5.7.2 Conservation of momentum in collisions

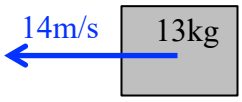
videos

Momentum (p) is defined as the product of an objects mass (m) and velocity (v):

$$p = m \times v$$

As velocity is a vector quantity, so is momentum (it has a direction and size).

On this course, we only deal with momentum in one dimension (forwards and backwards). We usually take momentum to the right to be positive and momentum to the left to be negative.

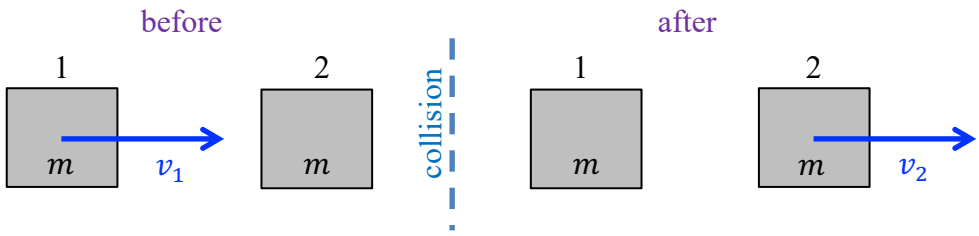


(1) What is the momentum of the block, above? What are the units?

(2) What would the momentum of the block (above) be if the arrow was pointing to the right?

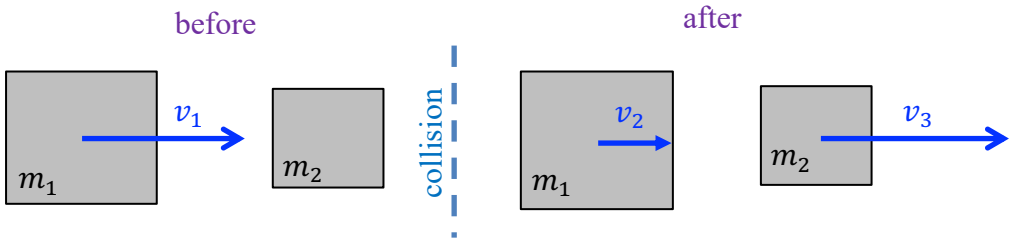
Conservation of momentum in collisions

When two objects collide, provided there are no external forces, the total momentum before the collision is equal to the total momentum after the collision. Let us look at some different situations:



In this situation, objects with the same mass (m) collide. Before the collision only object 1 has momentum, so the total momentum is just equal to $m \times v_1$. After the collision only object 2 has momentum, so the total momentum is $m \times v_2$. We can see from this that $v_1 = v_2$. After the collision, object 1 stops and object 2 moves off with the same speed as object 1 had before. This situation can be seen in snooker, when balls of the same mass collide straight on.

(3) What do you think would happen if object 1 had a larger mass than object 2?



In the situation above, a larger mass (m_1) collides with a stationary smaller mass (m_2). After the collision, both objects move to the right, but 2 has a larger velocity. Using the conservation of momentum, we can write:

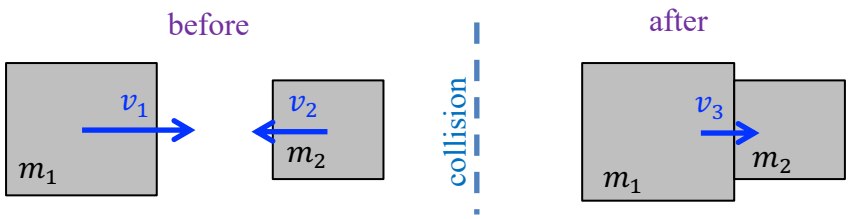
$$total\ momentum\ before = total\ momentum\ after$$
$$m_1 \times v_1 = m_1 \times v_2 + m_2 \times v_3$$

Worked example

Question:
Object 1 has a mass of 3.0kg and is travelling with a velocity of 2.4m/s. It collides with a stationary object 2, with a mass of 1.5kg. After collision, object 1 has a velocity of 1.0m/s. What is the velocity of object 2?
Answer:

$$total\ momentum\ before = total\ momentum\ after$$
$$m_1 \times v_1 = m_1 \times v_2 + m_2 \times v_3$$
$$3 \times 2.4 = 3 \times 1 + 1.5 \times v_3$$
$$\therefore v_3 = \frac{(7.2 - 3)}{1.5} = 2.8m/s$$

(4)✐Object 1 has a mass of 2.5kg and is travelling with a velocity of 3.4m/s. It collides with a stationary object 2, with a mass of 2.1kg. After collision, object 1 has a velocity of 2.0m/s. What is the velocity of object 2?



In this situation (above) the objects both have momentum before. The second mass has negative momentum (because it is moving left). After the collision the masses are stuck together, so their masses combine ($m_1 + m_2$) and they have a combined velocity (v_3). We can write:

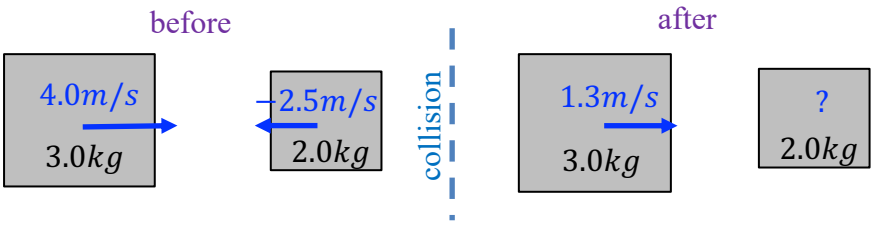
$$total\ momentum\ before = total\ momentum\ after$$
$$m_1 \times v_1 + m_2 \times v_2 = (m_1 + m_2) \times v_3$$

Worked example

Question:
Two objects with mass 10.0kg and 5.0kg, and velocities 3.0m/s and -2.0m/s, respectively, collide. The 10.0kg mass sticks to the 5.0kg mass and they move off together. What combined velocity do they have after the collision?
Answer:

$$total\ momentum\ before = total\ momentum\ after$$
$$m_1 \times v_1 + m_2 \times v_2 = (m_1 + m_2) \times v_3$$
$$10 \times 3 + 5 \times (-2) = (10 + 5) \times v_3$$
$$v_3 = \frac{(30 - 10)}{15} = 1.3m/s$$

(5) Two objects with mass 3.0kg and 2.0kg, and velocities 5.0m/s and -3.0m/s, respectively, collide. The 3.0kg mass sticks to the 2.0kg mass and they move off together. What combined velocity do they have after the collision?



(6) Two objects, above, with masses of 3.0kg and 2.0kg are moving in opposite directions with velocities of $4.0m/s$ *and* $-2.5m/s$*, respectively. After the collision, the 3.0kg object is travelling with a velocity of* $1.3m/s$*. What is the velocity of the 2.0kg object? (Hint: Remember to start with "*$total\ momentum\ before = total\ momentum\ after$*".)*

Elastic and inelastic collisions

When two objects collide, the total kinetic energy may be conserved. This means, if we add up the kinetic energies ($E_k = 0.5 \times m \times v^2$) of the objects before and after, they should be equal. This type of collision is called an elastic collision.

When two objects collide, and the total kinetic energy is not conserved, we say that the collision is inelastic.

(7) Is the collision in question 6 elastic or inelastic?