Collisions and the principle of conservation of momentum

Starter

1. **(Review of last lesson)** A particle of mass 2 kg is moving in a straight line, with a speed of 5 m/s. A force of 11 N acts on the particle for 6 seconds, in the direction of motion. Find
   (a) the magnitude of the change in momentum of the particle
   (b) the speed of the particle at the end of this time.

2. **(Review of last lesson)** A body of mass 5 kg is moving with speed 7 m/s when a force is applied to it for 8 seconds. Its speed then is again 7 m/s but in the opposite direction. Find the magnitude of the force that has caused this change.

3. An object A of mass m_A collides with object B which has mass m_B. Prior to the collision they had velocities u_A and u_B respectively and after the collision their velocities are v_A and v_B. Find the impulse of both objects.

Notes

By Newton's 3rd law, there is an equal and opposite reaction so:

Impulse on A $=-$ Impulse on B $\Rightarrow$ $mv_A - mu_A = -(mv_B - mu_B)$

Rearranging gives: $mu_A + mu_B = mv_A + mv_B$

Momentum before collision equals momentum after the collision

Principle of conservation of momentum

If two objects moving along the same line collide with each other, the total momentum of the two objects is the same after the collision as it was before.

N.B. "Coalesce" means the objects stick together.

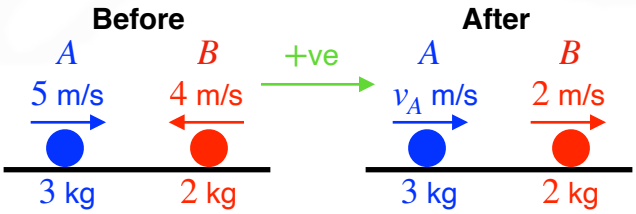
Solving momentum problems

1. Draw a before/after diagram with the relevant information.
2. Choose a positive direction at the start of the question.
3. Use the principle of conservation of momentum (CoM)

E.g. 1 A particle, A, of mass 3 kg, travelling at 5 m/s collides head-on with a particle B with mass 2 kg and travelling at 4 m/s. If, after impact, B moves in the opposite direction at 2 m/s, find the velocity of A.

N.B. A "head-on" collision means the objects are moving towards each other.

Working:



CoM: $3 \times 5 - 2 \times 4 = 3v_A + 2 \times 2$

Note the negative sign since B is initially travelling in the opposite direction.

$$7 = 3v_A + 4$$
$$v_A = 1$$

Since $v_A > 0$ it is travelling in the defined positive direction.

The velocity of A is 1 m/s in its original direction of motion.

E.g. 2 A bullet of mass 0.1 kg is fired horizontally, at 80 m/s, into a stationary block of wood that is free to move on a smooth horizontal plane. The wooden block, with the bullet embedded in it, moves off with speed 5 m/s. Find the mass of the block.

Modelling in collision questions with spheres

It is assumed that:

- the spheres are smooth
- the impulse acts along the line of centres
- none of the spheres is spinning

E.g. 3 A particle, A, of mass 5 kg travelling with speed 6 m/s, collides directly with a stationary particle B of mass 10 kg. If A is brought to rest by the impact find the speed with which B begins to move.

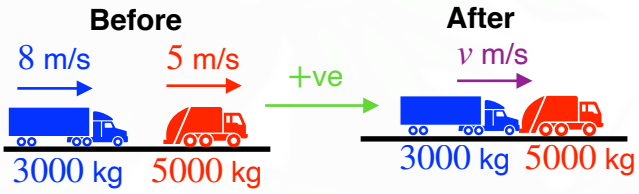
E.g. 4 A three-tonne articulated lorry is moving along a track at 8 m/s towards a five-tonne bin lorry travelling at 5 m/s on the same road. If the lorries become coupled at impact find the velocity at which they continue to move if they were travelling

(a) in the same direction

(b) in the opposite direction.

Make sure you give the direction of motion.

Working: (a)



CoM: $3000 \times 8 + 5000 \times 5 = (3000 + 5000) \times v$

$49000 = 8000v$

$v = 6.125$

The velocity at which they continue to move is 6.75 m/s in the same direction as the original direction of the trucks.

Video: Conservation of linear momentum

Video: Colliding and separating

Solutions to Starter and E.g.s

Exercise

p60 3B Qu 1-10

M1 p133 Ex 8B Qu 1-10

Summary

Principle of conservation of momentum: the momentum before the collision equals the momentum after the collision

N.B. "Coalesce" means the objects stick together.

Solving momentum problems:

1. Draw a before/after diagram with the relevant information.
2. Choose a positive direction at the start of the question.
3. Use the principle of conservation of momentum (CoM)