The Law of Conservation of Momentum

ll 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?

Before

$p_i = 5 \frac{kgm}{s}$ $v_i = 0$ so $p_i = 0$

After

$v_f = 0$ so $p_f = 0$ $p_f = 5 \frac{kgm}{s}$

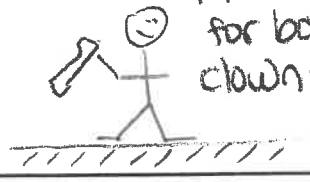
$\Delta p_{cue} = p_f - p_i$
$= 0 - 5 \frac{kgm}{s}$
$= -5 \frac{kgm}{s}$

$\Delta p_{8ball} = p_f - p_i$
$= 5 \frac{kgm}{s} - 0$
$= 5 \frac{kgm}{s}$

equal and 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?

B



$p_i = 0$ for both clown + shoe

A

$p_f = -80 \frac{kgm}{s}$ $p_f = 80 \frac{kgm}{s}$

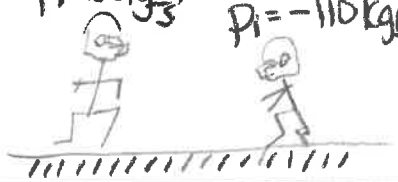
$\Delta p_{clown} = p_f - p_i$
$= -80 \frac{kgm}{s} - 0$
$= -80 \frac{kgm}{s}$

$\Delta p_{shoe} = p_f - p_i$
$= 80 \frac{kgm}{s}$

equal and opposite

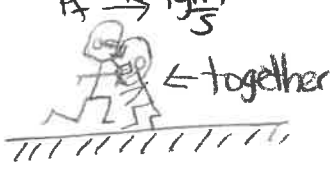
Ex: A fullback is traveling to the right with a momentum of 120 kgm/s while a linebacker is traveling to the left with a momentum of 110 kgm/s. If they stick together, what is their total momentum before and after they collide?

B



$p_i = 120 \frac{kgm}{s}$ $p_i = -110 \frac{kgm}{s}$

A



$p_f = 10 \frac{kgm}{s}$ ← together

$p_{iT} = p_{1i} + p_{2i}$
$= 120 \frac{kgm}{s} + -110 \frac{kgm}{s}$
$= +10 \frac{kgm}{s}$

$p_{fT} = p_{1f} + p_{2f}$
$= +10 \frac{kgm}{s}$

notice total momentum is the same

The Law of Conservation of Momentum:

In an isolated system, momentum is neither created nor destroyed during an interaction (collision).

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

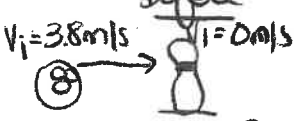
$$p_i = p_f$$

$$m_{1i} v_{1i} + m_{2i} v_{2i} = m_{1f} v_{1f} + m_{2f} v_{2f}$$

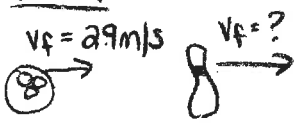
1) Elastic Collisions: E_K is conserved $E_{K_i} = E_{K_f}$

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?

Before



After



$$m_1 v_{1_i} + m_2 \cancel{v_{2_i}}^{0} = m_1 v_{1_f} + m_2 v_{2_f}$$

$$m_1 v_{1_i} - m_1 v_{1_f} = m_2 v_{2_f}$$

$$v_{2_f} = \frac{m_1 v_{1_i} - m_1 v_{1_f}}{m_2}$$

$$= \frac{(7.1\,kg \cdot 3.8 m/s) - (7.1\,kg \cdot 2.9 m/s)}{0.4\,kg}$$

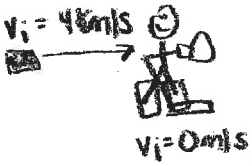
$$= 15.98 = \boxed{16\ m/s}$$

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?

2) Inelastic Collisions: E_K is not conserved $E_{K_i} \neq E_{K_f}$

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?

Before



After

$$m_1 v_{1_i} + m_2 \cancel{v_{2_i}}^{0} = m_t v_f \quad \leftarrow \text{consider as one object}$$

$$m_1 v_{1_i} = m_t v_f$$

$$v_f = \frac{m_1 v_{1_i}}{m_t}$$

$$= \frac{(0.105\,kg)(48 m/s)}{(75.105\,kg)}$$

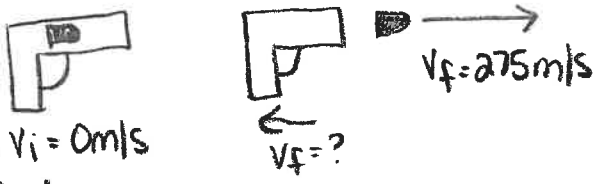
$$\boxed{v_f = 0.067\ m/s}$$

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?

3) Explosions – single object (or +) break away

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?

Before / After



One object

$m_T v_i = m_1 v_{1f} + m_a v_{af}$

$0 = m_1 v_{1f} + m_a v_{af}$

$v_{1f} = \frac{-m_a v_{af}}{m_1} = \frac{-(0.050\text{ kg})(275\text{ m/s})}{5.0\text{ kg}}$

$v_{1f} = -2.8$ 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)

Assign students to go back + finish rest of examples

1b- 1.5 m/s [E]

2b- 1200 m/s [straight]

3b- 25 m/s [E]