Power

- Average Power = Work/time
  - **Units: Joule per second (J/s) – watt (W)**
- $\text{Work}_{NET} = \Delta\text{Energy}$

- IF ***F*** constant and same direction as ***d*,**

  Average Power = Force * Δd/Δt = Force * average vel

A winch is lifting a 350-kg crate. Starting from rest, it takes 4.0s to lift the crate 1.5m and reach a speed of 0.75m/s. The crate then continues upward at this constant speed.

(a) What is the average power of the winch during the first period?

$$W_{NET}=\Delta KE$$

$$W_{NET}=W_{Gravity}+W_{winch}$$

$$\text{Avg Power}=W_{winch}/t$$

Avg Power = 1311 W

(b) What is the average power of the winch during the period of constant velocity?

Avg Power = Force · velocity

Const, velocity (F_{NET}=0) F_{winch}=mg

Avg Power = 2573 W

Chapter 7- Impulse and Momentum

- *Work*: force over distance; related to change in KE
- Impulse: force over time; related to change in *momentum.*
- *Momentum* of an object: $\vec{p} = m \cdot \vec{\mathbf{v}}$
- Impulse and momentum are VECTOR quantities

$$\sum \vec{F} = m\vec{a}$$

$$\sum \vec{F} = m \frac{(\vec{v}_f - \vec{v}_0)}{\Delta t}$$

final momentum

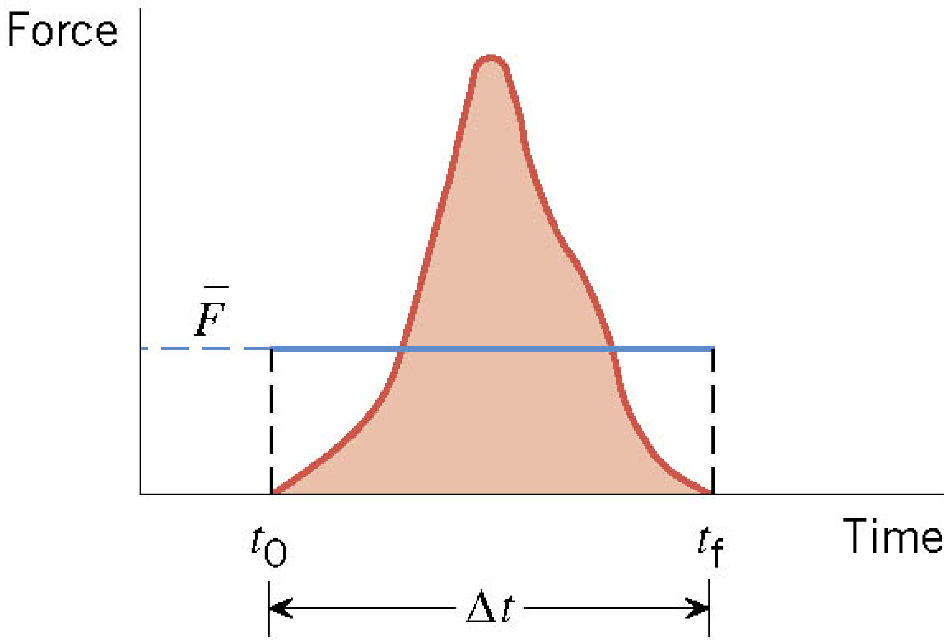
$$\boxed{\sum \vec{F} \Delta t = m\vec{v}_f - m\vec{v}_0}$$

initial momentum

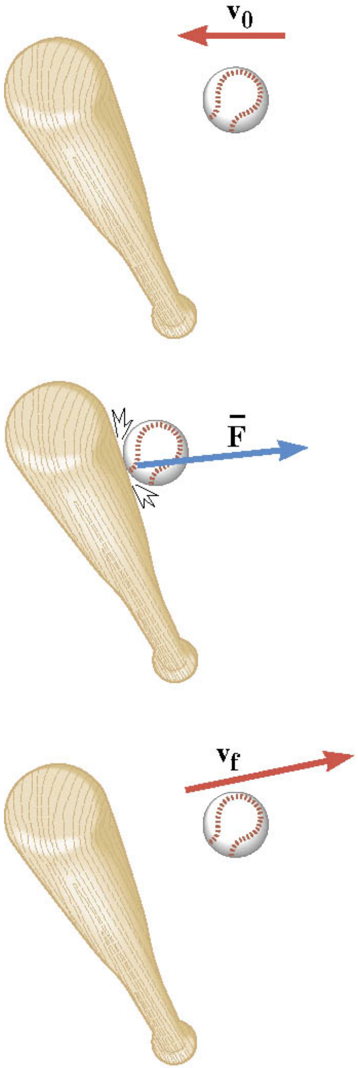
$$\vec{J} = \Delta \vec{p}$$

$$J_X = \Delta p_X \qquad J_Y = \Delta p_Y$$

Hitting a baseball: F versus t graph



(b)



- Impulse equal to area under F vs t graph
- Remember. It is a *vector* quantity: need to account for direction.

Impulse-Momentum Theorem

Impulse $\rightarrow$ change in momentum

$$\vec{J} = \Delta\vec{p}$$

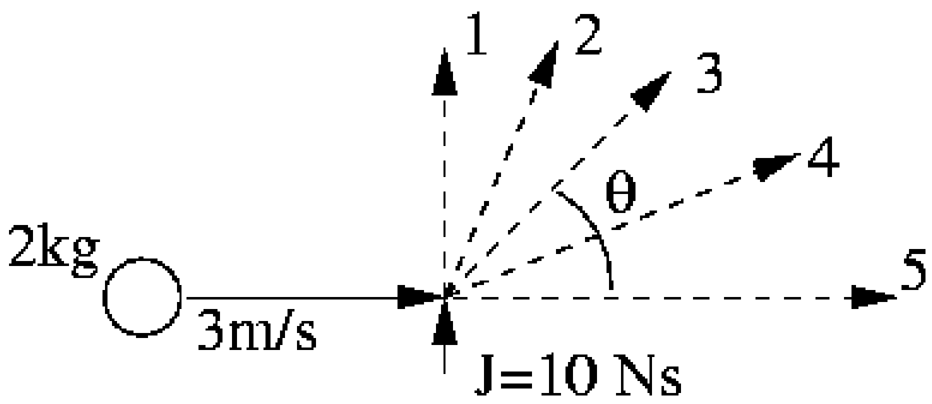
- *J* : impulse ($F\Delta t$) :
- Δp: change in momentum (p_f-p_i)
- *Both are* **vector** *quantities!!!*
- Units: N.s OR kg.m/s (check dimensions!)

Two baseballs are pitched with the same speed. Ball A is hit by the batter and it bounces back with the same speed. Ball B is bunt hit and it does not bounce back up at all. Which ball receives the greater impulse from the bat?

1. $\boxed{\text{Ball A}}$
2. Ball B
3. Both feel the same impulse

Greater change in momentum (not only stopped, but reversed direction)

A 2kg puck is traveling along at 3m/s. An impulse of 10Ns is exerted on the puck at an angle perpendicular to its motion. Which path best describes the motion of the puck after the impulse?



(1) $\theta = 90^\circ$

(2) $45^\circ < \theta < 90^\circ$

(3) $\theta = 45^\circ$

(4) $0^\circ < \theta < 45^\circ$

(5) $\theta = 0^\circ$

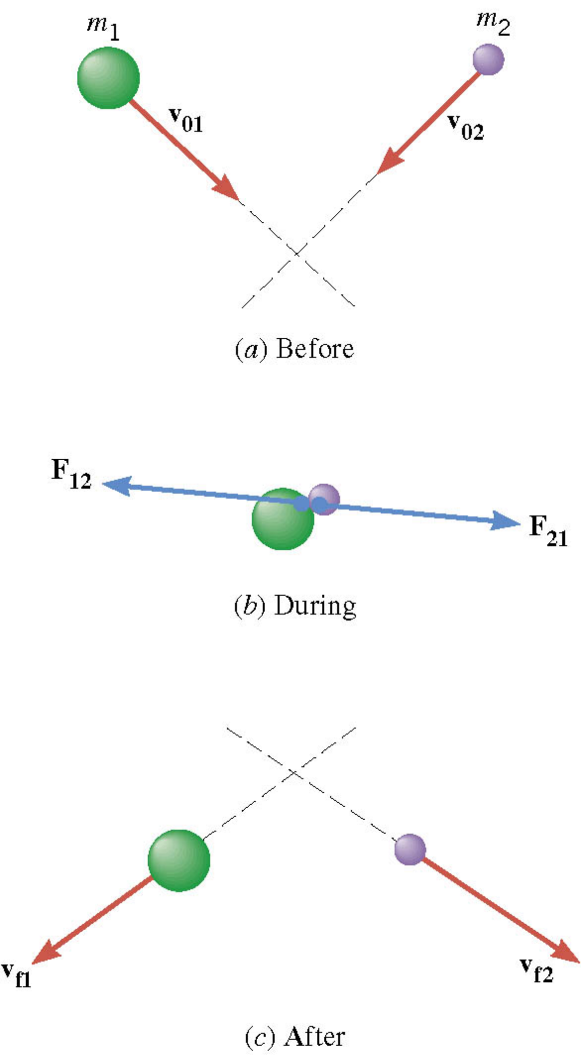
$J = \Delta p_y = 10$ Ns

After impulse, $p_x = 6$ kg m/s (same as before)

$p_y = 10$ kg m/s

Greater momentum in y than in x

Collisions



- During collision: $F_{12} = - F_{21}$ during whole time (Newton's 3rd law)
- $J_{12} = J_{21}$
- (Sum ext forces + sum int forces)*Δt $= p_f - p_0$
- Sum int forces always zero

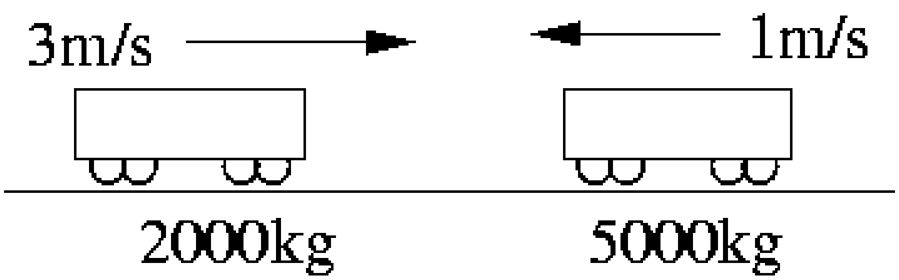
$$\vec{F}_{ext}\Delta t = \Delta\vec{p}$$

- If sum of average external forces = 0

$$\vec{p}_0 = \vec{p}_f$$

- Momentum stays same (*conserved*!) if there are no external forces

Two small railroad cars are traveling at each other with the masses and speeds shown below. If you take the two cars as the system, what is the initial total momentum of the system? (it's a vector!)



(1) 11000 kgm/s to the left

(2) 1000 kgm/s to the left

(3) 0 kgm/s

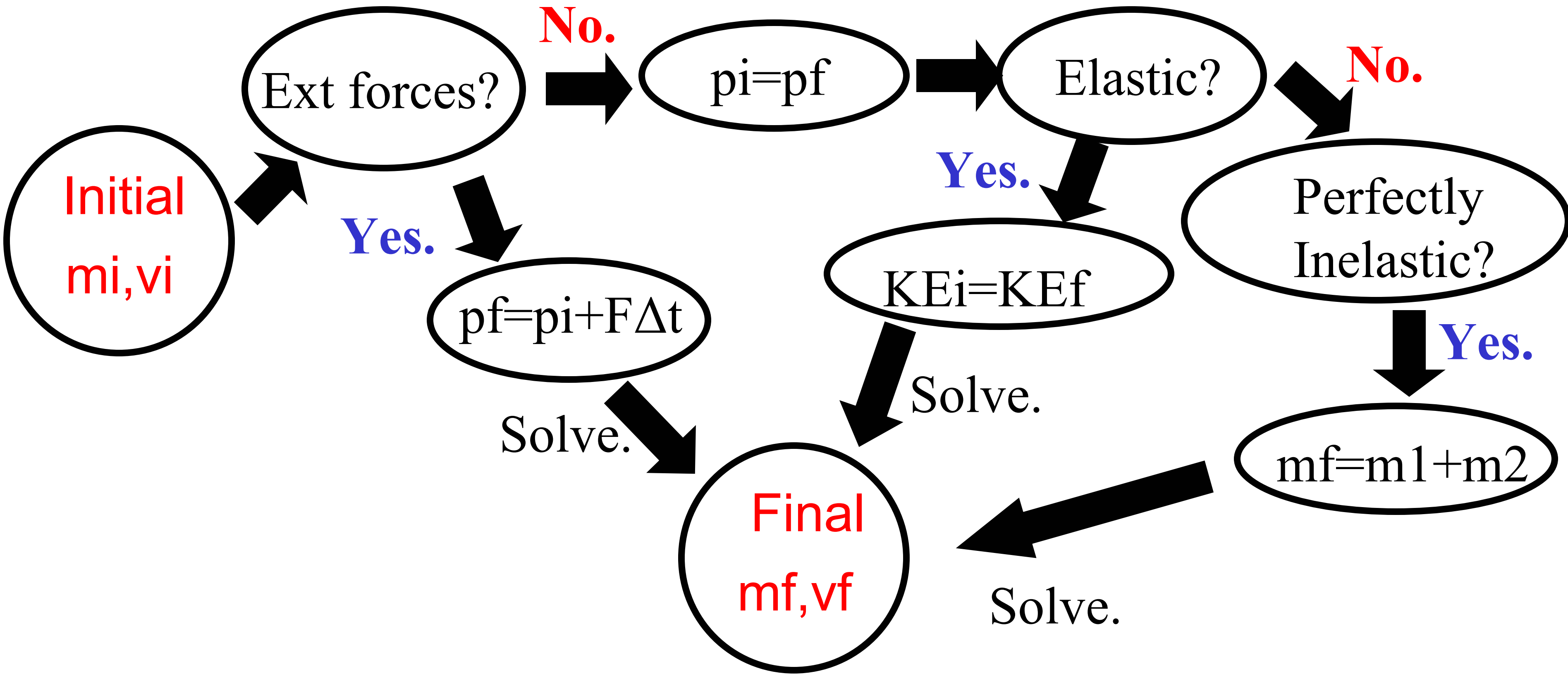
(4) 1000 kgm/s to the right

(5) 11000 kgm/s to the right

6000 kg m/s to right; 5000 kg m/s to left

Classifying Collisions

- All collisions conserve momentum (if no ext forces)
- If it also conserves KE, ***ELASTIC***
- Otherwise, ***INELASTIC***
- "perfectly inelastic" – stick together (final v same)



Elastic Collisions

KE: $KE_{0,1} + KE_{0,2} = KE_{f,1} + KE_{f,2}$

$$\frac{1}{2}mv_{0,1}^2 + \frac{1}{2}mv_{0,2}^2 = \frac{1}{2}mv_{f,1}^2 + \frac{1}{2}mv_{f,2}^2$$

p: $p_{0,1} + p_{0,2} = p_{f,1} + p_{f,2}$

$$mv_{0,1} + mv_{0,2} = mv_{f,1} + mv_{f,2}$$

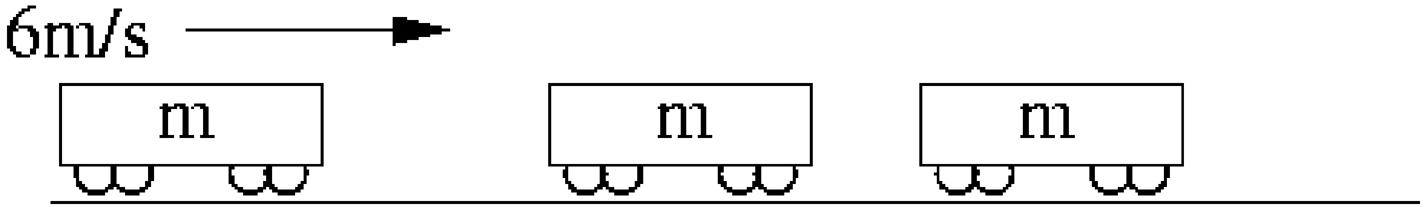
If object 2 initially at rest, can combine relationships (example 7)

After some algebra:

$$v_{f,1} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)v_{0,1} \qquad v_{f,2} = \left(\frac{2m_1}{m_1 + m_2}\right)v_{0,1}$$

Only for elastic collisions!!!!

Three railroad cars of equal mass are on a track. The one on the left is approaching at 6m/s. Ignoring friction, when they have all linked up as one, what is their speed?



(1) 1 m/s   (2) 2 m/s   (3) 3 m/s   (4) 4 m/s

(5) 5 m/s   (6) 6 m/s   (7) 12 m/s   (8) 18 m/s   (9) 0 m/s

$p_{initial} = p_{final}$

$m*6 = (3m) * v$

$v = 2$ m/s

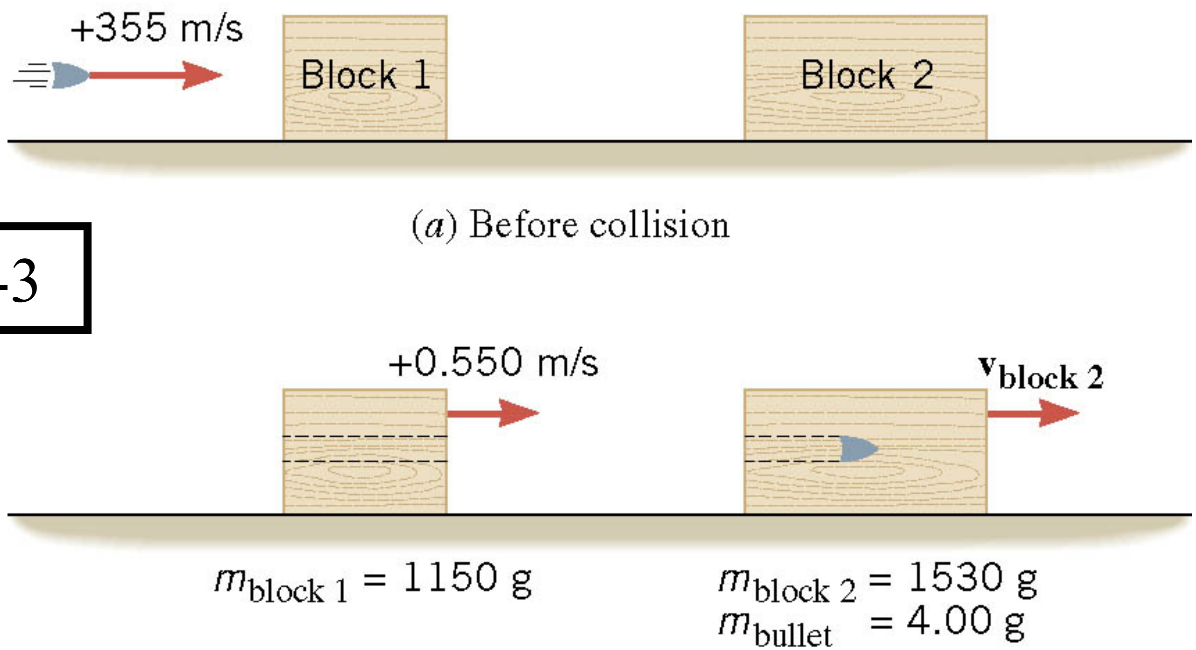
Problem 65 – Cutnell and Johnson

A 4.00-g bullet is moving horizontally with a velocity of +355 m/s, where the + sign indicates that it is moving to the right. The mass of the first block is 1150 g, and its velocity is +0.550 m/s after the bullet passes through it. The mass of the second block is 1530 g.

(a) What is the velocity of the second block after the bullet imbeds itself? $\boxed{0.513\text{m/s}}$

(b) Find the ratio of the total kinetic energy after the collision to that before the collision.

$$\boxed{KE_{After} / KE_{Before} = 1.49\text{e-}3}$$



(a) Before collision

(b) After collision

Problem 65 – Cutnell and Johnson - extended

A 4.00-g bullet is moving horizontally with a velocity of +355 m/s, where the + sign indicates that it is moving to the right. The mass of the first block is 1150 g, and its velocity is +0.550 m/s after the bullet passes through it. The mass of the second block is 1530 g.

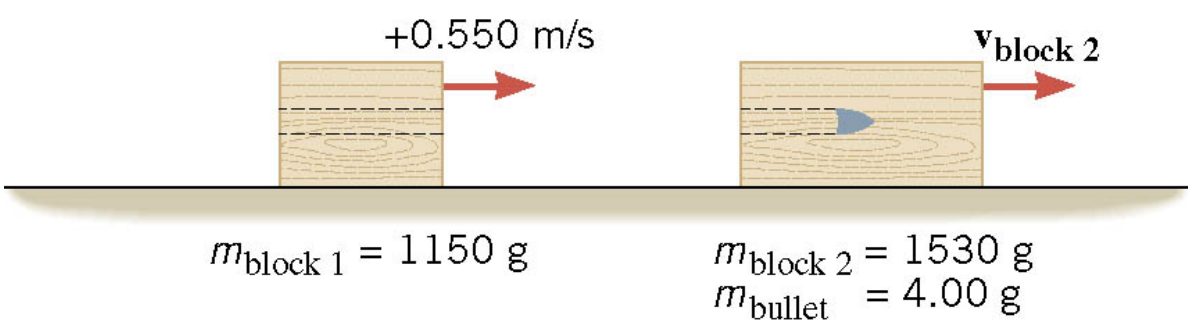
(c) What is the speed of the bullet after the collision with Block 1 and before the collision with Block 2?

$\boxed{197\text{m/s}}$

(d) What is the average force of the bullet on Block 1 if it takes 0.400ms?

(e) What is the average force of the bullet on the block if it stops over a distance of 4.00cm?

(a) Before collision

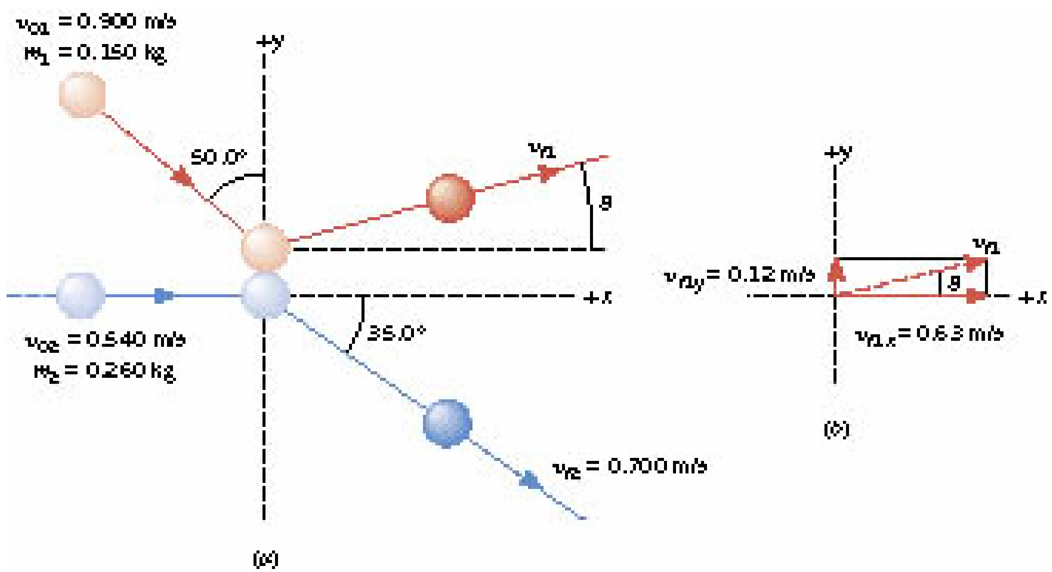


(b) After collision

2-d Collisions

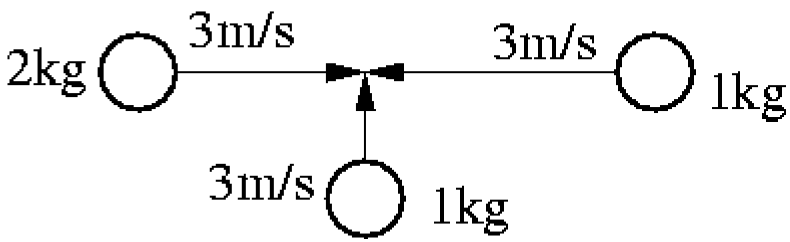
- If no net external force, momentum conserved in *each dimension* (x and y)

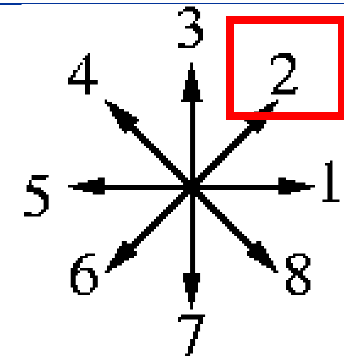
$$p_{initial,x} = p_{final,x} \qquad p_{initial,y} = p_{final,y}$$



Break into components, solve for x and y.

Three pucks collide and stick together. Initial speeds and masses are given. What is the direction of the 3 pucks after the collision? (choose an axis only if exactly on that axis)





9 if stationary

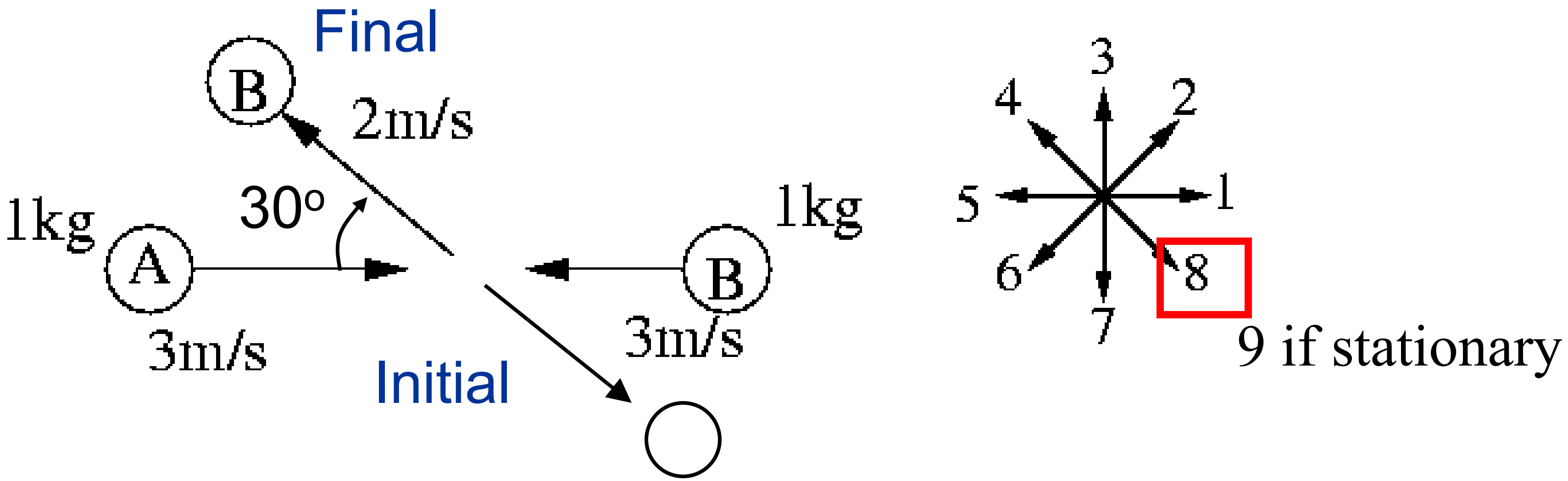
Remember: $\vec{p}_f = \vec{p}_i$

Initial momentum of system: up and to the right.

Final momentum: same!

Direction?

Two pucks collide. Initial speeds and masses are given. What is the direction of Puck A after the collision? (choose an axis only if exactly on that axis) (extra: is the collision elastic or inelastic?)



Initial momentum: zero

Final momentum: Same – Zero.

Therefore if B up and to the left, A will go down and to right.

Can you find the angle for A?

Center of Mass (CM)

- Typically same as center of gravity
- CM is point of interest for extended objects
- Conservation of Energy – use CM
- Projectile motion – use CM
- Collisions: $v_{\text{initial, CM}} = v_{\text{final,CM}}$

$$x_{cm} = \frac{m_1 x_1 + m_2 x_2 + \cdots}{m_1 + m_2 + \cdots}$$

$$\Delta x_{cm} = \frac{m_1 \Delta x_1 + m_2 \Delta x_2 + \cdots}{m_1 + m_2 + \cdots}$$

$$v_{cm} = \frac{m_1 v_1 + m_2 v_2 + \cdots}{m_1 + m_2 + \cdots}$$

Chapter 6

$$W = F\, s \cos\theta$$

$$W_{NET} = \Delta KE$$

$$W_{NC} = \Delta E$$

$$E_F = E_0 + W_{NC}$$

$$(KE_F + PE_F) = (KE_0 + PE_0) + W_{NC}$$

$$PE = mgh$$

$$KE = (1/2)\, mv^2$$

$$F_{\text{FRICTION}} = \mu F_N$$

$$\overline{P} = \frac{\text{Work}}{\text{Time}} \qquad \overline{P} = F\overline{v}$$

$$\overline{P} = \frac{\text{Change in Energy}}{\text{Time}}$$

Chapter 7

$$\vec{J} = \overline{\vec{F}}\Delta t \qquad \vec{p} = m\vec{v}$$

$$\left(\sum \overline{\vec{F}}\right)\Delta t = mv_f - mv_0 \qquad \vec{p}_{initial} = \vec{p}_{final}$$

$$v_{f,2} = \left(\frac{2m_1}{m_1 + m_2}\right)v_{0,1}$$

$$v_{f,1} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)v_{0,1}$$

$$x_{cm} = \frac{m_1 x_1 + m_2 x_2 + \cdots}{m_1 + m_2 + \cdots}$$

$$v_{cm} = \frac{m_1 v_1 + m_2 v_2 + \cdots}{m_1 + m_2 + \cdots}$$