Unit 6: Momentum

The Law of Conservation of Momentum

Recall Newton's 3 rd Law:

For every action force there is an equal and opposite reaction force.

Two colliding objects experience equal and opposite forces for the Same amount of time, then their impulses…

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

…must be equal and opposite.

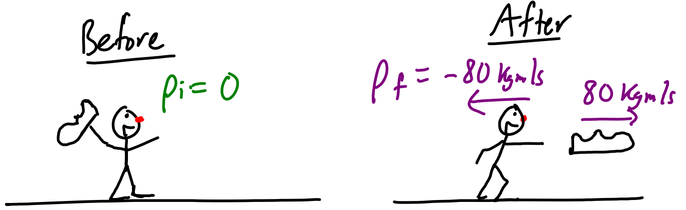
Ex: A cue ball is traveling with a momentumof 5 kgm/s east and strikes the 8 ball. If the cue ball comes to a stop what is the change in momentum on the cue ball? How about on the 8 ball?

$\Delta p_{cue} = p_f - p_i = 0 - 5\text{ kgm/s}$
$= -5\text{ kgm/s}$

$\Delta p_8 = p_f - p_i = 5\text{ kgm/s} - 0$
$= 5\text{ kgm/s}$

Equal + opposite

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?



$p_i = 0$ (not moving)

$p_f = 80\text{ kgm/s} + (-80\text{ kgm/s})$
$= 0$

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?

$p_i = p_1 + p_2 = 120\text{ kgm/s} + (-110\text{ kgm/s})$
$= 10\text{ kgm/s}$

$p_f = 10\text{ kgm/s}$ SAME

The Law of Conservation of Momentum:

In an isolated system, momentum is not created or destroyed during any interaction (collision).

An isolated system means… no external forces act on the system.

$$\boxed{p_i = p_f}$$

$$\boxed{m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}}$$

1) Elastic Collisions:

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?

$V_{1i} = 3.8\,m/s$ $\quad V_{2i} = 0$ $\quad V_{1f} = 2.9\,m/s$ $\quad V_{2f} = ?$

$$m_1 V_{1i} + \overset{0}{\cancel{m_2 V_{2i}}} = m_1 V_{1f} + m_2 V_{2f}$$

$$m_1 V_{1i} = m_1 V_{1f} + m_2 V_{2f}$$

$$V_{2f} = \frac{m_1 V_{1i} - m_1 V_{1f}}{m_2} = \frac{(7.1\,kg)(3.8\,m/s) - (7.1\,kg)(2.9\,m/s)}{0.40\,kg}$$

$$= \boxed{16\,m/s}$$

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?

$V_{1i} = 4.5\,m/s$ $\quad V_{2i} = -5.0\,m/s$ $\quad V_{1f} = -2.0\,m/s$ $\quad V_{2f} = ?$

negative

$$m_1 V_{1i} + m_2 V_{2i} = m_1 V_{1f} + m_2 V_{2f}$$

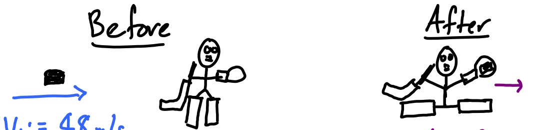
$$V_{2f} = \frac{m_1 V_{1i} + m_2 V_{2i} - m_1 V_{1f}}{m_2}$$

$$= \frac{(0.25\,kg)(4.5\,m/s) + (0.25\,kg)(-5.0\,m/s) - (0.25\,kg)(-2.0\,m/s)}{0.25\,kg}$$

$$= \boxed{1.5\,m/s} \text{ or } \boxed{1.5\,m/s\ (East)}$$

2) Inelastic Collisions:

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?



$V_{1i} = 48\,m/s$ $\quad V_{2i} = 0$ $\quad V_f = ?$

$$m_1 V_{1i} + \overset{0}{\cancel{m_2 V_{2i}}} = m_+ V_f$$ ← consider them as one object.

$$m_1 V_{1i} = m_+ V_f$$

$$V_f = \frac{m_1 V_{1i}}{m_+} = \frac{(0.105\,kg)(48\,m/s)}{(75.105\,kg)}$$

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

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?

$V_{1i} = ?$ $\quad V_{2i} = 0$ $\quad V_f = 8.6\,m/s$

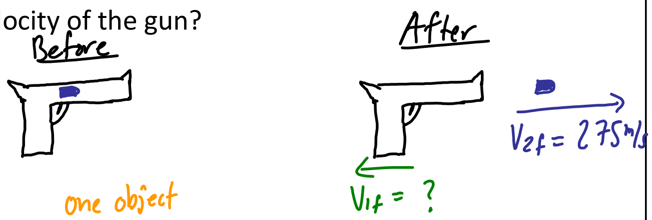
$$m_1 V_{1i} + \overset{0}{\cancel{m_2 V_{2i}}} = m_+ V_f$$

$$V_{1i} = \frac{m_+ V_f}{m_1} = \frac{(5.035\,kg)(8.6\,m/s)}{0.035\,kg}$$

$$= \boxed{1200\,m/s}$$

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?



one object

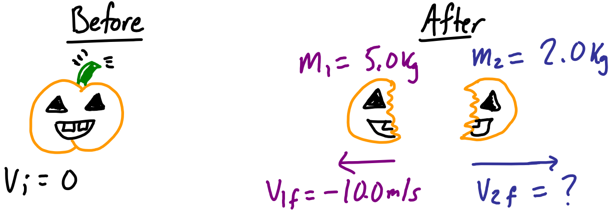
$$m_T V_i = m_1 V_{1f} + m_2 V_{2f}$$

$$0 = m_1 V_{1f} + m_2 V_{2f}$$

$$V_{1f} = -\frac{m_2 V_{2f}}{m_1} = -\frac{(0.050\,kg)(275\,m/s)}{5.0\,kg}$$

$$= \boxed{-2.8\ m/s}$$

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)



$$\overset{0}{\cancel{m_T V_i}} = m_1 V_{1f} + m_2 V_{2f}$$

$$0 = m_1 V_{1f} + m_2 V_{2f}$$

$$V_{2f} = -\frac{m_1 V_{1f}}{m_2} = \frac{-(5.0\,kg)(-10.0\,m/s)}{2.0\,kg}$$

$$= \boxed{25\ m/s}$$

Worksheet 6.3 - 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 4.50×10^3 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 6.50×10^3 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?

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