

# **Grade 12 Physics**

SPH4U

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# Chapter 3

## Unit 2: Energy and Momentum

### 3.1 Conservation of Momentum

**Definition 3.1.1.** *Two or more objects interact and **exert forces from each other**. The forces in the interaction are a Newton's Third Law pair of forces (ie  $\vec{F}_{A/B} = -\vec{F}_{B/A}$ )*

#### 3.1.1 Equation

Consider a person standing on any icy surface throws a heavy object horizontally:

FBD for the person (Left) and the object (Right)

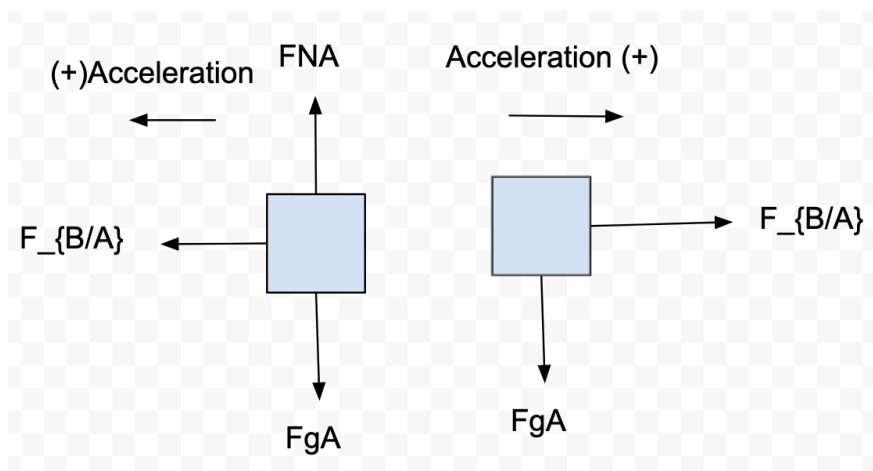


Figure 3.1: We will assume that the interaction forces are essentially the net force acting on the object

Equation for the object A:

$$\begin{aligned}\sum \vec{F}_A &= m_A * \vec{a}_A \\ \vec{F}_{B/A} &= m_A \vec{a}_A \\ \vec{F}_{B/A} &= m_A \frac{v_{fA} - v_{iA}}{\Delta t_A}\end{aligned}\tag{3.1}$$

Equation for the object B:

$$\begin{aligned}\sum \vec{F}_B &= m_B * \vec{a}_B \\ \vec{F}_{A/B} &= m_B \vec{a}_B \\ \vec{F}_{A/B} &= m_B \frac{v_{fB} - v_{iB}}{\Delta t_B}\end{aligned}\tag{3.2}$$

**Lemma 3.1.2.** From Newton's third law, we know  $\vec{F}_{A/B} + \vec{F}_{B/A} = 0$

We add 3.1 and 3.2 together:

$$m_A \frac{v_{fA} - v_{iA}}{\Delta t_A} + m_B \frac{v_{fB} - v_{iB}}{\Delta t_B} = 0$$

We know the time for both object should be the same.

$$\begin{aligned}m_A * v_{fA} + m_B * v_{fB} &= m_A * v_{iA} + m_B * v_{iB} \\ \vec{P}_{A2} + \vec{P}_{B2} &= \vec{P}_{A1} + \vec{P}_{B1}\end{aligned}\tag{3.3}$$

3.3 is the law of **Conservation of Momentum**

Always write this line at the beginning of your analysis

**Definition 3.1.3.** (The Law of Conservation of Momentum): The total momentum of a system of objects after an interaction is **equal** to the total momentum of the system before the interaction.

According to the 3.1.3, we can understand the total momentum of the system is **constant through out** the interaction.

The law assume that any other force that could **accelerate** any objects in the system during the interaction is **negligible**

## 3.2 Types of Collisions

### 3.2.1 Definitions

Collisions are typically classified based on the amount of **kinetic energy** the system has after the collision, in comparison to the amount of kinetic energy the system had before the collision. In other words, **how does  $E'_k$  with  $E_k$ ?**

### 3.2.2 Elastic Collisions

In an elastic collision, the kinetic energy of the system after the collision is **equal** to the kinetic energy of the system before the collision. In mathematics, the equation can be represented by:

$$E_k' = E_k$$

*Remark.* This does not mean the kinetic energy of the system after the collision is **equal** to the kinetic energy of the system before the collision (Unlike momentum)

#### Steps of the collision

*Remark.* This is on a horizontal frictionless surface, so we can ignore Gravitational Potential Energy

**Before the collision:** The mechanical energy is entirely in the form of kinetic energy

**First half of collision:** The interaction forces cause the object to start deform. As the object deforms, they transfer  $E_k$  to  $E_s$ .

**At the approximate midpoint of the collision:** The deformation of the object is at a maximum.  $E_s$  is the maximum and  $E_k$  is the minimum.

**During the second half of the collision:** The restoring forces are now doing *positive work* on the system, transferring elastic potential energy **back into**  $E_k$

**After the collision:** The system's mechanical energy is now entirely  $E_k$ , at this time,  $E_s = 0$ . All  $E_s$  is transferred to  $E_k$ .

### Head-on Collision

**Before the Collision:** System's mechanical energy is entirely  $E_k$

**During the first half of the collision:** The spring gets compressed.  $E_k$  is transformed into  $E_s$ .

**At the mid-point of the collision:**

- Spring is at the most compressed point.
- Distance between cars is minimized
- $\vec{v}_A = \vec{v}_B$
- $E_k$  is minimized
- $E_s$  is maximized

**During the second half of the collision:**

- $\vec{v}_A < \vec{v}_B$
- Distance between the carts is increasing
- $E_s$  is being transferred back into  $E_k$

**After the collision:** The system is entirely  $E_k$  now

*Remark.* Elastic collisions **cannot occur** between visible objects in real life. At least some of the energy will be lost as thermal or sound.

### 3.2.3 Inelastic Collision

So for this collision,  $E_k'$  is less than  $E_k$

It is impossible for a system to have more kinetic energy after the collision, than it had before the collision, unless:

1. One of the objects had **stored energy** before the collision, which was transferred into kinetic energy during the collision.
2. An **external** force (such as force of gravity) is doing positive work on the system, during the collision.

**Completely inelastic collision**

In this collision, the maximum amount of kinetic energy that could be "lost" is lost as a result of the collision.

After the collision, the objects involved in the collision will be **stack/attached together**

**Apple and Arrow** is an example of this question.

The following condition must be met for a Perfectly Inelastic Collision:

- $\vec{v}_A' = \vec{v}_B' = \vec{v}^*$