14 FEB 12

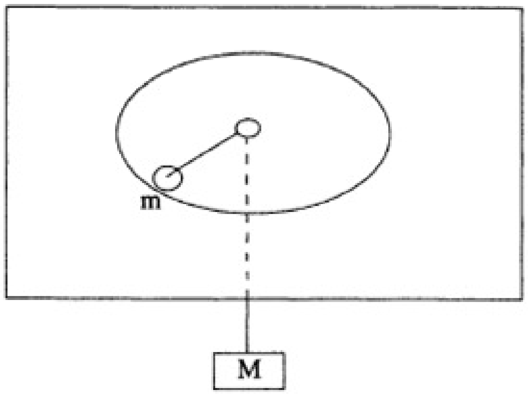
• DAY 94 •

- HW ✓ & Q & A with Warm-up
- Introduction to Ch9: CoM & Linear Momentum
  - → Calculating Center of Mass
  - → Impulse & Collisions
- Momentum with clickers
- Homework Assignment

☆ end of page

warm-up

A puck of mass m is attached to a hanging mass M by a light string through the hole in the center of the horizontal, frictionless table. Mass m rotates with uniform speed v and the hanging mass M stays at rest as shown below.



5. If the rotating mass m is doubled and everything else remains unchanged, the speed of the new mass would be

(A) v
(B) 2v
(C) v/2
(D) $\sqrt{2}$ v
(E) v / $\sqrt{2}$

$\frac{mv^2}{r} = \#$

$2m\frac{v^2}{r}$

$\frac{2m\left(\frac{1}{\sqrt{2}}v\right)^2}{r}$

$\frac{2m \cdot \frac{1}{2}v^2}{r} = \frac{mv^2}{r}$

q2

2 Figure 9-26 shows an overhead view of four particles of equal mass sliding over a frictionless surface at constant velocity. The directions of the velocities are indicated; their magnitudes are equal. Consider pairing the particles. Which pairs form a system with a center of mass that (a) is stationary, (b) is stationary and at the origin, and (c) passes through the origin?

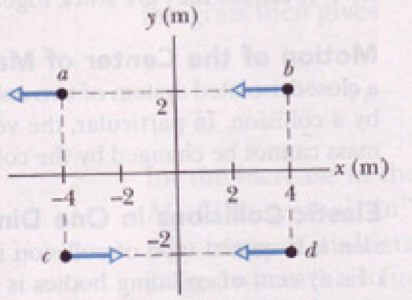


FIG. 9-26 Question 2.

(a) a & c, c & d, c & b

(b) c & b

(c) b & d, maybe a & d

* end of page

q3

3 The free-body diagrams in Fig. 9-27 give, from overhead views, the horizontal forces acting on three boxes of chocolates as the boxes move over a frictionless confectioner's counter. For each box, is its linear momentum conserved along the x axis and the y axis?

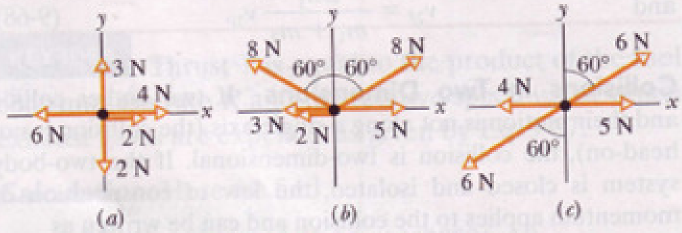


FIG. 9-27 Question 3.

(a) x : yes
y : no

(b) x: yes
y: no

(c) x: no
y: yes

★ end of page

q4

4 Figure 9-28 shows four groups of three or four identical

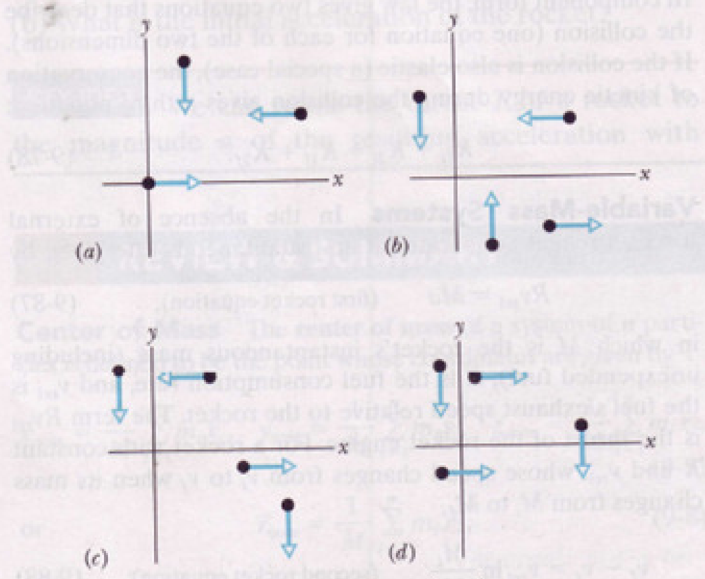


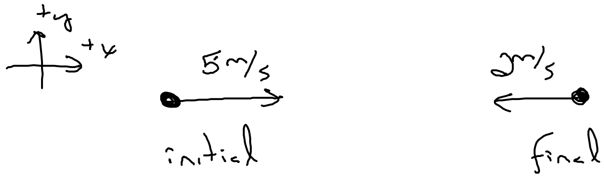
FIG. 9-28 Question 4.

particles that move parallel to either the x axis or the y axis, at identical speeds. Rank the groups according to center-of-mass speed, greatest first.

d, c, a, b

★ end of page

•18 A 0.70 kg ball moving horizontally at 5.0 m/s strikes a vertical wall and rebounds with speed 2.0 m/s. What is the magnitude of the change in its linear momentum?



$$\Delta p = p_f - p_i = mv_f - mv_i$$

$$= m(v_f - v_i)$$

$$= (0.7\,kg)(-2\,m/s - 5\,m/s)$$

$$= -4.9\ kg \cdot m/s$$

$\therefore$ the magnitude is $|-4.9\,kg \cdot m/s| = \boxed{4.9\ kg \cdot m/s}$

☆ end of page

•19 A 2100 kg truck traveling north at 41 km/h turns east and accelerates to 51 km/h. (a) What is the change in the truck's kinetic energy? What are the (b) magnitude and (c) direction of the change in its momentum? ILW

$m = 2{,}100\,\text{kg}$

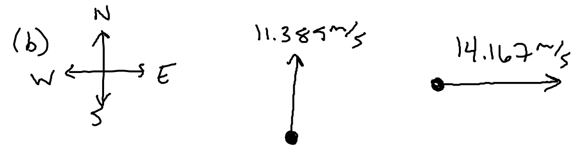
$41\,\frac{\text{km}}{\text{h}} = 11.389\,\text{m/s} \qquad 51\,\frac{\text{km}}{\text{h}} = 14.167\,\text{m/s}$

(a) $\Delta K = K_f - K_i = \tfrac{1}{2}mv^2 - \tfrac{1}{2}mv_0^2 = \tfrac{1}{2}m\left(v^2 - v_0^2\right)$

$= \tfrac{1}{2}(2100\,\text{kg})\left[(14.167\,\text{m/s})^2 - (11.389\,\text{m/s})^2\right]$

$= \boxed{74{,}544.296\,\text{J}} \approx 75\,\text{kJ}$

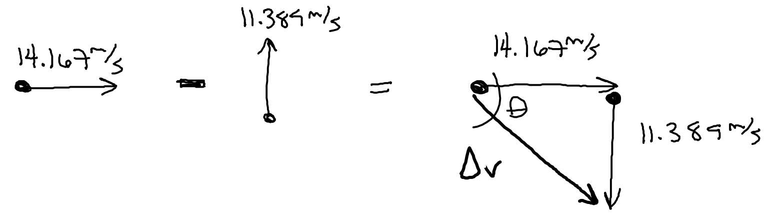
(b)



looking at only magnitude $|\Delta v| = |14.167\,\text{m/s} - 11.389\,\text{m/s}| = 2.778\,\text{m/s}$

$|\Delta p| = m|\Delta v| = (2100\,\text{kg})(2.778\,\text{m/s}) = \boxed{5833.8\,\text{kg}\cdot\text{m/s}}$

(c) $\vec{v}_f - \vec{v}_i \Rightarrow$

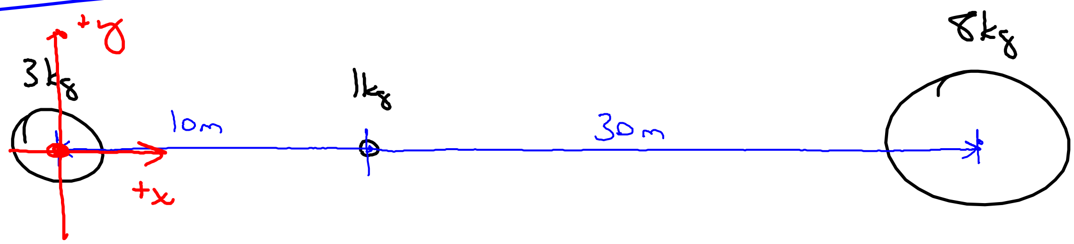


$\theta = \tan^{-1}\left|\frac{11.389}{-14.167}\right| = \boxed{38.796° \text{ below } +\hat{x}}$

★ end of page

If everyone is registered for the AP exams by 01MAR12, then the class will earn a 10/10 quiz grade.

⇒ Center of Mass Calculation

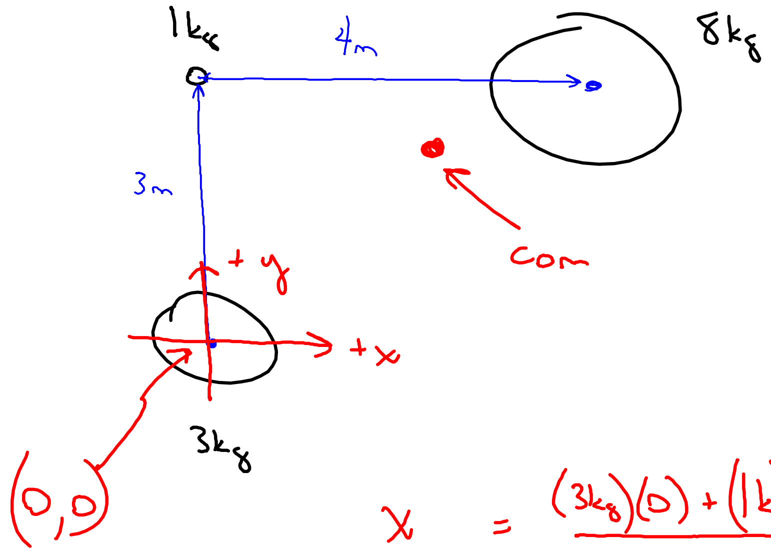


$$x_{com} = \frac{1}{M}\sum_{i=1}^{n} m_i x_i$$

$$x_{com} = \frac{m_1x_1 + m_2x_2 + m_3x_3}{M} = \frac{(3kg)(0) + (1kg)(10m) + (8kg)(40m)}{12kg}$$

$$= 27.5\ m$$

☆ end of page



$$x_{com} = \frac{1}{M} \sum_{i=1}^{n} m_i x_i$$

$$y_{com} = \frac{1}{M} \sum_{i=1}^{n} m_i y_i$$

$$x_{com} = \frac{(3kg)(0) + (1kg)(0) + (8kg)(4m)}{12\,kg} = 2.667m$$

$$y_{com} = \frac{(3kg)(0) + (1kg)(3m) + (8kg)(3m)}{12\,kg} = 2.25m$$

$$(x_{com}, y_{com}) \Rightarrow (2.667m, 2.25m)$$

☆ end of page

⇒ **Recall**: $\vec{F} = \dfrac{\Delta \vec{p}}{\Delta t} \Rightarrow \vec{F} = \dfrac{d\vec{p}}{dt}$ ← time rate of change of momentum

(average) (instantaneous)

also: $\vec{p} = m\vec{v} \Rightarrow \vec{F} = \dfrac{d(m\vec{v})}{dt} = m\dfrac{d\vec{v}}{dt} + \vec{v}\dfrac{dm}{dt}$

$$= m\vec{a} + \vec{v}\frac{dm}{dt}$$

⇒ KE vs. $\vec{p}$

- Kinetic energy is a scalar.
- Momentum is a vector.

- Kinetic energy can be converted to GPE or EPE or even thermal. For conservative forces, total mechanical energy is conserved.
- Momentum is conserved ("before" equals "after") only if no external forces act on the system
- Depending of what is conserved, one might apply both conservation of mechanical energy AND conservation of momentum OR one may only be able to apply one of the conservation laws at a moment in the motion.
- Don't ever assume (just) KE is conserved

Consider a 1,000kg truck moving at 1m/s and a 1kg apple moving at 1,000m/s.

Compare and contrast the KE & p.

$p = mv$

truck $p_t = (1{,}000\,kg)(1\,m/s) = 1{,}000\ kg \cdot m/s$

apple $p_a = (1\,kg)(1{,}000\,m/s) = 1{,}000\ kg\ m/s$

$KE = \frac{1}{2}mv^2$

⇒ Is it possible for two different objects to have the same magnitude of momentum & the same KE?

$$m_1 v_1 = m_2 v_2$$

$$\tfrac{1}{2} m_1 v_1^2 = \tfrac{1}{2} m_2 v_2^2$$

I know of only two cases. Can you find them? Can you find more?

- The force is what changes the velocity of a given mass and thus changes the momentum (magnitude or direction)

- if the net external force acting on a particle or system of particles, then total linear momentum of the system cannot change

TOTAL MOMENTUM IS CONSERVED

$$\vec{P}_{before} = \vec{P}_{after}$$

$$m_i \vec{v}_i = m_f \vec{v}_f$$

Impulse

p211 → good stuff

start with $\vec{F}(t) = \frac{d\vec{p}}{dt}$

$$\int_{t_1}^{t_2} d\vec{p} = \int_{t_1}^{t_2} \vec{F}(t)\,dt$$

$$\vec{J} = \int_{t_1}^{t_2} F(t)\,dt \quad \text{(definition of impulse)}$$

$$\int_{t_1}^{t_2} d\vec{p} \Rightarrow \Delta\vec{p} = \vec{p}_f - \vec{p}_i$$

$$= m\vec{v}_f - m\vec{v}_i$$

$$\vec{J} = \Delta\vec{p} = m\vec{v}_f - m\vec{v}_i$$

$$J_x = \Delta p_x \quad \text{and} \quad J_y = \Delta p_y$$

☆ end of page

- if we don't know how the force varies in time...

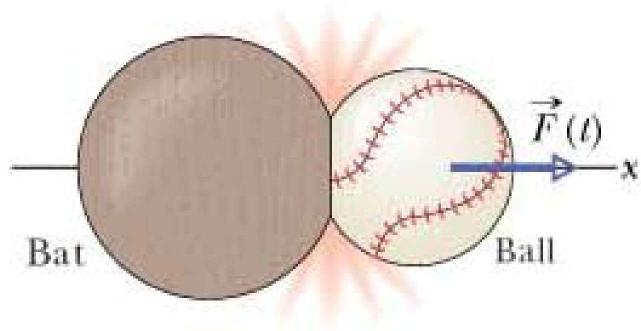
$$J = F_{avg} \Delta t \qquad N \cdot s$$

magnitudes!

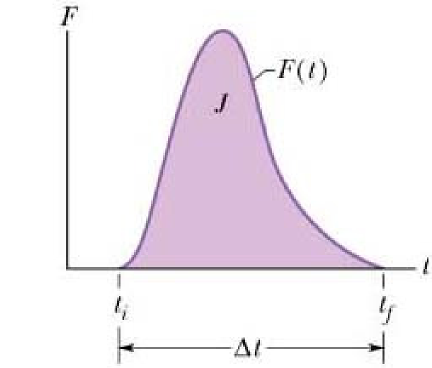
- CHECK POINT 4 see book (p 212)

- $J = \Delta p \Rightarrow J = F_{avg} \Delta t \Rightarrow$ ☆ $\boxed{\Delta p = F_{avg} \Delta t}$ ☆

☆ end of page



$$J = F_{avg} \Delta t$$

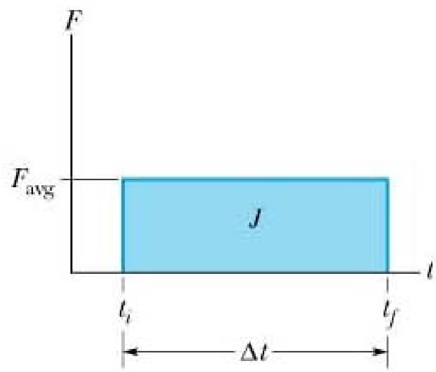


(a)

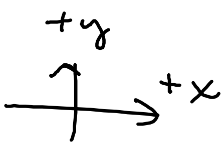
the integral

$$\int_{t_i}^{t_f} F(t)\,dt$$

yield J (or Δp)

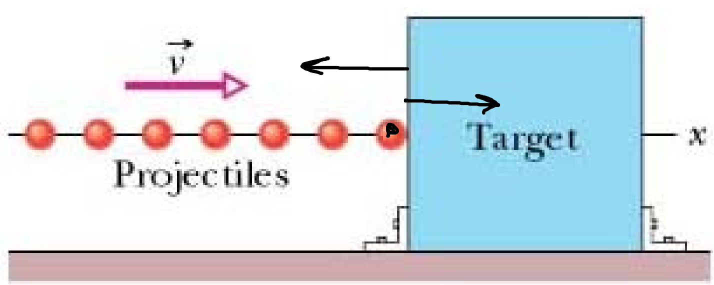


(b)

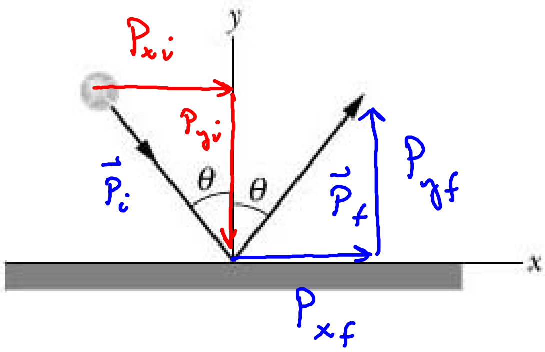


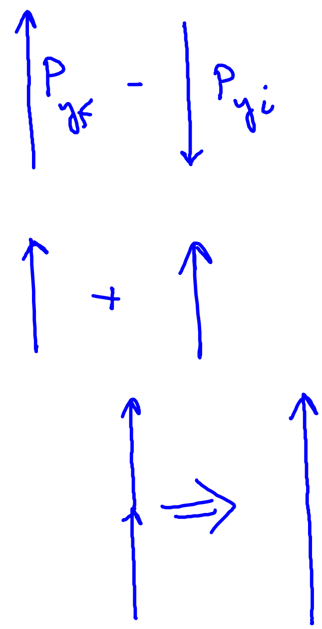
$$\vec{J} = \Delta\vec{p} = \vec{p}_f - \vec{p}_i$$

$$= m\vec{v}_f - m\vec{v}_i$$



CHECKPOINT 5





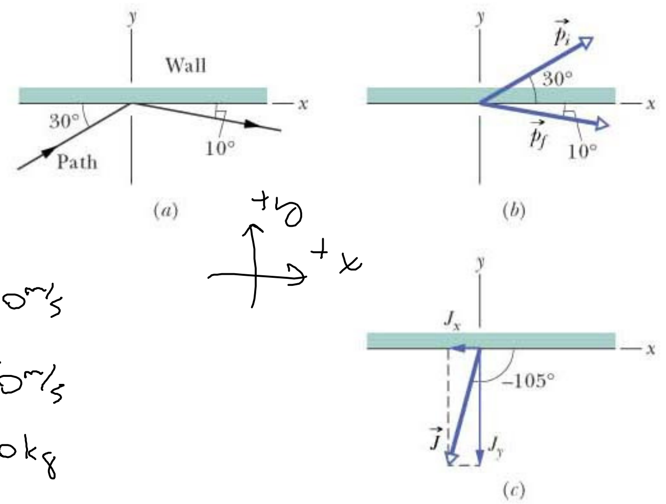
(a) discuss $\Delta P_x = 0$

(b) disuss ΔP_y

(c) what's the direction of Δp?

☆ end of page

What is the impulse on the driver due to the collision?



$v_i = 70\,m/s$

$v_f = 50\,m/s$

$m = 80\,kg$

$\Delta p_x = ?$

$$\Delta p_x = m v_{x_f} - m v_{x_i}$$

$$v_{x_f} = +v_f \cos\theta_f$$

$$v_{x_i} = +v_i \cos\theta_i$$

→ J_x

$\Delta p_y = ?$

$$\Delta p_y = m v_{y_f} - m v_{y_i}$$

$$v_{y_f} = -v_f \sin\theta_f$$

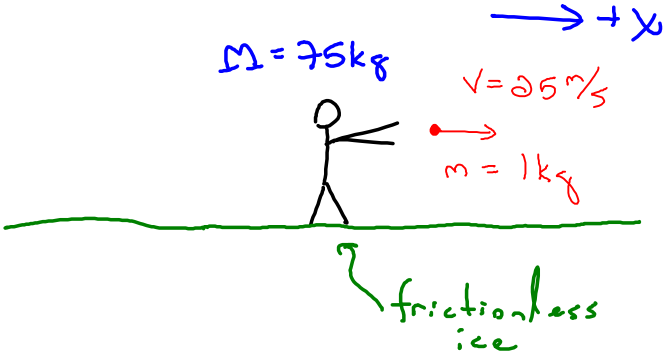
$$v_{y_i} = +v_i \sin\theta_i$$

→ J_y

$$J = \sqrt{J_x^2 + J_y^2}$$

☆ end of page

⇒ The Miser (conservation of momentum)



$$\vec{P}_{before} = 0$$

$$\vec{P}_i = \vec{P}_f$$

$$0 = m_g \vec{V}_g + m_m \vec{V}_m$$

$$0 = (1kg)(+25 m/s) + (75kg)(\vec{V}_m)$$

$$0 = 25 \, kg\,m/s + 75kg \, \vec{V}_m$$

$$-25 \, kg\,m/s = 75 \, kg \, \vec{V}_m$$

$$V_m = -\frac{1}{3} m/s$$

assign hw

★ Homework Assignment ★

HRW Chapter 9 problems: 2, 23, 27, 36, 39, 40

DUE THURSDAY: READ & TAKE NOTES 9-8, 9-9, 9-10

★ end of page