1.4 Elastic and inelastic collisions

Learning objectives:

- What is the difference between an elastic collision and an inelastic collision?
- What is conserved in a perfectly elastic collision?
- Are any real collisions ever perfectly elastic?

Specification reference: 3.4.1

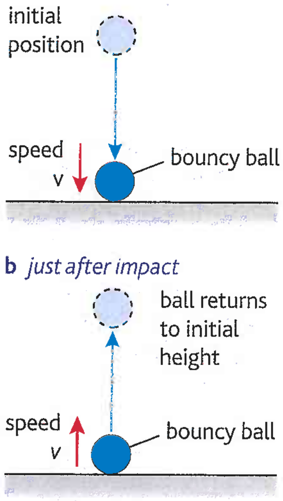

Figure 1 *An elastic impact*

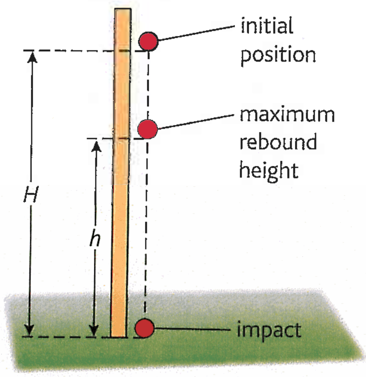

Figure 2 *Testing an impact*

Drop a bouncy rubber ball from a measured height onto a hard floor. The ball should bounce back almost to the same height. Try the same with a cricket ball and there will be very little bounce! An **elastic** ball would be one that bounces back to exactly the same height. Its **kinetic energy** just after impact must equal its kinetic energy just before impact. Otherwise, it cannot regain its initial height. There is no loss of kinetic energy in an **elastic collision**.

An elastic collision is one where there is no loss of kinetic energy.

- A squash ball hitting a hard surface bounces off the surface with little or no loss of speed. If the ball is perfectly elastic, there is no loss of speed on impact and no loss of kinetic energy.
- A very low speed impact between two cars is almost perfectly elastic, provided no damage is done. Some of the initial kinetic energy of the two vehicles may be converted to sound. If the collision causes damage to the vehicles, however, the kinetic energy after the collision is less than before the collision, so the collision is not elastic and may be described as **inelastic**.

A totally inelastic collision is one where the colliding objects stick together.

- A railway wagon that collides with and couples to another wagon is an example of a totally inelastic collision. Some of the initial kinetic energy is converted to other forms of energy.
- A vehicle crash in which the colliding vehicles lock together is another example of a totally inelastic collision. The total kinetic energy after the collision is less than the total kinetic energy before the collision.

A partially inelastic collision is where the colliding objects move apart, and have less kinetic energy after the collision than before.

To work out if a collision is elastic or inelastic, the kinetic energy of each object before and after the collision must be worked out.

Examples

1 For a ball of mass m falling in air from a measured height H above the floor and rebounding to a height h,

  i the kinetic energy immediately before impact = loss of potential energy through height $H = mgH$,

  ii the kinetic energy immediately after impact = gain of potential energy through height $h = mgh$.

So the height ratio h/H gives the fraction of the initial kinetic energy that is recovered as kinetic energy after the collision.

2 For a collision between two objects, the kinetic energy of each object can be worked out using the kinetic energy formula $E_K = \frac{1}{2}mv^2$, where m is the mass of the object and v is its speed. Using this formula, the total initial kinetic energy and the total final kinetic energy can be worked out if the mass, initial speed and speed after collision of each object is known.

Worked example:

A railway wagon of mass 8000 kg moving at $3.0\,\text{m s}^{-1}$ collides with an initially stationary wagon of mass 5000 kg. The two wagons separate after the collision. The 8000 kg wagon moves at a speed of $1.0\,\text{m s}^{-1}$ without change of direction after the collision. Calculate:

a the speed and direction of the 5000 kg wagon after the collision,

b the loss of kinetic energy due to the collision.

Solution

a The total initial momentum = 8000 × 3 = $24\,000\,\text{kg m s}^{-1}$

The total final momentum = (8000 × 1.0) + 5000*V*, where *V* is the speed of the 5000 kg wagon after the collision.

Using the Principle of Conservation of Momentum

$$8000 + 5000V = 24\,000$$

$$5000V = 24\,000 - 8000 = 16\,000$$

$$V = \frac{16\,000}{5000} = 3.2\,\text{m s}^{-1}$$

b Kinetic energy of the 8000 kg wagon before the collision

$$= \tfrac{1}{2} \times 8000 \times 3.0^2 = 36\,000\,\text{J}$$

Kinetic energy of the 8000 kg wagon after the collision

$$= \tfrac{1}{2} \times 8000 \times 1.0^2 = 4000\,\text{J}$$

Kinetic energy of the 5000 kg wagon after the collision

$$= \tfrac{1}{2} \times 5000 \times 3.2^2 = 25\,600\,\text{J}$$

∴ loss of kinetic energy due to the collision = 36 000 − (4000 + 25 600)

= 6400 J

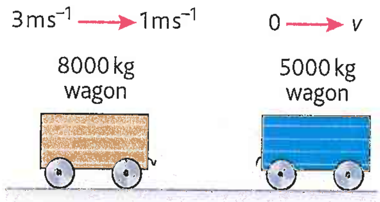

Figure 3

AQA Examiner's tip

Momentum is always conserved in collisions. Total energy is always conserved, but kinetic energy may be converted to other forms.

Link

Excitation by collision in a gas occurs when the gas molecules undergo collisions and are excited to higher energy states. Such a collision is inelastic because the kinetic energy of the colliding particles is less after the collision than before. See AS Physics Topic 3.3, page 35.

Summary questions

1 a A squash ball is released from rest above a flat surface. Describe how its energy changes if:

i it rebounds to the same height,

ii it rebounds to a lesser height.

b In (a) (ii), the ball is released from a height of 1.20 m above the surface and it rebounds to a height of 0.90 m above the surface. Show that 25% of its kinetic energy is lost in the impact.

2 A vehicle of mass 800 kg moving at a speed of $15.0\,\text{m s}^{-1}$ collided with a vehicle of mass 1200 kg moving in the same direction at a speed of $5.0\,\text{m s}^{-1}$. The two vehicles locked together on impact. Calculate:

a the velocity of the two vehicles immediately after impact,

b the loss of kinetic energy due to the impact.

3 An ice puck of mass 1.5 kg moving at a speed of $4.2\,\text{m s}^{-1}$ collides head on with a second ice puck of mass 1.0 kg moving in the opposite direction at a speed of $4.0\,\text{m s}^{-1}$. After the impact, the 1.5 kg ice puck continues in the same direction at a speed of $0.80\,\text{m s}^{-1}$. Calculate:

a the speed and direction of the 1.0 kg ice puck after the collision,

b the loss of kinetic energy due to the collision.

4 The bumper cars at a fairground are designed to withstand low-speed impacts without damage. A bumper car of mass 250 kg moving at a velocity of $0.90\,\text{m s}^{-1}$ collides elastically with a stationary car of mass 200 kg. Immediately after the impact, the 250 kg car has a velocity of $0.10\,\text{m s}^{-1}$ in the same direction as it was initially moving in.

a i Calculate the velocity of the 200 kg car immediately after the impact.

ii Show that collision was an elastic collision.

b Without further calculations, discuss the effect of the impact on the driver of each car.