

Momentum Notes

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Momentum is a vector quantity, it is the product of the mass of the object multiplied by the velocity of the object. Though we normally just say that momentum is the mass multiplied by velocity.

The Law of Momentum

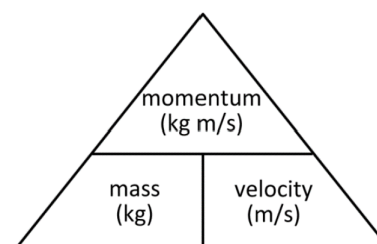
The law of momentum states: in a closed system, momentum before a collision is the same as the momentum after the collision. Momentum is always conserved.

A closed system: a group of objects where no energy or mass can enter or leave, and no external forces (like friction or air resistance) act on them. In real life very few systems would be closed ones but for the GCSE we just treat all systems like they're closed ones. The exam board want us to use the phrase "closed system".

The momentum of an object is calculated using the equation:

$$\text{momentum} = \text{mass (kg)} \times \text{velocity (m/s)}$$

$$p = m \times v$$



p is the symbol for momentum. The unit of momentum is kg m/s.

Reducing Momentum

We often see questions involving reducing momentum in exams. They are typically about a safety feature like seat belts, air bags or packaging around delicate objects. It doesn't matter what they ask about, the concept is the same. Questions on these features can always be answered using the following:

1. The feature increases the time taken to stop (during the collision).
2. So, the rate of change of momentum decreases.
3. Reducing the force that is experienced by the object.

Calculating rate of change of momentum

The rate of change of momentum of an object is calculated using the equation:

$$\text{Force} = \text{mass (kg)} \times \frac{(\text{change in velocity m/s})}{\text{time}}$$

$$F = m \times \frac{\Delta v}{t} \quad \text{it can also be written as} \quad F = \frac{mv - mu}{t}$$

Let's look at some example questions where we use the equation for momentum.

Example 1: A dog with a mass of 35 kg is running at a speed of 3 m/s. Calculate the momentum of the dog.

$$\text{momentum} = \text{mass (kg)} \times \text{velocity (m/s)}$$

$$\text{momentum} = 35 \text{ kg} \times 3 \text{ m/s}$$

$$\text{momentum} = 105 \text{ kg m/s}$$

Example 2: A box of eggs is falling from a kitchen shelf. It has a momentum of 2 kg m/s and a speed of 5 m/s. Calculate the mass of the box of eggs.

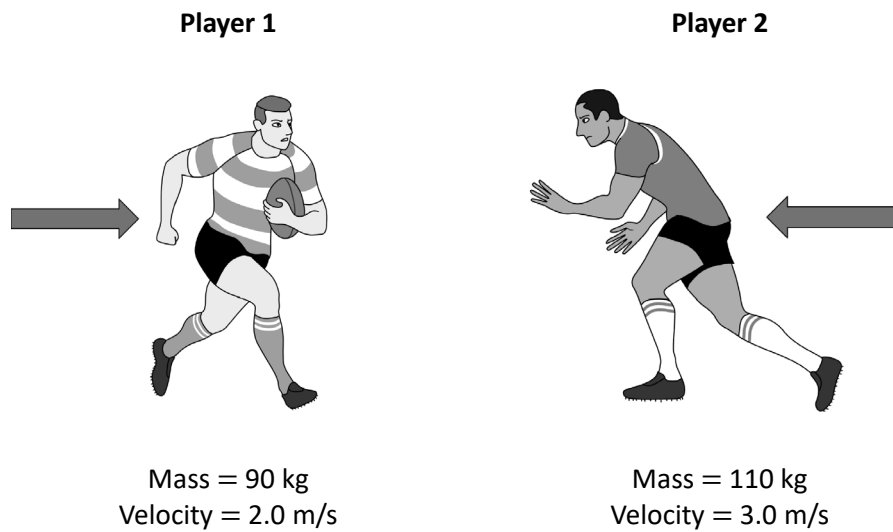
$$\text{mass (kg)} = \text{momentum kg m/s} \div \text{velocity (m/s)}$$

$$\text{mass} = 2 \text{ kg m/s} \div 5 \text{ m/s}$$

$$\text{mass} = 0.4 \text{ kg}$$

Example 3: the figure below shows two rugby players moving towards each other. They collide and then move off together. Immediately after the collision the two players move **together** to the left.

Calculate the velocity of the **two** players immediately after the collision.



Step 1: calculate the momentum of player 1.

$$\begin{aligned}\text{momentum of player 1} &= \text{mass} \times \text{velocity} \\ \text{momentum of player 1} &= 90 \text{ kg} \times 2.0 \text{ m/s} \\ \text{momentum of player 1} &= \mathbf{180 \text{ kg m/s}}\end{aligned}$$

Step 2: calculate the momentum of player 2.

$$\begin{aligned}\text{momentum of player 2} &= \text{mass} \times \text{velocity} \\ \text{momentum of player 2} &= 110 \text{ kg} \times 3.0 \text{ m/s} \\ \text{momentum of player 2} &= \mathbf{330 \text{ kg m/s}}\end{aligned}$$

Step 3: calculate the difference in momentum of players by taking one away from the other.

$$180 \text{ kg m/s} - 330 \text{ kg m/s} = \mathbf{-150 \text{ kg m/s}}$$

Step 4: calculate the combined mass of both players. As they are moving to the left together then we treat them both as one object so they will have one mass.

$$90 \text{ kg} + 110 \text{ kg} = 200 \text{ kg}$$

Step 5: now that we have the new momentum and the new mass, we use the momentum equation to calculate the velocity after the collision.

$$\begin{aligned}\text{velocity (m/s)} &= \text{momentum (kg m/s)} \div \text{mass (kg)} \\ \text{velocity (m/s)} &= -150 \text{ kg m/s} \div 200 \text{ kg} \\ \text{velocity} &= \mathbf{-0.75 \text{ m/s}}\end{aligned}$$