1.5 Explosions

Learning objectives:

- What energy changes take place in an explosion?
- What can we always say about the total momentum of a system that has exploded?
- What are the consequences when, after the explosion, only two bodies move apart?

Specification reference: 3.4.1

Figure 1 *The gun barrel recoils when the shell is fired. Large springs fitted to the barrel take away and store the kinetic energy of the barrel as it recoils*

When two objects fly apart after being initially at rest, they recoil from each other with equal and opposite amounts of momentum. So they move away from each other in opposite directions. Consider Figure 2 where a trolley of mass m_A and a trolley of mass m_B, initially at rest and in contact, move apart at speeds v_A and v_B respectively when the rod is tapped to release the spring-loaded bolt in trolley A.

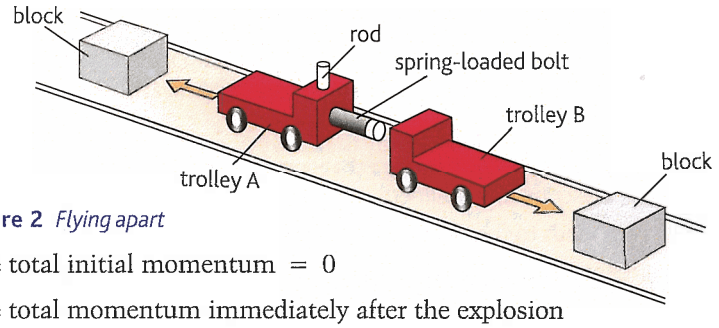

Figure 2 *Flying apart*

The total initial momentum = 0

The total momentum immediately after the explosion

= momentum of A + momentum of B

$= m_A v_A + m_B v_B$

Using the Principle of Conservation of Momentum, $m_A v_A + m_B v_B = 0$

$$\therefore \quad m_B v_B = -m_A v_A$$

The minus sign means that the two masses move apart from each other in opposite directions.

For example, if $m_A = 1.0\,\text{kg}$, $v_A = 2.0\,\text{m s}^{-1}$ and $m_B = 0.5\,\text{kg}$,

$$\text{then } v_B = -\frac{m_A v_A}{m_B} = -4.0\,\text{m s}^{-1}$$

So A and B move apart at speeds of $2.0\,\text{m s}^{-1}$ and $4.0\,\text{m s}^{-1}$ in opposite directions.

Link

The α particles from a given isotope are always emitted with the same kinetic energy because they are emitted with the same speed. This is because each α particle and the nucleus that emits it move apart with equal and opposite amounts of momentum. This isn't the case with β particles because a neutrino or antineutrino is emitted as well. See *AS Physics* Topic 1.2.

Testing a model explosion

In Figure 2, when the spring is released from one of the trolleys, the two trolleys, A and B, push each other apart. The blocks are positioned so that the trolleys hit the blocks at the same moment. The distance travelled by each trolley to the point of impact with the block is equal to its speed × the time taken to travel that distance. As the time taken is the same for the two trolleys, the distance ratio is the same as the speed ratio. Because the trolleys have equal (and opposite) amounts of momentum, the ratio of their speeds is the inverse of the mass ratio. The distance ratio should therefore be equal to the inverse of the mass ratio. In other words, if trolley A travels twice as far as trolley B, then the mass of A must be half the mass of B (so they carry away equal amounts of momentum).

Note: In this experiment, the kinetic energy of the two trolleys immediately after they separate from each other is equal to the energy stored in the spring when it was originally compressed. For two or more objects that fly apart due to an explosion, their total kinetic energy immediately after the explosion is less than the total chemical energy released in the explosion because heat, light and sound all carry away energy.

Summary questions

1 A shell of mass 2.0 kg is fired at a speed of 140 m s^{-1} from an artillery gun of mass 800 kg. Calculate the recoil velocity of the gun.

2 In a laboratory experiment to measure the mass of an object X, two identical trolleys A and B, each of mass 0.50 kg, were initially stationary on a track. Object X was fixed to trolley A. When a trigger was pressed, the two trolleys moved apart in opposite directions at speeds of 0.30 m s^{-1} and 0.25 m s^{-1}.

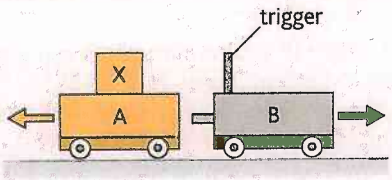

Figure 3

a Which of the two speeds given above was the speed of trolley A? Give a reason for your answer.

b Show that the mass of X must have been 0.10 kg.

3 Two trolleys, X of mass 1.20 kg and Y of mass 0.80 kg, are initially stationary on a level track.

a When a trigger is pressed on one of the trolleys, a spring pushes the two trolleys apart. Trolley Y moves away at a velocity of 0.15 m s^{-1}.

i Calculate the velocity of X.

ii Calculate the total kinetic energy of the two trolleys immediately after the explosion.

b In part a, if the test had been carried out with trolley X held firmly, calculate the speed at which Y would have recoiled, assuming the energy stored in the spring before release is equal to the total kinetic energy calculated in a ii.

4 A person in a stationary boat of total mass 150 kg throws a rock of mass 2.0 kg out of the boat. As a result, the boat recoils at a speed of 0.12 m s^{-1}. Calculate a the speed at which the rock was thrown from the boat, b the kinetic energy gained by i the boat, ii the rock.