principle #4

Conservation of Linear Motion

- **Law of Conservation of Momentum**: In an isolated system, the *total* momentum of all objects (ie. system) before an interaction is *equal* to the *total* momentum of all objects (ie. system) after the interaction
  - $p_{total,before} = p_{total,after}$ or $\sum p = \sum p'$ ← means "the sum of"
  - important * An **isolated system** is defined when no net external forces act on the object or a collection of objects (ie. system) ← ie. friction

- * The conservation of momentum can be used in situations that involve a *collision or explosion* of some type. This can include situations when objects collide and bounce off each other or when objects collide and stick together.

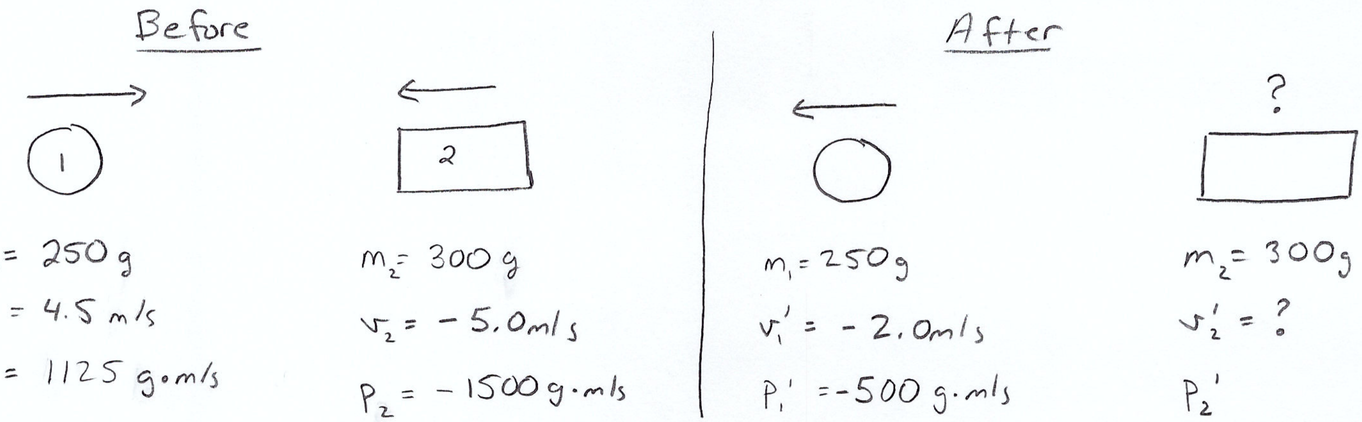
- Steps for solving collision/explosion problems in an isolated system using the conservation of momentum
  1. Draw momentum vector diagrams for each object before and after the collision
  2. Determine the momentum of each object where possible (this may include using variables is information is missing)
     - Using $p = mv$
     - Label the direction of each momentum vector using + or –
  3. Add up the momentum of *all objects* ***before*** the collision/explosion and set it **equal** to the sum of the momentum of *all objects* ***after*** the collision/explosion. This is the law of conservation of momentum.
  4. Solve for the unknown

- * Recall Newton's laws of motion and how they can apply to collision/explosion questions
  - Newton's 3rd Law: For every action, there is an opposite and equal reaction. (for theory questions!)
  - For example, during a collision between a large truck and a small compact car, both vehicles will experience the same force during the collision.

EXAMPLES:

1. A 250g toy car travelling east at 4.5m/s collides head on with a 300g toy truck traveling west at 5.0m/s. After the collision the 250g toy car is travelling west at 2.0m/s. What is the velocity of the 300 toy truck after the collision?

↳ vector



Before

$m_1 = 250\,g$

$v_1 = 4.5\,m/s$

$P_1 = 1125\,g\cdot m/s$

$m_2 = 300\,g$

$v_2 = -5.0\,m/s$

$P_2 = -1500\,g\cdot m/s$

After

$m_1 = 250\,g$

$v_1' = -2.0\,m/s$

$P_1' = -500\,g\cdot m/s$

$m_2 = 300\,g$

$v_2' = ?$

P_2'

$$P_{total} = P'_{total}$$

$$1125 + (-1500) = (-500) + P_2'$$

$$-375 = (-500) + P_2'$$

$$+125\,g\cdot m/s = P_2'$$

but $p = mv$

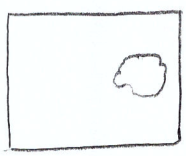
$$\therefore\ v_2' = \frac{P_2'}{m} = \frac{+125\,g\cdot m/s}{300\,g} = +0.41\overline{6}\,m/s$$

$$\boxed{v_2' = 0.42\,m/s,\ \text{east}}$$

2. A satellite starts to drift off course. The path of the satellite is corrected by the engine thrusters expelling some gas. The expulsion of 65kg of gas increases the speed of the satellite by 7.5m/s. If the average exit speed of the gas is 118 m/s, what is the mass of the satellite?

↳ explosion!

Before

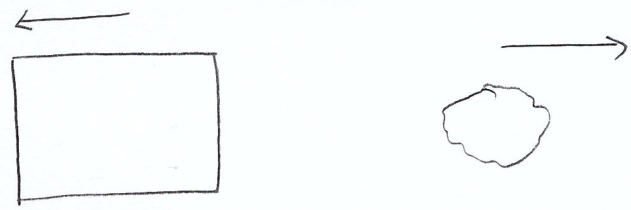


$m = m_1 + 65\text{kg}$

$v =$ assume 0

$p = 0$

After



m_1

$v_1' = 7.5\,\text{m/s}$

$p_1' = m_1(7.5\,\text{m/s})$

$m_2 = 65\,\text{kg}$

$v_2' = -118\,\text{m/s}$

$p_2' = -7670\,\text{kg}\cdot\text{m/s}$

$$\sum p = \sum p'$$

$$0 = m_1(7.5) + (-7670)$$

$$7670 = m_1(7.5)$$

$$1022.\overline{6} = m_1$$

$$\therefore \boxed{m_1 = 1.0 \times 10^3\ \text{kg}}$$

3. A 1.1×10^3kg car travelling east at a velocity of 25km/h collides head on with a second car travelling west at a velocity of 15km/h. During the collision, the two cars lock together. If the velocity of the locked cars is 3.3km/h east, what is the mass of the second car?

Before

1 →

$m_1 = 1.1 \times 10^3$

$v_1 = 25$

$p_1 = 2.75 \times 10^4$

2 ←

$m_2 = ?$

$v_2 = -15$

$p_2 = m_2(-15)$

After

1+2 →

$m = m_1 + m_2$

$v' = 3.3$

$p' = (m_1 + m_2)(3.3)$

$$\Sigma p = \Sigma p'$$

$$2.75 \times 10^4 + p_2 = p'$$

$$2.75 \times 10^4 + m_2(-15) = (m_1 + m_2)(3.3)$$

$$2.75 \times 10^4 - m_2(15) = (3.3)(m_1) + (3.3)(m_2)$$

$$2.75 \times 10^4 - (3.3)(m_1) = (3.3)(m_2) + m_2(15)$$

$$2.75 \times 10^4 - (3.3)(1.1 \times 10^3) = m_2(3.3 + 15)$$

$$23870 = m_2(18.3)$$

$$m_2 = 1304.37\ldots \text{ kg}$$

$$\boxed{m_2 = 1.3 \times 10^3 \text{ kg}}$$

*****Now try pg. 51 #1 (acceptable), 2, 5, 7-9, (intermediate), 11(excellence)*****

Linear Momentum Review

An empty freight car of mass m coasts along a track at 2.00 m/s until it couples to a stationary freight car of mass $2m$. The final speed of the two freight cars immediately after collision is

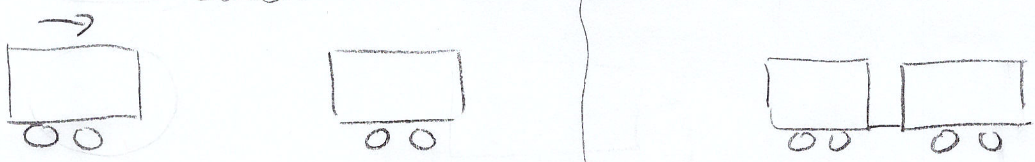
A. 1.50 m/s

B. 1.33 m/s

C. 1.15 m/s

→ (D.) 0.667 m/s

Before | After



Before		After
$m = m$	$m = 2m$	$m = m + 2m = 3m$
$v = +2.00$	$v = 0.0$	$v = ?? = x$
$p = +(2.00)m$	$p = 0.0$	$p = 3m(x)$

$$P_{total} = +2.00m + 0 \quad = \quad P_{total} = 3m(x)$$

$$+2.00\cancel{m} = 3\cancel{m}(x)$$

$$+2.00 = 3x$$

$$+0.\bar{6} = x$$

$\therefore$ $v_f = 0.667$ m/s, right