Momentum

KEY CONCEPTS

This lesson will focus on the following:

- Defining momentum
- Impulse
- Principle of conservation of momentum

TERMINOLOGY & DEFINITIONS

Momentum (p): is the product of mass and the velocity of a moving object

Impulse: is the change in momentum (Δp)

Elastic collision: a type of collision where kinetic energy is conserved. (Kinetic energy before collision is equal to kinetic energy after collision). No loss in energy is encountered

Inelastic collision: a type of collision where kinetic energy is not conserved

X-PLANATION OF KEY CONCEPTS AND TERMINOLOGIES

Momentum

The momentum of an object is calculated using the formula:

$$\mathbf{p} = m \times v$$

where **p** – momentum

m – mass of an object in kilograms

v – velocity of an object in $\mathbf{m \cdot s^{-1}}$

The unit of measurement for momentum is $\mathbf{kg \cdot m \cdot s^{-1}}$.

Impulse

Impulse is the change in momentum. Impulse = Δp. Impulse is also given by the product of the resultant force and the period of time the force is acting on an object: $F\Delta t = \Delta p$. Thus the unit of measurement of impulse can also be expressed as N·s. The mass of an object is usually intact and does not change except in an explosion. Therefore, the change in momentum is usually as a result of change in the velocity of the object. Thus $F\Delta t = \Delta p = m(V_f - V_i)$. From this equation, it can be deduced that the resultant force acting on an object is given by the rate of change of momentum and

that the change in momentum is in the direction of the force: $F = \dfrac{m(V_f - V_i)}{\Delta t}$

The force is measured in Newton (N).

If the force acts for a short period on an object, its magnitude is big and the impact it makes on the object is huge. The fronts of modern cars are made to crumple when involved in an accident (collision). The crumple zone makes the time of contact to be longer so that the impact of the force is be minimised.

PRINCIPLE OF CONSERVATION OF MOMENTUM

Total momentum in a closed system remains constant in both magnitude and direction.

The principle of conservation of momentum is used to solve problems based on collisions.
- For two objects that separate after collision.
- For two objects that couple after collision.
- For two coupled objects that separate after an explosion:
- Elastic collision – a type of collision where kinetic energy is conserved. (Kinetic energy before collision is equal to kinetic energy after collision). No loss in energy is encountered.
- Inelastic collision – a type of collision where kinetic energy is not conserved.

X-AMPLES

1. 1.1   A truck of mass 24 000 kg moves to the right at 10 m•s⁻¹. Calculate the momentum of the truck.

    1.2.   A tennis ball of 500 g is thrown towards a wall at 12 m•s⁻¹. What is the momentum of the tennis ball?

2. A 4 kg object moving towards the north at 6 m•s⁻¹ decreased its velocity to 3 m•s⁻¹ while moving in the same direction.

    2.1   Calculate the change in momentum of the object.

    2.2   If it took the object 2 seconds to change its velocity, what is the magnitude of the force that caused the change in momentum?

3. A 0,4 kg ball travels at 20 m•s⁻¹ towards a bat and it is hit back at a velocity of 30 m•s⁻¹. Calculate the force exerted by the bat on the ball if the time of contact is 0,01 seconds.

4. In a railway shunting yard, a locomotive of mass 4 000 kg travels to the east at 1,5 m•s⁻¹ and collides with a stationary goods wagon of mass 3 000 kg. The two separate after collision, and the goods wagon moves to the east at 2,8 m•s⁻¹.

    4.1   Calculate the magnitude and direction of the locomotive immediately after the collision.

    4.2   Name and state in words the law you used to answer 4.1.

X-ERCISE

A trolley of 8 kg mass is moving on a horizontal frictionless surface at 4 m•s⁻¹. A 5 kg bag of bird feed is allowed to fall perpendicularly onto the trolley.

1. Calculate the velocity of the trolley and the bag after the bag was placed onto the trolley.

2. Determine whether the collision between the trolley and the bag was placed onto the trolley.

ANSWERS

1. Vf = 0,9 m•s⁻¹ in the original direction

2. Total Eki = 64 J; Total Ekf = 5,27 J. Total Kinetic energy not conserved. Collision inelastic.