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March 8, 2022 11:19 AM

Unit 3 Momentum

1- Momentum

Any moving object has momentum which depends on:		Where:
1. mass 2. velocity	$\vec{P} = m \cdot \vec{v}$ $kg \cdot (m/s)$	p= momentum m= mass (kg) v= vel (m/s)

- Momentum is a vector quantity, meaning is has both magnitude and direction
- The units are kg m/s but can also be written as N.s

Ex 1: Calculate the momentum of a 6.2 kg pumpkin traveling at a velocity of 5.0 m/s west.

5m/s [W] ← 6.2kg

$p = mv = 6.2(5) = \boxed{31\ kg\,m/s\ [West]}$

Ex 2: A baseball of mass 0.14 kg is moving at 35.0 m/s. a. Find the momentum of the baseball.

$p = mv = 0.14(35) = \boxed{4.9\ kg\,m/s}$

fast

b. Find the velocity at which a bowling ball, mass 7.6 kg, would have the same momentum as the baseball

V=? m= 7.6kg

$p = mv$

$4.9 = 7.6(v)$ $\boxed{v = 0.645\ m/s}$

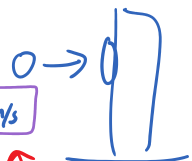
Remember that: Δ delta Change = $\Delta\vec{P} = \vec{P}_f - \vec{P}_i$

Ex 3:

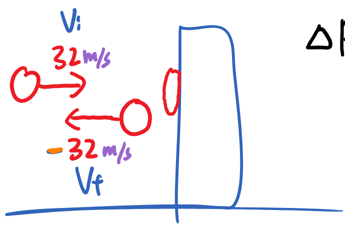
a) A 0.50 kg water balloon is thrown against a wall at 32 m/s (V_i) coming to a stop ($V_f = \emptyset$). What was its change in momentum?

$\Delta P = P_f - P_i = mV_f - mV_i$

$\Delta P = m[V_f - V_i] = 0.50[0 - 32] = \boxed{-16\ kg\,m/s}$



b) A 0.50 kg bouncy ball is thrown at 32 m/s, bouncing back with the same speed. How does its change in momentum compare to that of the water balloon?



$\Delta P = m(V_f - V_i)$

$= 0.5[-32 - 32]$

$= \boxed{-32\ kg\,m/s}$

more

Momentum: Worksheet 1

1. Calculate the momentum of a 4.0 kg object traveling at a velocity of 12.0 m/s east.

2. A 5.0 kg object has a momentum of 25.0 kgm/s west. What is its velocity?

3. An object has a velocity of 8.0 m/s south and a momentum of 36.0 kgm/s south. What is its mass?

4. An object has a velocity of 2.0 m/s east and a momentum of 29 kgm/s. What is the weight of the object?

5. A 6.6 N object is traveling at a velocity of 3.0 m/s north. What is the object's momentum?

6. A 7.0 kg object travels 2.6 m west in 1.1 s. Assuming uniform velocity, what is the momentum of the object?

7. A 5.0 kg object is dropped from a height of 2.5 m above the floor. What is the object's momentum after 0.25 s?

8. A 1.0 kg ball hits the floor with a velocity of 2.0 m/s. If the ball bounces up with a velocity of 1.6 m/s, what is the ball's change in momentum?

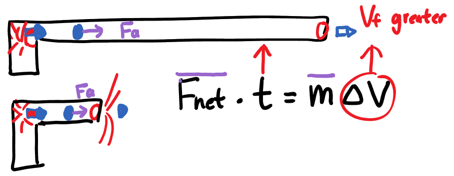
9. A 0.144 kg baseball is pitched horizontally at + 38 m/s. The batter hits a horizontal line drive at – 38 m/s (the opposite direction!). What is the ball's change in momentum?

10. The 1205 kg physics dragster is traveling at 35 km/h east when it hits the gas and accelerates at 12.5 m/s^2 for 3.25 s. What is its change in momentum during this time?

1) 48 kgm/s E 2) 5.0 m/s W 3) 4.5 kg 4) 140 N 5) 2.0 kgm/s 6) 17 kgm/s 7) -12 kgm/s 8) 3.6 kgm/s 9) -11 kg m/s 10) 49 000 kgm/s

$$\frac{dp}{dt} = \frac{\Delta p}{\Delta t} = \frac{m\Delta v}{\Delta t} = ma$$

Fnet



$F_{net} \cdot t = m\Delta V$

Unit 4 Momentum
2 - Impulse

Impulse: Change in momentum ΔP

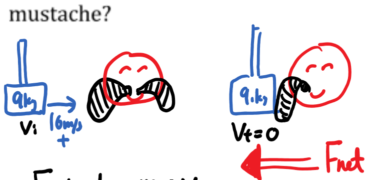
We can derive the change in momentum from newton's 2nd Law:

$$\frac{m\Delta V}{t} = F_{net}$$

Not on formula sheet.

$$\text{Impulse} \quad \Delta P = \boxed{F_{net} \cdot t = m\Delta V}$$

Ex: Luigi is sick of taking orders. He swings a 9.0 kg hammer at 16 m/s when Mario's mustache brings it to a stop in 0.25 s. What is the net force exerted on Mario's mustache?

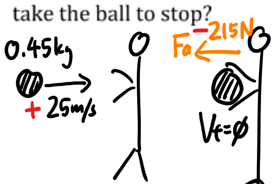


$F_{net} \cdot t = m\Delta V$

$F \cdot 0.25 = 9kg\,[0-16]$

$\boxed{F = -576\ N}$

Ex. A soccer player kicks a 0.450 kg ball at 25.0 m/s east. If the goalie stops the ball by exert 215 N of force, how long does it take the ball to stop?

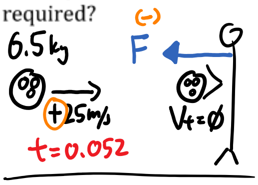


$F_{net} \cdot t = m\Delta V$

$(-215)(t) = 0.45\,(0-25)$

$\boxed{t = 0.052 \text{ sec}}$

If the goalie stops the 6.5 kg bowling ball traveling at the same velocity in the same amount of time, how much force is required?



$F_{net} \cdot t = m\Delta V$

$F \cdot 0.052 = 6.5(0-25)$

$\boxed{F = -3106\ N}$

3125

3100 ish

Example: Impulse in 2D

A 1250 kg car traveling east at 25 m/s turns due north and continues on at 15 m/s. What was the impulse of the car exerted while turning the corner?

$F_{net} \cdot t$

15, 1250 × 15

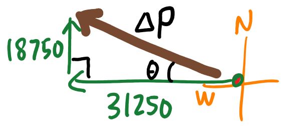
$P_f = mV_f = 18750\ kg\,m/s\ [N]$

1250 × 25

$P_i = mV_i = 31250\ kg\,m/s\ [E]$

$\text{Impulse} = \Delta P = P_f - P_i$

	x	y
P_f	∅	18750
(−)	(−)	(−)
P_i	31250	∅
ΔP	−31250	18750



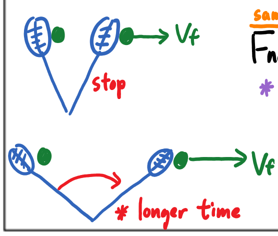
$\Delta P = \sqrt{18750^2 + 31250^2}$

$\tan\theta = \frac{18750}{31250}$

$\boxed{\Delta P = 36443\ kg\,m/s \quad \theta = 31°\ [N \text{ of } W]}$

59° [W of N]

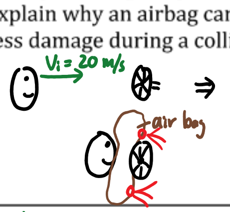
Example: Coaches for many sports such as baseball, tennis and golf can often be heard telling their athletes to "follow through" with their swing. How does this help a weaker player hit a ball farther than a stronger player?



$\underset{\text{same}}{F_{net}} \cdot \uparrow t = \underset{\text{same}}{m}\,\uparrow\Delta V$

* more time in contact means greater ΔV → faster Vf !!

Example: Using the principle of impulse, explain why an airbag can help people sustain less damage during a collision.



t (short)

F (Big)

$F_{net} \cdot \uparrow t = \downarrow m\Delta V$

* Longer time to stop → more time to slow down → less force required.

WS # 2 $\Delta P = F_{net} \cdot t = m[V_f - V_i]$

Momentum: Worksheet 2 - Impulse

1. A rocket at rest with a mass of 9.5 x 10^3 kg is acted on by an average net force of 1.5 x 10^5 N upwards for 15 s. What is the final velocity of the rocket?

2. A 26.3 kg object is traveling at 21.0 m/s north. What average net force is required to bring this object to a stop in 2.60 s?

$\Delta P = F_{net} \cdot t = m \Delta V$

$V_f = 0$ F

$t = 2.6$ sec

21 m/s $= V_i$ (+)

$F(2.6) = (26.3)(0-21)$

$F = -212$ N

$\boxed{F = 212\text{N [S]}}$

3. An average force of 31.6 N south is used to accelerate a 15.0 kg object uniformly from rest to 10.0 m/s. What is the change in momentum?

4. An average net force of 25.0 N acts north on an object for 7.20 x 10^{-1} s. What is the change in momentum of the object?

5. A 5.00 kg object accelerates uniformly from rest to a velocity of 15.0 m/s east. What is the change in momentum on the object?

$p = mv$ $\Delta P = F_{net} \cdot t = m \Delta V$

WS # 1 and 2

6. An average net force caused an 11.0 kg object to accelerate uniformly from rest ($V_i = \emptyset$). If this object travels 26.3 m west in 3.20 s, what is the change in momentum of the object?

$d = 26.3$, $t = 3.2$, $V_i = \emptyset$, $a = ?$

$d = \cancel{V_i t} + \frac{1}{2}at^2$

$-26.3 = \frac{1}{2}a(3.2)^2$

$a = -5.14$ m/s²

$F_{net} = ma$

$F_{net} = 11(5.14)$

$F_{net} = -56.5$ N

$\Delta P = F_{net} \cdot t$

$= 56.5(3.2)$

$\Delta P = 181$ kgm/s [West]

7. A 1.30 kg object is dropped from a height of 6.5 m. How far did the object fall when its momentum is 6.0 kgm/s?

~~6.5m~~ $d = ?$ $P = 6$ kgm/s

$P_f = mV_f$

$6 = 1.3(V_f)$

$V_f = 4.62$ m/s

$V_i = \emptyset$, $V_f = -4.62$ m/s, $a = -9.8$ m/s², $d = ?$

$V_f^2 = \cancel{V_i^2} + 2ad$

$(4.62)^2 = 2(-9.8)d$

$\boxed{d = -1.09\text{ m}}$

$\boxed{\text{drop } 1.09\text{ m}}$

8. An average net force of 16.0 N acts on an object for 2.00 x 10^{-1} s causing it to accelerate from rest to 3.50 m/s. What is the mass of the object?

9. A 0.500 kg object is thrown vertically upward with an average applied force of 8.20 N by a student. The force is applied through a displacement of 1.50 m.

a. What is the average net force acting on the object?

$F_a = 8.2$N

$F_g = mg = 4.9$N (0.5)

$F_{net} = F_a - F_g = 3.3$N

$8.2 - 4.9$

b. What is the velocity of the object when it leaves the student's hand? (Assume initial velocity is zero)

$V_i = \emptyset$, $V_f = ?$, $a = 6.6$, $d = 1.5$m

$F_{net} = ma$ $3.3 = 0.5(a)$ $a = 6.6$

$V_f^2 = \cancel{V_i^2} + 2ad$

$V_f^2 = 2(6.6)(1.5)$

$\boxed{V_f = 4.45\text{ m/s}}$

1) 240 m/s 2) 212 N South 3) 150 kgm/s 4) 18 Ns 5) 75 kgm/s 6) 180. kgm/s 7) 1.1 m 8) 0.914 kg 9)a. 3.30 N b. 4.45 m/s

$P_1 = 100$ → ← $P_2 = -70$ ⇒ ← $P_1 =$, $P_2 = 80$ →

$P_{total} =$ b4 $P_{total} =$ after

Unit 3 Momentum

3 -The Law of Conservation of momentum

Recall Newton's 3rd Law:

For every action there is an equal and opposite reaction force

Two colliding objects experience equal and opposite forces for the same amount of time, hence their impulses…….. same

$$\Delta p = F_{net}t$$

…… must be equal and opposite.

Ex: A cue ball is traveling with a momentum of 5 kgm/s east and strikes the 8 ball. If the cue ball comes to a stop what is the change in momentum on the cue ball? How about on the 8 ball?

Before: $P_1 = 5\ kgm/s$, $P_2 = \emptyset$ (mv)

After: $P_{1f} = \emptyset$, $P_{2f} = ?$

cue $\Delta P_1 = P_f - P_i = \emptyset - 5 = -5\ kgm/s$

⑧ $\Delta P_2 = +5\ kgm/s$ ← P_{2f}

Ex. A clown is stuck on a sheet of frictionless ice. He hurls one of his clown shoes with momentum of 80 kgm/s east. What is his momentum before and after he throws his shoe?

Before: $P_1 = \emptyset$, $P_2 = \emptyset$, $P_T = \emptyset$

After: $P_{1f} = -80$ (Mv), $P_{2f} = 80\ kgm/s$ (mV), $P_T = \emptyset$

Ex: A fullback is traveling to the right with a momentum of 120 kgm/s while a linebacker is traveling to the left with a momentum of 110 kgm/s. If they stick together, what is their total momentum before and after they collide?

$P_1 = 120\ kgm/s$ →, $P_2 = -110\ kgm/s$ ←

$P_T = 10\ kgm/s$

$P_{Tf} = 10\ kgm/s$ →

The Law of Conservation of Momentum

In an isolated system, momentum is not created or destroyed during any interaction. "Collision"

An isolated system means…….. not Net Force !!

sum of = total.

$$\boxed{\Sigma P_i = \Sigma P_f}$$

* For 2 objs collisions in 1D only.

$$m_1V_1 + m_2V_2 = m_1V_{1f} + m_2V_{2f}$$

Add to formula sheet.

B4: m_1 V_1 5kg 2m/s, m_2 V_2 10kg $-3\ m/s$ ⇒ After: V_{1f} $-5\ m/s$ 5kg, 10kg $V_{2f} = 0.5\ m/s$

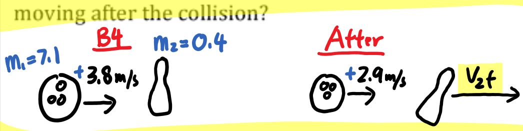
$$\underbrace{+10\ kgm/s \quad -30\ kgm/s}_{-20\ kgm/s} \qquad \underbrace{-25\ kgm/s + \boxed{5\ kgm/s}}_{-20\ kgm/s}$$

1) Collisions (separate after)

Ex: A 7.1 kg bowling ball is rolling to the right at 3.8 m/s when it collides with a stationary 0.40 kg bowling pin. After the collision, the bowling ball is

Ex: A 0.25 kg cue ball is traveling east at 4.5 m/s when it collides head on with a 0.25 kg eight ball traveling west at 5.0 m/s. After the collision the cue ball is

Ex: A 7.1 kg bowling ball is rolling to the right at 3.8 m/s when it collides with a stationary 0.40 kg bowling pin. After the collision, the bowling ball is traveling at 2.9 m/s to the right. How fast is the pin moving after the collision?



$$\Sigma P_i = \Sigma P_f$$

$$m_1V_1 + m_2V_2 = m_1V_{1f} + m_2V_{2f}$$

$$7.1(3.8) + \emptyset = 7.1(2.9) + (0.4\,kg)V_{2f}$$

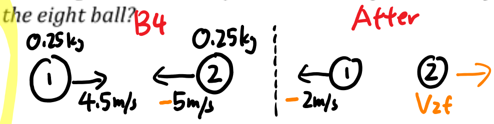
(−)

$$6.39 = 0.4\,V_{2f}$$

$$\boxed{V_{2f} = +16\ m/s}$$

Right

Ex: A 0.25 kg cue ball is traveling east at 4.5 m/s when it collides head on with a 0.25 kg eight ball traveling west at 5.0 m/s. After the collision the cue ball is traveling west at 2.0 m/s. What is the final velocity of the eight ball?



$$\Sigma P_i = \Sigma P_f$$

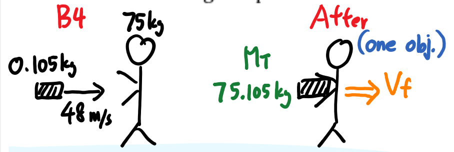
$$\overset{0.25}{\cancel{m_1}}V_1 + \overset{0.25}{\cancel{m_2}}V_2 = \overset{0.25}{\cancel{m_1}}V_{1f} + \overset{0.25}{\cancel{m_2}}V_{2f}$$

$$4.5 + (-5) = (-2) + V_{2f}$$

$$\boxed{V_{2f} = 1.5\ m/s\ [East]}$$

2) Collision (combined after)

Ex: A 0.105-kg hockey puck moving at 48 m/s is caught by a 75-kg goalie at rest. If the ice is frictionless, at what velocity will the goalie slide on the ice after catching the puck?



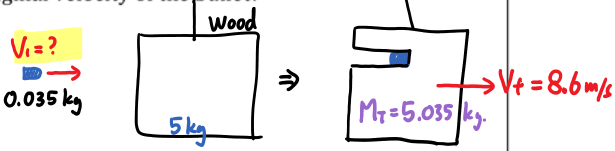
$$m_1V_1 + m_2V_2 = M_T V_f$$

$$0.105(48) + \emptyset = 75.105(V_f)$$

$$\boxed{V_f = 0.067\ m/s}$$

6.7 cm/s

Ex: A 35.0-g bullet strikes a 5.0-kg stationary wooden block and embeds itself in the block. The block and bullet move together at 8.6 m/s. What was the original velocity of the bullet?



$$m_1V_1 + m_2V_2 = M_T V_f$$

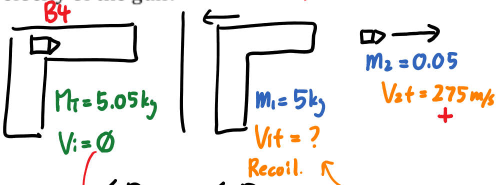
$$0.035\,V_1 + \emptyset = 5.035(8.6)$$

$$\boxed{V_1 = 1237\ m/s}$$

WS #3 Q1-4

3) Explosions

Ex: A 0.050 kg bullet is fired from a 5.0 kg gun. If the velocity of the bullet is 275 m/s, what is the recoil velocity of the gun?



$$\Sigma P_i = \Sigma P_f$$

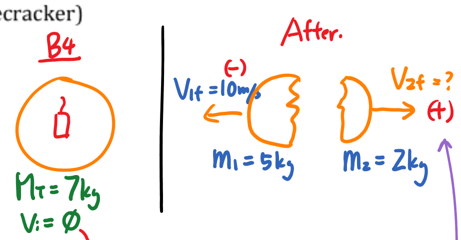
$$M_T V_i = m_1 V_{1f} + m_2 V_{2f}$$

$$\emptyset = 5 V_{1f} + 0.05(275)$$

$$-13.75 = 5 V_{1f}$$

$$\boxed{V_{1f} = -2.75 \text{ m/s}}$$

Ex: A firecracker sits in a 7.0 kg pumpkin. After it explodes, the pumpkin splits into two chunks. A 5.0 kg piece travels west at 10.0 m/s. What is the mass and velocity of the other piece? (Ignore the mass of the firecracker)



$$M_T V_i = m_1 V_{1f} + m_2 V_{2f}$$

$$\emptyset = 5(-10) + 2 V_{2f}$$

$$V_{2f} = \boxed{+25 \text{ m/s}}$$

1-4 5-8

WS #3 Q 1-8

Worksheet 3 Collisions

1) A 30.0 kg object moving to the right at a velocity of 1.00 m/s collides with a 20.0 kg object moving to the left with a velocity of 5.00 m/s. If the 20.0 kg object continues to move to the left at a velocity of 1.25 m/s, what is the velocity of the 30.0 kg object?

2) A 4.50 x 10^3 kg railway car is moving east at a velocity of 5.0 m/s on a level frictionless track when it collides with a stationary 6.50 x 10^3 kg caboose. If the two cars lock together upon impact, how fast are they moving after collision?

3) A 925 kg car moving at a velocity of 18.0 m/s right collides with a stationary truck of unknown mass. The two vehicles lock together and move off at a velocity of 6.50 m/s. What is the mass of the truck?

4) A 50.0 g bullet strikes a 7.00 kg wooden block. If the bullet becomes imbedded in the block and they both move off at a velocity of 5.00 m/s, what was the initial speed of the bullet?

5. A 40.0 g hot dog moving with a velocity of 9.00 m/s to the right collides with a 55.0 g hot dog bun with a velocity of 6.00 m/s to the left. If the two objects stick together upon collision, what is the velocity of the combined masses?

0.04 kg → V_1 9 m/s   0.055 kg ← V_2 −6 m/s   ⇒   M = 0.095 kg V_f

$$\Sigma P_i = \Sigma P_f$$

$$m_1 V_1 + m_2 V_2 = M_T V_f$$

$$0.04(9) + (0.055)(-6) = 0.095\, V_f$$

$$0.03 = 0.095\, V_f$$

$$V_f = \boxed{0.316 \text{ m/s Right.}}$$

6. A 76 kg student, standing at rest on a frictionless surface throws a 0.20 kg cream pie horizontally at 22 m/s at Mr. Trask who is standing to the student's left. What was the velocity of the student after they throw the pie?

7. A 25 kg turkey is fired from a 1.1 *x* 10^3 kg turkey launcher. If the horizontal velocity of the turkey is 325 m/s east, what is the recoil of the launcher?

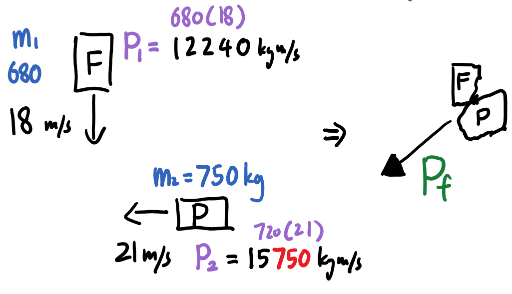
8. A rail vehicle with a rocket engine is being tested on a smooth track. Starting from rest the engine is fired for a short period of time, releasing 4.5 *x* 10^2 kg of gases. It is estimated that the average velocity of the gases is 1.4 *x* 10^3 m/s to the right, and that the maximum velocity of the vehicle is 45 m/s left. What is the mass of the vehicle?

1) 1.50 m/s left or -1.50 m/s 2) 2.0 m/s east 3) 1640 kg 4) 705 m/s 5) 0.316 m/s right 6) 0.058 m/s right 7) 7.4 m/s west 8) 14000 kg

Unit 3 Momentum
4 – Collisions in 2-D

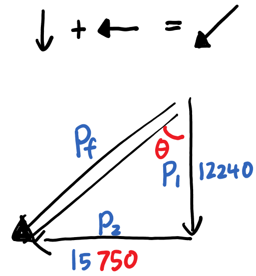
When dealing with collisions in 2-dimensions it is important to remember that momentum is a vector with magnitude and direction. When finding the **total momentum** we have to do:

(2D) **Collisions at 90°:**
A 750 kg Peugeot travelling at 21 m/s West collides with a 680 kg Fiat travelling at 18 m/s South. If the two cars become entwined what is their total final velocity?



$\Sigma P_i = \Sigma P_f$

$\vec{P}_1 + \vec{P}_2 = \vec{P}_f$



$P_f^2 = 12240^2 + 15750^2$

$P_f = 19947$ kg m/s $= M_T V$ ← 750 + 680

$\boxed{V_f = 14 \text{ m/s}}$

$\theta = \tan^{-1}\left(\frac{15750}{12240}\right)$

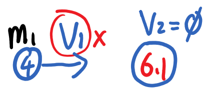
$\boxed{\theta = 52° \text{ [W of S]}}$

Remember that it is momentum that is conserved, so we need to add the momenta NOT Velocities

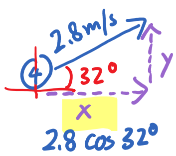
Collisions not at 90° (because life is never that easy...):

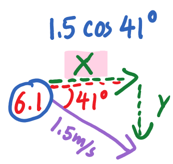
Example 1) A 4.0 kg bowling ball is moving east at an unknown velocity when it collides with a 6.1 kg frozen cantaloupe at rest. After the collision, the bowling ball is traveling at a velocity of 2.8 m/s 32° [N of E] and the cantaloupe is traveling at a velocity of 1.5 m/s 41° [S of E]. What was the initial velocity of the bowling ball?

Before



After





Component Method

1. We need to break the final momenta of the two objects into x and y components:
2. We then add the **individual x** and the **individual y** components to find our total momentum.
3. Don't forget to solve for the initial velocity (magnitude and direction):

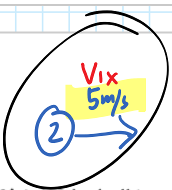
$$\Sigma P_{ix} = \Sigma P_{fx}$$

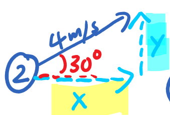
$$m_1 (V_{ix}) = m_1 V_{1fx} + m_2 V_{2fx}$$

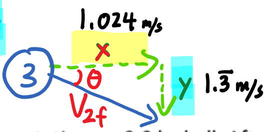
$$4\text{kg}(V_i) = 4\text{kg}(2.8 \cos 32) + 6.1\text{kg}(1.5 \cos 41°)$$

$$\boxed{V_{ix} = 4.1 \text{ m/s}}$$

Notice that the total momentum is all in the X-direction! This should be no surprise since the bowling ball was initially only moving in the x direction.







Example 2) A 2.0 kg ball is moving at a velocity of 5.0 m/s to the East. It collides with a stationary 3.0 kg ball. After the collision, the 2.0 kg ball moves at a velocity of 4.0 m/s 30° North of East. What is the velocity of the 3.0 kg ball?

Before $\Sigma P_{ix} = \Sigma P_{fx}$

After $\Sigma P_{iy} = \Sigma P_{fy}$

Example 2) A 2.0 kg ball is moving at a velocity of 5.0 m/s to the East. It collides with a stationary 3.0 kg ball. After the collision, the 2.0 kg ball moves at a velocity of 4.0 m/s 30° North of East. What is the velocity of the 3.0 kg ball?

Before

$$\Sigma P_{ix} = \Sigma P_{fx}$$

$$\overset{2}{m_1}(5\,m/s) = \overset{2}{m_1}(4\cos 30^\circ) + \overset{3}{m_2} V_x$$

$$V_x = 1.024\ m/s$$

After

$$\Sigma P_{iy} = \Sigma P_{fy}$$

$$\varnothing = \overset{2}{m_1}(4\sin 30^\circ) + \overset{3}{m_2} V_y$$

$$V_y = -1.\overline{3}\ m/s$$

$$V_{2f}^2 = V_x^2 + V_y^2 \qquad \theta = \tan^{-1}\left(\frac{1.\overline{3}}{1.024}\right) = 52.5^\circ\ [S\ of\ E]$$

$$V_{2f} = 1.68\ m/s$$

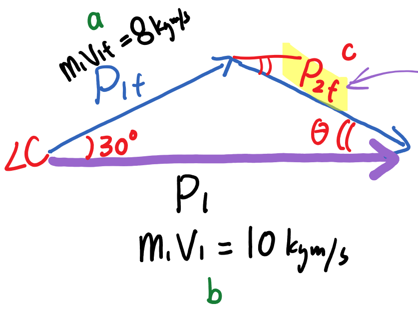
Vector Addition Method:

Simply add the vectors and solve with the sine or cosine law. Notice that the total momentum is either the initial or the final because momentum is conserved.

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

$$\overrightarrow{P_i} = \overrightarrow{P_{1f}} + \overrightarrow{P_{2f}}$$

$$c^2 = a^2 + b^2 - 2ab\cos(\angle C)$$



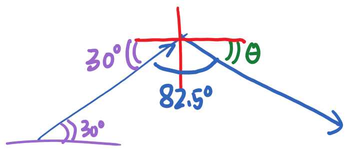
$$P_{2f}^2 = 8^2 + 10^2 - 2(8)(10)\cos(30^\circ)$$

$$P_{2f} = 5.043\ kg\,m/s = \overset{3kg}{m_2} V_{2f}$$

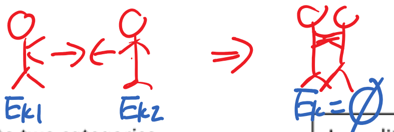
$$V_{2f} = 1.68\ m/s$$

$$\frac{\sin\angle B}{b} = \frac{\sin\angle C}{c}$$

$$\frac{\sin\angle B}{10} = \frac{\sin 30^\circ}{5.043} \qquad \angle B = 82.5^\circ$$



$$\theta = 180 - 30 - 82.5 = 67.5^\circ\ [S\ of\ E]$$



Collisions can be grouped into two categories,

1. Elastic Collisions are those in which Kinetic Energy is Conserved
   $E_{ki} = E_{kf}$

2. Inelastic Collisions are those in which Kinetic Energy is Not Conserved.
   $E_{ki} \neq E_{kf}$

- Totally Inelastic Collisions are those in which the colliding objects **stick together** resulting in the ***greatest loss in Kinetic Energy***

Ⓐ→ ←Ⓑ ⇒ ⒶⒷ

In reality collisions are generally somewhere in between perfectly elastic and perfectly inelastic. As a matter of fact, it is impossible for a **macroscopic** collision to ever be perfectly elastic. Perfectly elastic collisions can only occur at the **atomic** or **subatomic level**.

Why can't macroscopic (large) collision ever be truly elastic?

Some of the initial Ek is lost due to sound / heat / virbation / light .... etc.

	Total Momentum $\sum P_i = \sum P_f$	Kinetic Energy $\sum E_{ki} = \sum E_{kf}$	Total Energy (including Energy loss) $\sum E_T = \sum E_T$
Elastic Collision	Conserved	Conserved	Conserved
Inelastic Collision	Conserved	not conserved.	conserved.

Example 3) A 2.0 kg ball moving to the right at 4.0 m/s collides with a 4.0 kg ball moving to the left at 3.0 m/s. After the collision, the 2.0 kg ball has a velocity of 4.0 m/s to the left.

a) Determine the velocity of the 4.0 kg ball.
b) Is the collision *elastic or inelastic*? If inelastic how much Kinetic energy is lost?

B4: ② 4 m/s → ← −3 m/s ④ ⇒ After: ← −4 m/s ② ④ → 1 m/s. ($V_{2f} = ?$)

$$\sum P_i = \sum P_f$$

$$m_1 V_1 + m_2 V_2 = m_1 V_{1f} + m_2 V_{2f}$$

$$2(4) + 4(-3) = 2(-4) + 4 V_{2f}$$

$\therefore \boxed{V_{2f} = 1 \text{ m/s.}}$

b) Check $E_k = \frac{1}{2} m v^2$

$E_{k_1} = \frac{1}{2}(2)(4)^2$ $\quad E_{k_2} = \frac{1}{2}(4)(3)^2$

16 J $\quad$ 18 J

$\sum E_{ki} = 34$ J

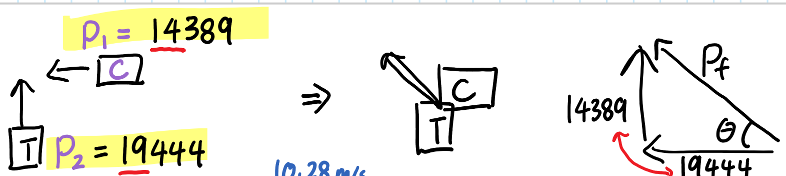
$E_{k1f} = \frac{1}{2}(2)(4)^2$ $\quad E_{k2f} = \frac{1}{2}(4)(1)^2$

16 J $\quad$ 2 J

Lost Energy → $\sum E_{kf} = 18$ J

not same

$\therefore$ Inelastic Collision!!



Worksheet 4

1. A 1.4 × 10³ kg car is westbound at a velocity of 37.0 km/h (10.28 m/s) when it collides with a 2.0 × 10³ kg truck northbound at a velocity of 35 km/h. If these two vehicles lock together upon collision, what is the initial velocity of the vehicles after collision? 9.72 m/s

$P_f^2 = 14389^2 + 19444^2$ $\quad \therefore \boxed{V_f = 7.1 \text{ m/s}}$ $\boxed{\theta = 54° \text{ N of W}}$

Worksheet 4

10.28 m/s   19444

1. A 1.4×10^3 kg car is westbound at a velocity of 37.0 km/h when it collides with a 2.0×10^3 kg truck northbound at a velocity of 35 km/h. If these two vehicles lock together upon collision, what is the initial velocity of the vehicles after collision? 9.72 m/s

$P_1 = m_1 V_1$

$P_2 = m_2 V_2$

$P_f^2 = 14389^2 + 19444^2$

$P_f = 24189 = M_T V_f$ $(1400+2000)$

$\therefore \boxed{V_f = 7.1 \text{ m/s}}$ $\boxed{\theta = 54° \text{ N of W}}$

$\theta = \tan^{-1}\left(\frac{14389}{19444}\right)$

(7.2 m/s 37° W of N)

2. A 6.2 kg object heading north at 3.0 m/s collides with an 8.0 kg object heading west at 3.5 m/s. If these two masses stick together upon collision, what is their velocity after collision?

(2.4 m/s 56° W of N)

3. A 4.0×10^4 N Truck moving west at a velocity of 8.0 m/s collides with a 3.0×10^4 N truck heading south at a velocity of 5.0 m/s. If these two vehicles lock together upon impact, what is their velocity?

(5.0 m/s 25° S of W)

4. A 50.0 kg object is moving east at an unknown velocity when it collides with a 60.0 kg stationary object. After collision, the 50.0 kg object is traveling at a velocity of 6.0 m/s 50.0° N of E and the 60.0 kg object is traveling at a velocity of 6.3 m/s 38° S of E.
   a. What was the velocity of the 50.0 kg object before collision?

   (9.86 m/s due east)

   b. Determine whether this collision was elastic or inelastic.

   (Ek loss of 340 J, so inelastic)

5. A 15.0 kg penguin waddling east at a velocity of 7.0 m/s collides with a stationary 10.0 kg penguin. After the collision the 15.0 kg penguin is traveling at a velocity of 4.2 m/s 20.0° S of E.
   a. What is the velocity of the 10.0 kg penguin after collision?

   (5.1 m/s 25° N of E)

   b. is this collision elastic or inelastic?

   (Inelastic, E_k loss of 110J)

6. A watermelon explodes into three equal masses. One mass moves east at 15.0 m/s. If a second mass moves at a velocity of 10.0 m/s 45.0° S of E, what is the velocity of the third mass? (Hint: the total momentum is zero, so how will your vector arrows add up?)