

Linear Momentum and Collisions

Reading reference: Chapter 9

Momentum

- A “quantity of motion”
- Equal to the product of an object’s mass and its velocity:

$$p = m \cdot v$$

- p = momentum (units = $\frac{kg \cdot m}{s}$)
- m = mass (kg)
- v = velocity (m/s)

How can momentum change?

- What must take place for momentum to change?
 - Either the mass or the velocity must change.
Since mass doesn’t typically change for a given object, the velocity must be changing.
- How? What happens to make the velocity change?

Momentum can be found by calculating...

- A. mass x velocity
- B. velocity / mass
- C. mass / velocity
- D. mass x force

A B C D E F



If a ball with a velocity of 50.0 m/s has the same momentum as that of a 10.0 kg cart rolling with a velocity of 20.0 m/s, what is the mass of the ball?

- A. 4.0 kg
- B. 5.0 kg
- C. 10.0 kg
- D. 2.5 kg

A B C D E F



Journal Entry:

- In two separate columns, list examples of each of the following:
 - 3 Events in which the momentum of something will change in a very short amount of time.
 - 3 Events in which the momentum of something will change over a longer amount of time.

What will most likely cause the greatest change in momentum?

- A. a large force acting over a short time
- B. a large force acting over a long time
- C. a small force acting over a short time

A B C D E F



When a golfer hits a golf ball, what is true about the forces acting on the golf club and the golf ball?

- A. the force on the club is larger because it is heavier
- B. the force on the ball is larger because it is what accelerates
- C. the forces on both the club and the ball are the same size

A B C D E F



Impulse

- Using Newton's 2nd law of motion, we can determine how forces can cause a change in momentum, and how time fits into the picture:

○ 2nd Law: $F = m \cdot a$

○ Sub. Def. of accel.: $F = m \cdot \left(\frac{\Delta v}{t}\right)$

○ Rearrange: $F \cdot t = m \cdot \Delta v$

Impulse-Momentum Theorem

- Impulse:** the product of the average force acting on an object and the time interval through which it acts

$$F \cdot t = m \cdot \Delta v$$

- Impulse-Momentum Theorem:**

- States that the **impulse** that acts on an object is equivalent to the magnitude of the **change in momentum** the object experiences!

Warm-up:

- The driver of a compact car (mass = 925 kg) is moving at 108 km/h on an interstate highway. He suddenly applies the brakes hard for 3.00 s. As a result, an average net force of 5.25×10^3 N acts on the car.
 - What is the car's change in momentum?
 - What is the final velocity of the car?

Warm-up solution:

$$F \cdot t = m \cdot (\Delta v)$$

Warm-up—Part 2

- If he had wanted to stop his car completely, what force would have been necessary?

Graphical analysis of Impulse:

Practice Problem #1

- A 2200 kg vehicle traveling at 26 m/s can be stopped by gently applying the brakes, by slamming on the brakes, or by crashing into a wall. Determine the average force required for each:
 - Left section: gently applying the brakes it stops in 21 s.
 - Center: It can be stopped in 3.8 s if the driver slams on the brakes
 - Right section: it can be stopped in 0.22 s if it hits a concrete wall.

Sketch a graph:

- To show all three situations for bringing the car to a stop:
- What quantity is the same for each situation?

Conservation of Momentum

- One of the fundamental laws of physics: total momentum of a system will always remain constant
- **System:** a set of objects for which the momenta and impulse (forces) will be measured and quantified
- **Total momentum remains constant.**
- **If an internal force causes a change in momentum of one object in the system, an equal and opposite force acted on a second object in the system to change its momentum.**

Collisions

<u>TYPE</u>	<u>Kinetic Energy</u>	<u>Momentum</u>
Elastic: Objects bounce off each other, undamaged <small>$(m_1v_1 + m_2v_2)_{initial} = (m_1v_1 + m_2v_2)_{final}$</small>	Conserved	Conserved
Inelastic: Objects impact and separate, but there has been damage done to each <small>$(m_1v_1 + m_2v_2)_{initial} = (m_1v_1 + m_2v_2)_{final}$</small>	NOT conserved	Conserved
Perfectly Inelastic: Objects impact and STICK TOGETHER as one larger mass with the same, slower velocity <small>$(m_1v_1 + m_2v_2)_{initial} = (m_1 + m_2)v_{final}$</small>	NOT conserved	Conserved

Example problem:

- A freight train is being assembled in a switching yard. Boxcar #1 has a mass of 6.5×10^4 kg, and Boxcar #2 has a mass of 9.2×10^4 kg. If car #1 is moving with a velocity of $+0.80$ m/s, and car #2 hits it from behind with a velocity of $+1.2$ m/s, with what velocity will the two cars move with together after connecting?

Example problem:


$$\Sigma p_{before} = \Sigma p_{after}$$

$$(m_1v_1 + m_2v_2)_{before} = (m_1 + m_2) \cdot v_{after}$$


$$(6.5 \times 10^4 \text{ kg})(0.80 \text{ m/s}) + (9.2 \times 10^4 \text{ kg})(1.2 \text{ m/s}) = (6.5 \times 10^4 \text{ kg} + 9.2 \times 10^4 \text{ kg})v_{after}$$

$$52000 \text{ kg} \cdot \text{m/s} + 110400 \text{ kg} \cdot \text{m/s} = (157000 \text{ kg}) \cdot v_{after}$$

$$\frac{162400 \text{ kg} \cdot \text{m/s}}{(157000 \text{ kg})} = v_{after} = 1.0 \text{ m/s}$$


 Problem 2:

- Starting from rest, two ice skaters push off against each other on smooth, level ice. Skater 1 has a mass of 54 kg and moves away from her friend (mass = 88 kg) with a velocity of 2.5 m/s. Find the “recoil” velocity of the second skater.


 Problem 2:

$$\begin{aligned}\Sigma p_{before} &= \Sigma p_{after} \\ (m_1 v_1 + m_2 v_2)_{before} &= (m_1 v_1 + m_2 v_2)_{after} \\ 0 &= (54\text{kg})(2.5\text{m/s}) + (88\text{kg})v_2 \\ \frac{-135\text{kg}\cdot\text{m/s}}{88\text{kg}} &= v_2 = 1.5\text{m/s}\end{aligned}$$