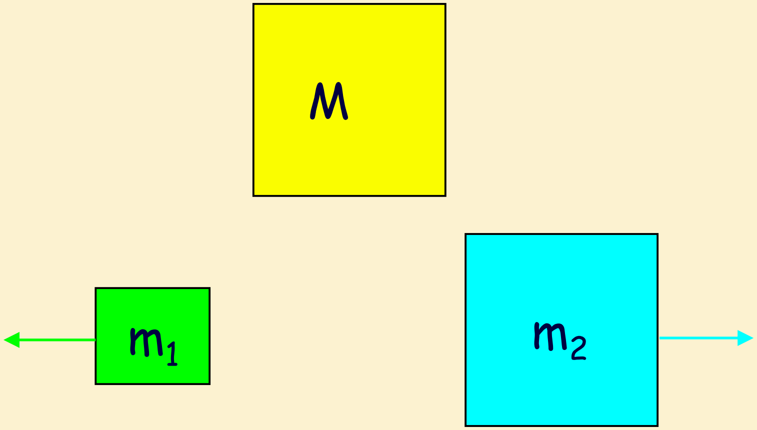
Collisions



“before”

“after”

Explosions



“before”

“after”

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:

$KE = ½mv^2 = ½mmv^2/m = ½m^2v^2/m$

$\Rightarrow KE = p^2/2m$

Useful for when two bodies have same momentum

Clicker Q

A railroad car is coasting along a horizontal track with speed V when it runs into and connects with a second identical railroad car, initially at rest. Assuming there is no friction between the cars and the rails, what is the speed of the two coupled cars after the collision?

A. V

B. V/2

C. V/4

D. 0

Demo with gliders

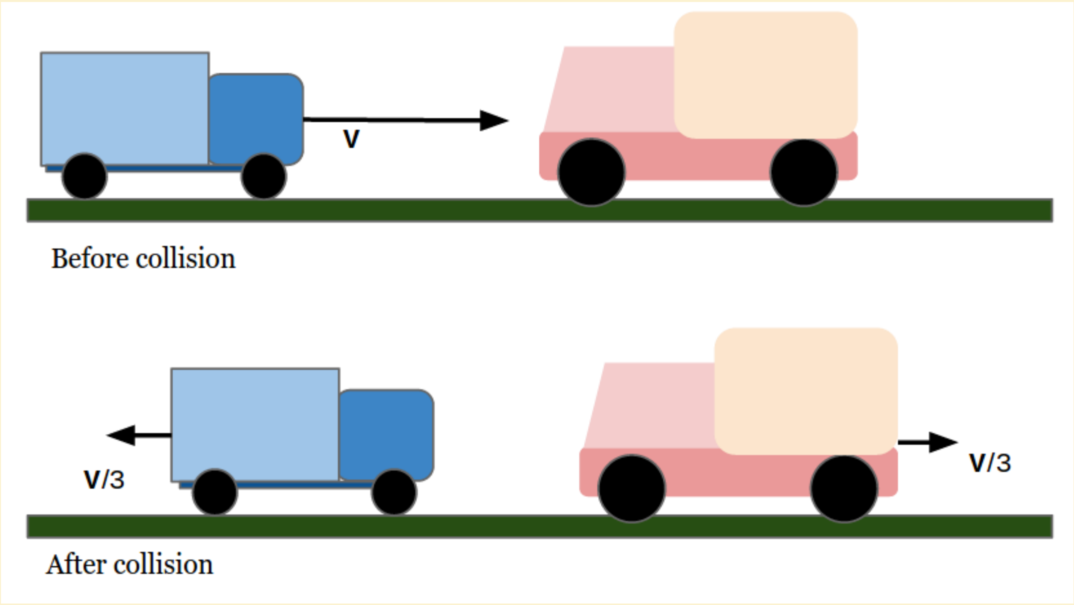
Clicker Q

What physical quantities are conserved in the above collision?

A. Only momentum of the cars is conserved
B. Only kinetic energy of the cars is conserved
C. Both are conserved
D. Neither are conserved

Initial: m, v   Final: 2m, v/2

Checkpoint 1



Consider the collision between two toy carts (no friction). The mass of the blue cart is *m* and the mass of the pink cart is *4m*. Initially the blue toy cart moves to the right at speed v and the pink toy cart is at rest. After the collision, the speed of both toy carts is v/3 in opposite directions. Was the collision elastic?

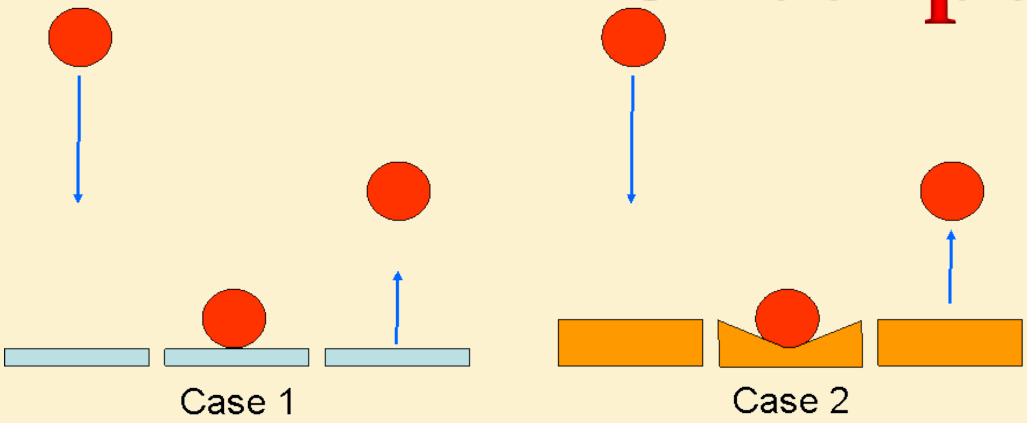
A) Yes

B) No

Elastic Collisions with Gliders

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

Checkpoint 2

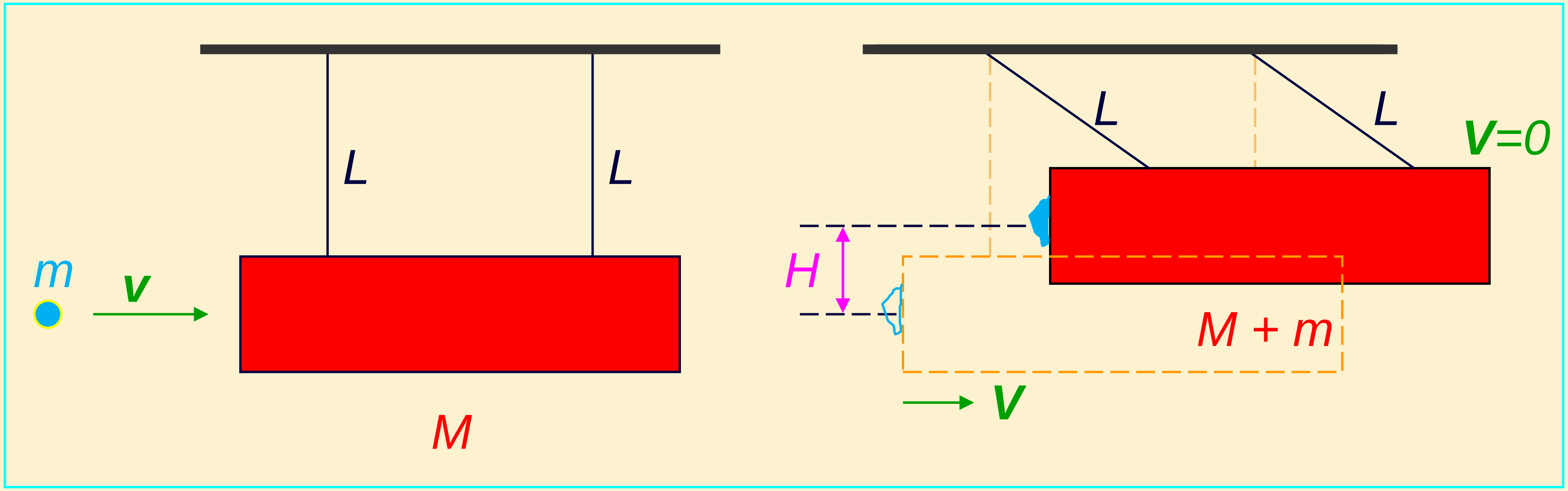


Identical balls are dropped from the same initial height and bounce back to half the initial height. In Case 1 the ball bounces off a cement floor and in case 2 the ball bounces off a piece of stretchy rubber.

In which case is the change in momentum of the ball between the instant just before the ball collides with the floor or rubber and the instant just after the ball leaves the floor or rubber the biggest?

A) Case 1
B) Case 2
C) Same in both

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) V^2+0 = 0+(M+m) g H

V = sqrt(2 g H)

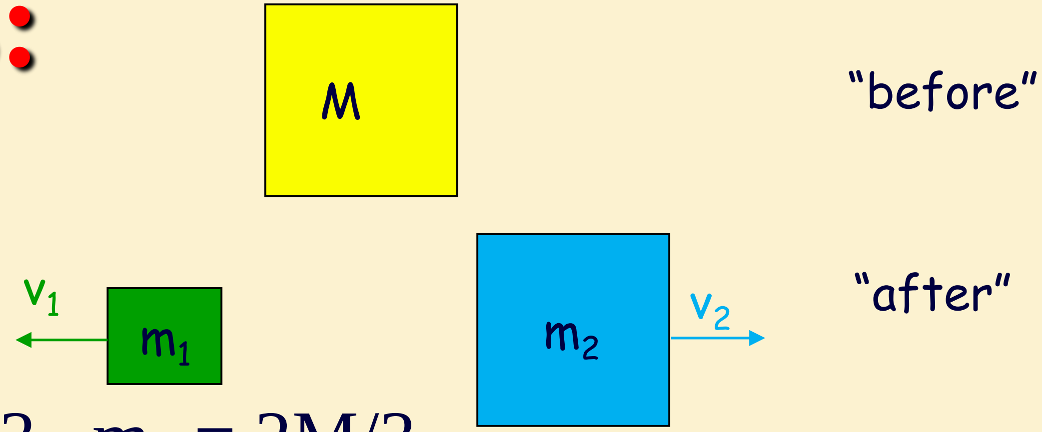
Combine: $$v = \frac{M+m}{m}\sqrt{2gH}$$

v(mph) = 3d(cm)

demo

Explosions:
Clicker Qs

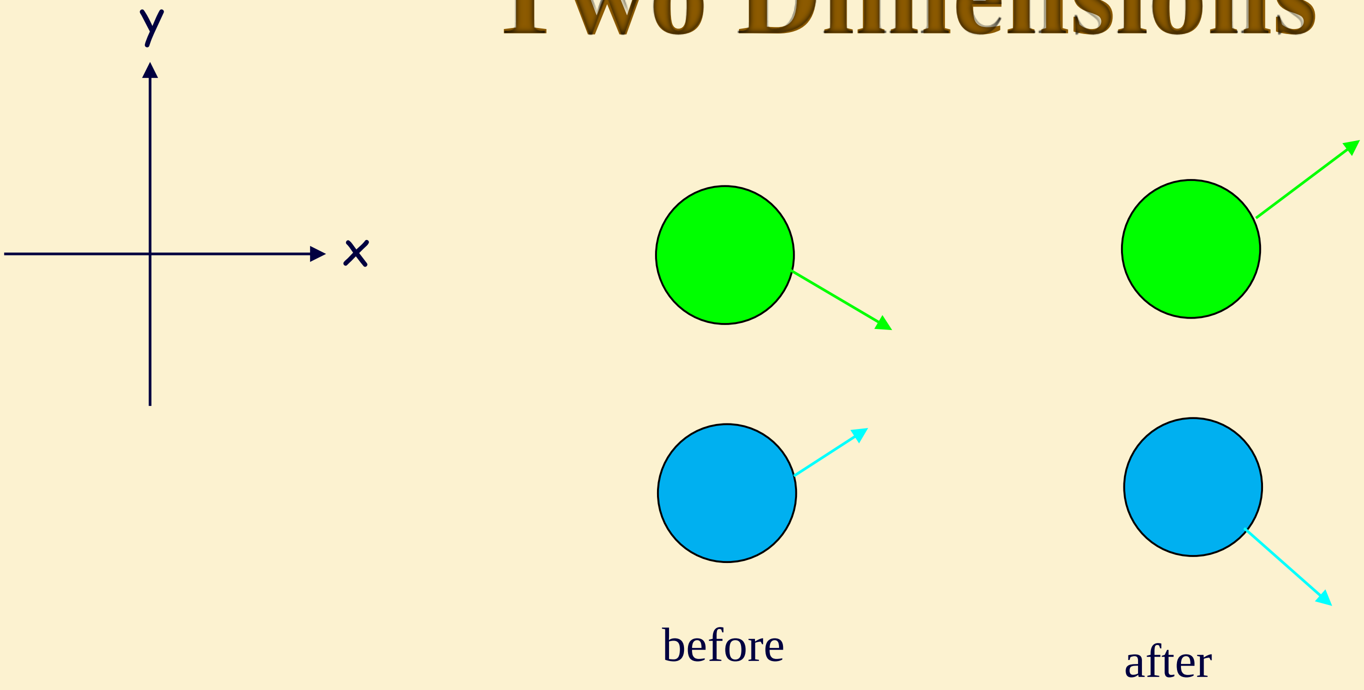
A=1, B=2, C=same



- Example: $m_1 = M/3$ $m_2 = 2M/3$
- Which block has larger |momentum|?
- Which block has larger speed?
- Which block has larger kinetic energy?
- Is kinetic energy conserved?

  A) Yes B) No

Collisions or Explosions in Two Dimensions

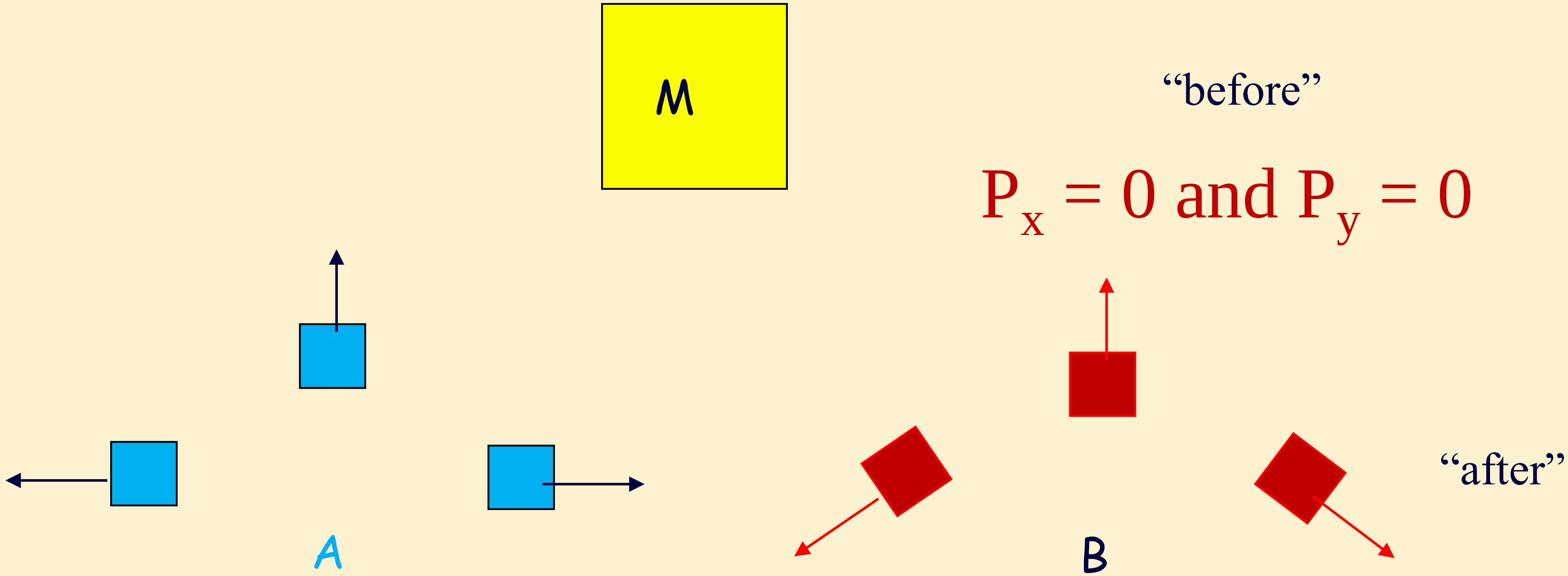


$P_{total,x}$ and $P_{total,y}$ *independently conserved*

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

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

Explosions Clicker Q



$P_{Net,\,x} = 0$, but $P_{Net,\,y} > 0$

$P_{Net,\,x} = 0$, and $P_{Net,\,y} = 0$

Which of these is possible? (Ignore friction and gravity)

A

B

C = both

D = Neither

Center of Mass

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

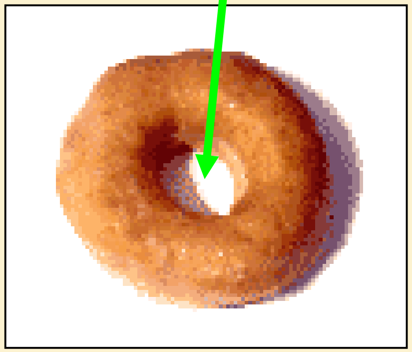
Center of Mass = Balance point

In practice do the above in x and y directions separately

$$x_{cm} = \frac{m_1 x_1 + m_2 x_{2+} \ldots}{\sum m_i} \qquad y_{cm} = \frac{m_1 y_1 + m_2 y_{2+} \ldots}{\sum m_i}$$

Center of Mass!

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



Center of Mass

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

$(P_{tot})/M_{tot} = V_{cm}$

$F_{ext} \Delta t = \Delta P_{tot} = M_{tot} \Delta V_{cm}$

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

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

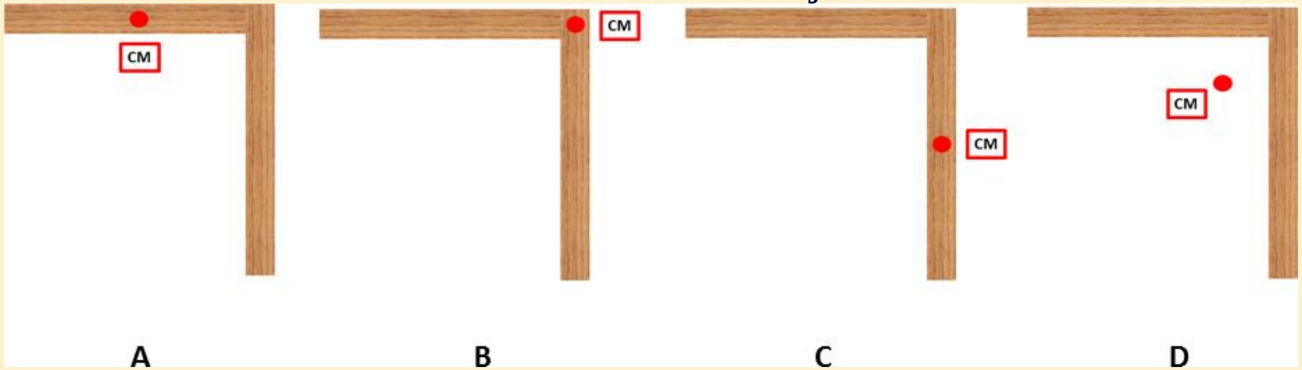
Center of Mass of a system behaves in a SIMPLE way

- moves like a point particle!
- velocity of CM is unaffected by collision if $F_{ext} = 0$

(pork chop demo)

Checkpoint 3 / Lect 12

An object is designed from two sheets of oak wood having the same mass and length, as shown in the figure. Where is the center of mass of the object located?



Recall from a previous commentary (Lec 5):

One of you said: **This stuff… has the potential to be cool.**

I responded: **I agree. You can even make money with it—more later**