Grade 12 Physics

SPH4U

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Contents

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)

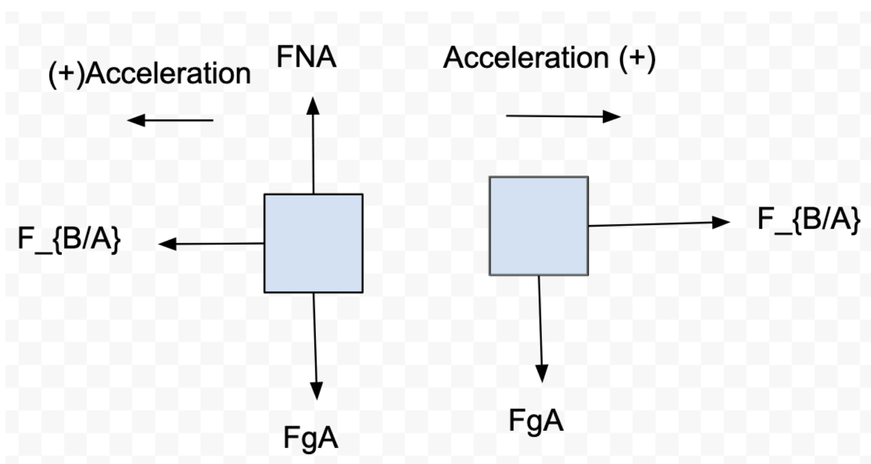

Figure 3.1: We will assume that the interaction forces are essentially the net force acting on the object

Equation for the object A:

$$\sum \vec{F_A} = m_A * \vec{a_A}$$
$$\vec{F_{B/A}} = m_A \vec{a_A}$$
$$\vec{F_{B/A}} = m_A \frac{\vec{v_{fA}} - \vec{v_{iA}}}{\Delta t_A} \tag{3.1}$$

Equation for the object B:

$$\sum \vec{F_B} = m_B * \vec{a_B}$$
$$\vec{F_{A/B}} = m_B \vec{a_B}$$
$$\vec{F_{A/B}} = m_B \frac{\vec{v_{fB}} - \vec{v_{iB}}}{\Delta t_B} \tag{3.2}$$

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:

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

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

$$m_A * \vec{v_{fA}} + m_B * \vec{v_{fB}} = m_A * \vec{v_{iA}} + m_B * \vec{v_{iB}}$$
$$\vec{P_{A2}} + \vec{P_{B2}} = \vec{P_{A1}} + \vec{P_{B1}} \tag{3.3}$$

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 syste has after the collision, in comparsion 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 horzontal frictionless surface, so we can ignore Gravational Potential Energy

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

First half ot collision:The interaction forces cause the object to start deform. As the object deform, 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 maxium 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 transfered to E_k.

Head-on Collision

Before the Collision: System's mechancial energy is entirely E_k

During the first half of the collision: The spring get 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 are minimumized
- $\vec{v_A} = \vec{v_B}$
- E_k is minimumized
- E_s is maximumized

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 rael life. At least some of the enery will be lost as thermal or sound.

3.2.3 Inelasic 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 object had **stored energy** before the colllision, which was transferred into kinetic enery 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 collusion, 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:

- $\vec{v_A}` = \vec{v_B}` = \vec{v}`$