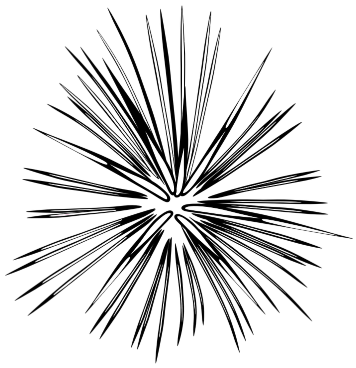
4.6.2 Conservation of momentum

videos

One of the most useful laws in dynamics is the law of conservation of momentum. This tells us that:

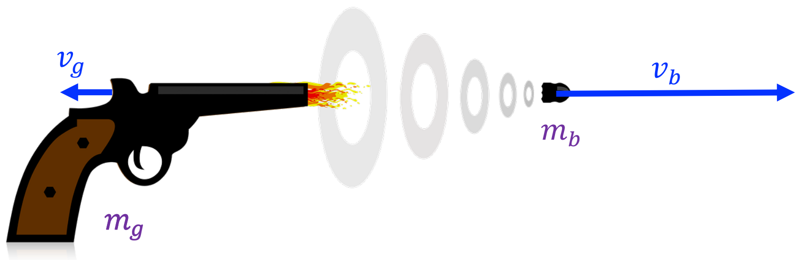
"In a closed system (with no external forces acting) linear momentum remains constant."

Explosions



When an explosion occurs, pieces fly in all directions. It would be strange to see all the pieces heading in one direction. This is a consequence of the conservation of momentum. The stationary object before the explosion has zero momentum (momentum *p=mv*, and *v=0ms*$^{-1}$). This must mean the total momentum after the explosion must also be zero. In 1 dimension, pieces heading to the right (positive momentum) must be balanced by pieces heading to the left (negative momentum). In 3D, this applies to all directions.

Consider a gun firing a bullet:



Before the gun fires, the bullet and the gun are stationary, and so have zero total momentum. After firing the bullet goes right, and so has positive momentum ($= m_b v_b$). The gun recoils left and has negative momentum ($= m_g v_g$). The momentum of the two added together should equal zero, because momentum is conserved. We can write:

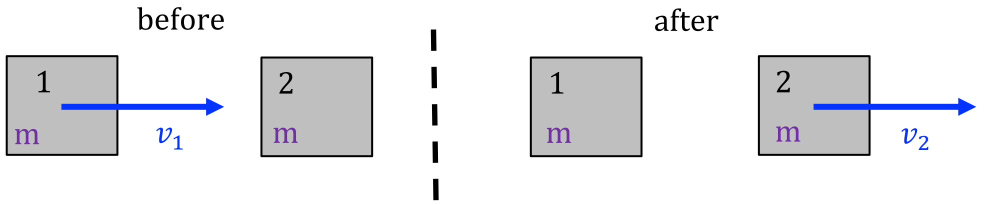
$$m_b v_b + m_g v_g = 0$$
$$\therefore m_b v_b = -m_g v_g$$

(1)✐The mass of the gun m_g is very much larger than the mass of the bullet m_b. How will the velocities of the bullet and gun compare?

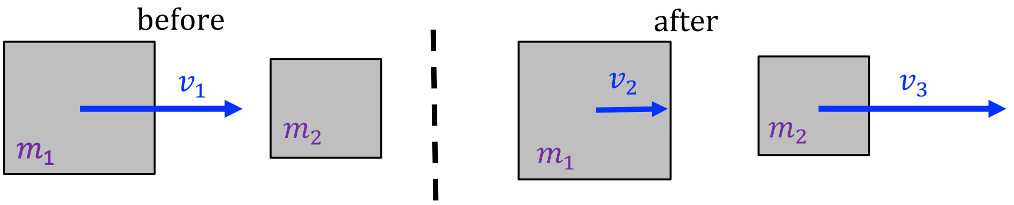
(2)✐A hand gun has a mass of 1.5kg, and a bullet has a mass of 0.016kg. If the gun recoils at 3.2ms^{-1}*, what is the velocity of the bullet?*

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:

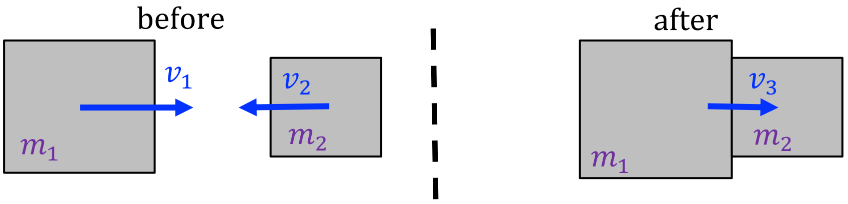


In this situation objects with the same mass (m) collide. Before the collision only 1 has momentum, so the total momentum is just mv_1. After the collision only 2 has momentum, so the total momentum is mv_2. We can see from this that $v_1 = v_2$. After the collision, ball one stops and ball 2 moves off with the same speed as ball 1 had before. This situation can be seen in snooker, when balls of the same mass collide straight on.



In this 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:

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



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, and they have a combined velocity. We can write:

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

(3)✏Two objects with mass 10kg and 5kg, and velocities 3ms^{-1} and -2ms^{-1}, respectively, collide. The 10kg mass moves off, separately, with a velocity of 1ms^{-1}. What velocity does the 5kg mass have?

Elastic and inelastic collisions

When two objects collide, the total kinetic energy may be conserved. This means, if we add up the kinetic energies ($E_k=½mv^2$) 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.

(4)✏Work out the total kinetic energies of the two masses (before and after) in the previous question and decide if the collision was elastic or inelastic.