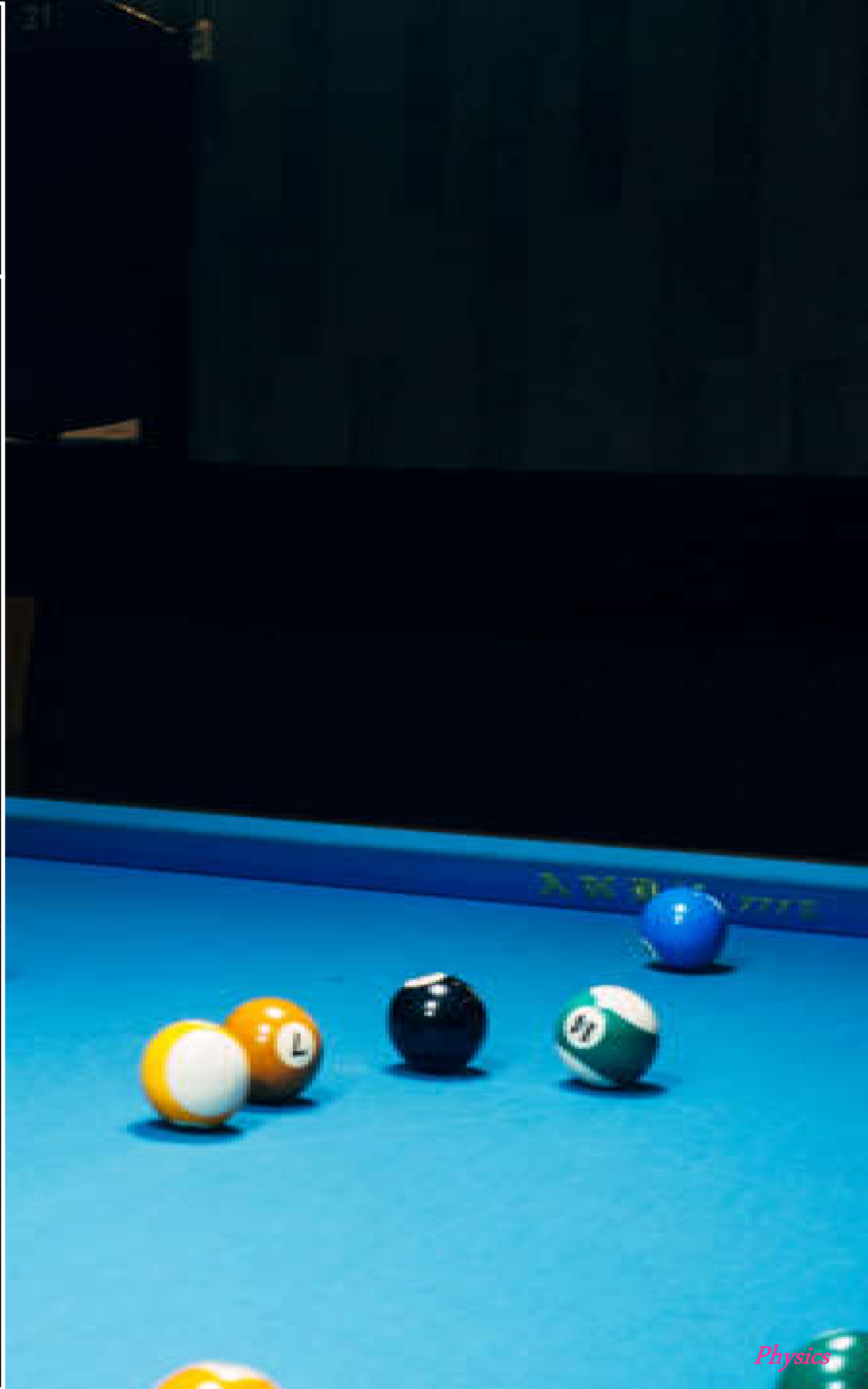
OGUN DIGICLASS

- **SUBJECT:** **PHYSICS**
- **CLASS:** **SENIOR SECONDARY SCHOOL**
- **TOPIC:** LINEAR MOMENTUM AND ITS CONSERVATION

Learning Objectives

- state the principle of conservation of momentum
- apply the principle of conservation of momentum to solve simple problems, including elastic and inelastic interactions between bodies in both one and two dimensions (knowledge of the concept of coefficient of restitution is not required)
- recognise that, for a perfectly elastic collision, the relative speed of approach is equal to the relative speed of separation
- understand that, while momentum of a system is always conserved in interactions between bodies, some change in kinetic energy may take place

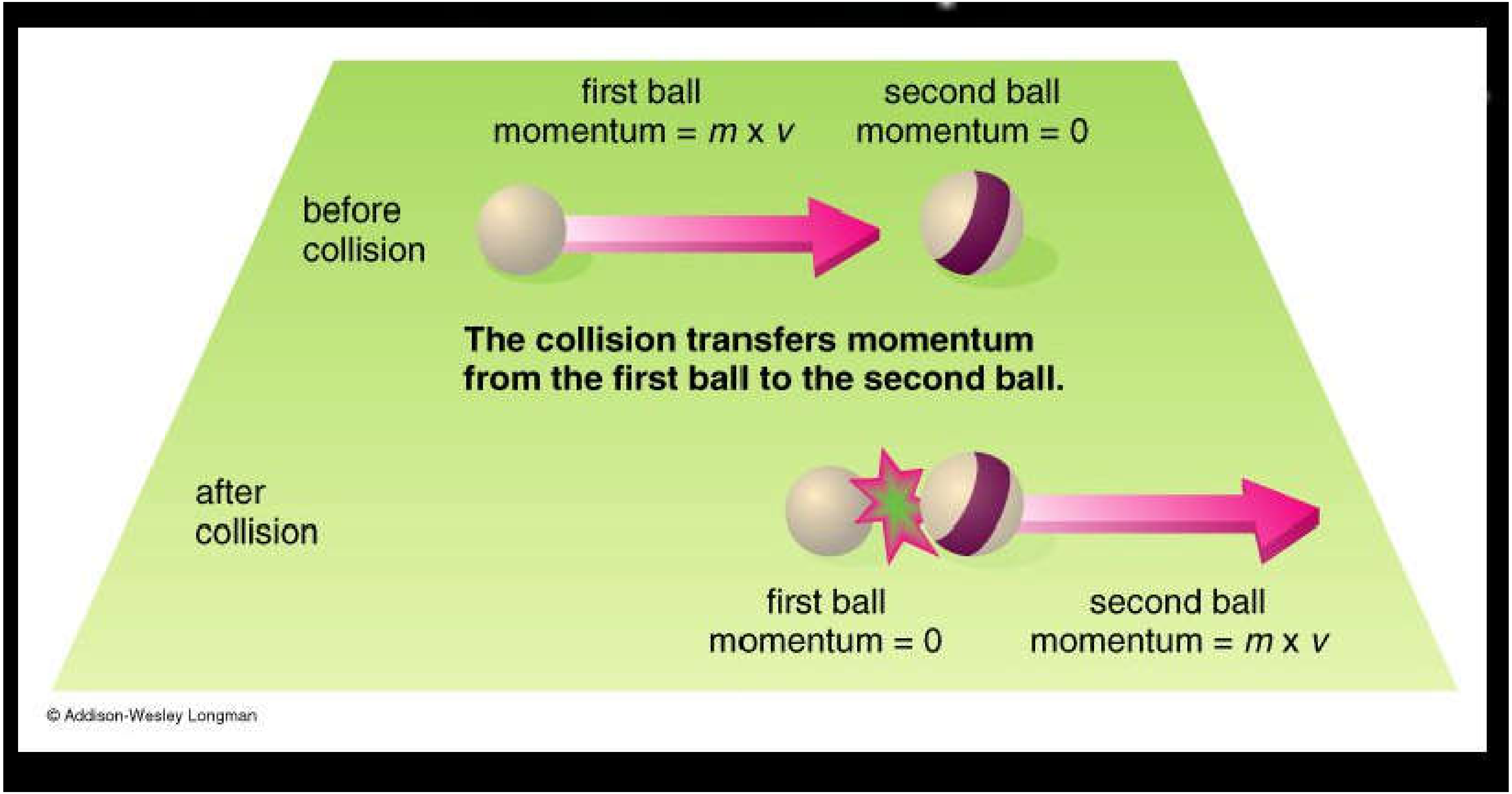


a) state the principle of conservation of momentum

Car moving to the left at 25 ms^{-1}.

A ball is fired to the right at 25 ms^{-1}.

a) state the principle of conservation of momentum

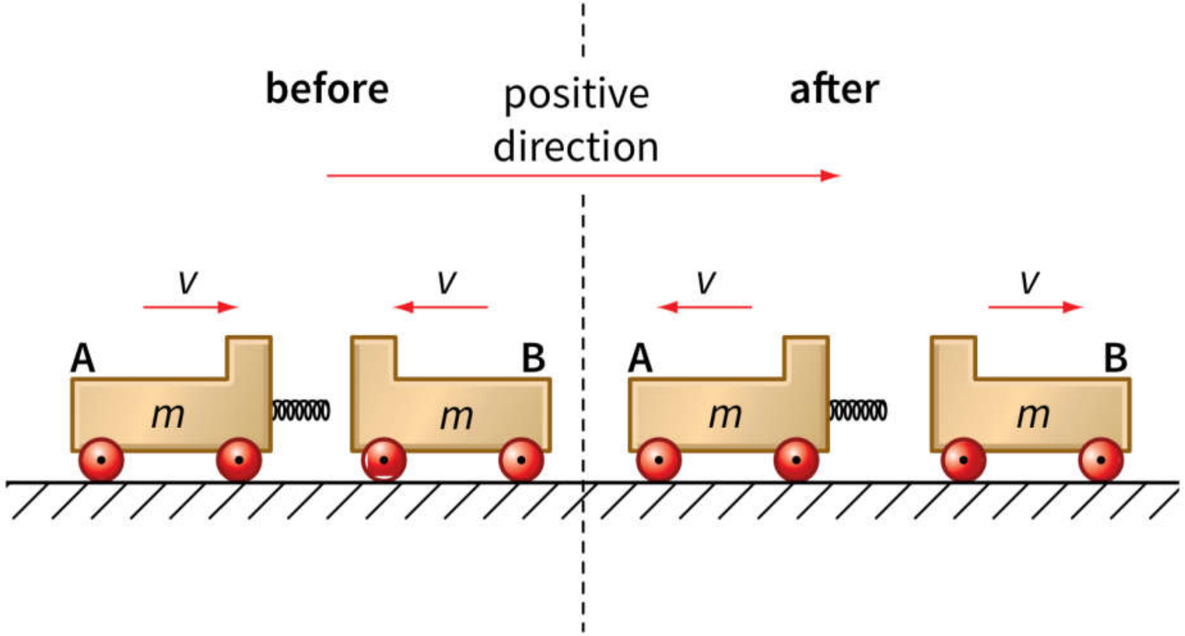


IMPORTANT

Conservation of momentum

The principle of conservation of momentum

The principle of conservation of momentum states that **for a closed system**, in any direction, the **total momentum before a collision = the total momentum after a collision.**



b) apply the principle of conservation of momentum to solve simple problems, including elastic and inelastic interactions between bodies in both one and two dimensions (knowledge of the concept of coefficient of restitution is not required)

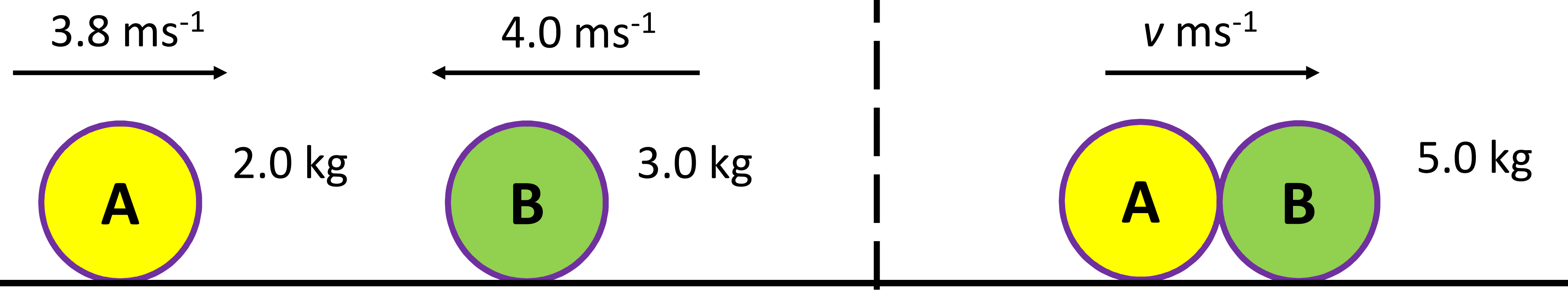
Total momentum before collision = total momentum after collision

$$m_a u_a + m_b u_b = m_a v_a + m_b v_b$$

$$(2.0 \times 3.8) + (3.0 \times -4.0) = 5 \times v$$

$$v = \frac{(2.0 \times 3.8) + (3.0 \times -4.0)}{5}$$

$$\boldsymbol{v = -\,0.88\ ms^{-1}}$$



The balls stick together upon impact

3 (a) (i) State the principle of conservation of momentum.

The principle of conservation of momentum states that for a closed system, in any direction, the **total momentum before a collision = the total momentum after a collision.** [2]

(b) An object A of mass 4.2 kg and horizontal velocity 3.6 m s^{-1} moves towards object B as shown in Fig. 3.1.

Fig. 3.1

Object B of mass 1.5 kg is moving with a horizontal velocity of 1.2 m s^{-1} towards object A.

The objects collide and then both move to the right, as shown in Fig. 3.2.

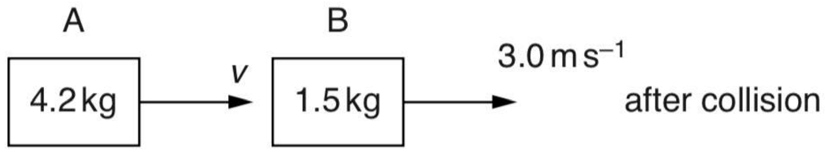


Fig. 3.2

Object A has velocity v and object B has velocity 3.0 m s^{-1}.

(i) Calculate the velocity v of object A after the collision.

Total momentum before collision = total momentum after collision

$$m_A u_A + m_B u_B = m_A v_A + m_B v_B$$

$$(4.2 \times 3.6) + (1.5 \times -1.2) = (4.2 \times v) + (1.5 \times 3.0)$$

$$4.2v = [(4.2 \times 3.6) + (1.5 \times -1.2)] - (1.5 \times 3.0)$$

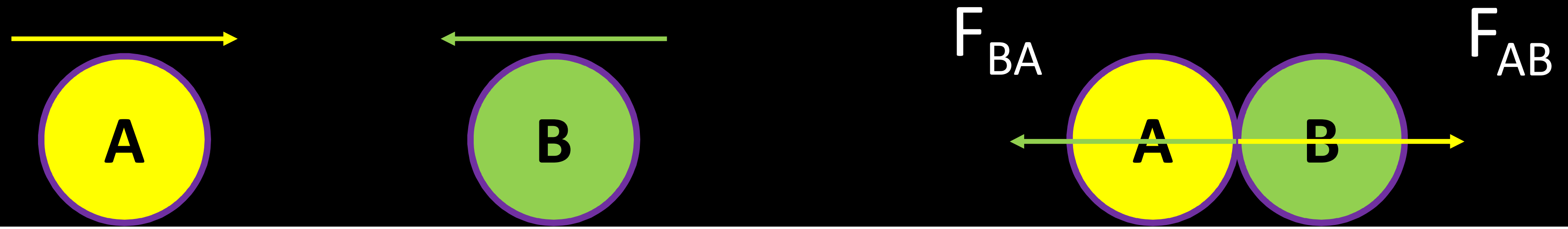
$$4.2v = 8.82$$

$$v = 2.1 \text{ ms}^{-1}$$

velocity = ...**2.1**........ m s^{-1} [3]

b) apply the principle of conservation of momentum to solve simple problems, including elastic and inelastic interactions between bodies in both one and two dimensions (knowledge of the concept of coefficient of restitution is not required)

Using Newton's 3rd law



F_{BA} is the force exerted by ball A on ball B
F_{AB} is the force exerted by ball B on ball A

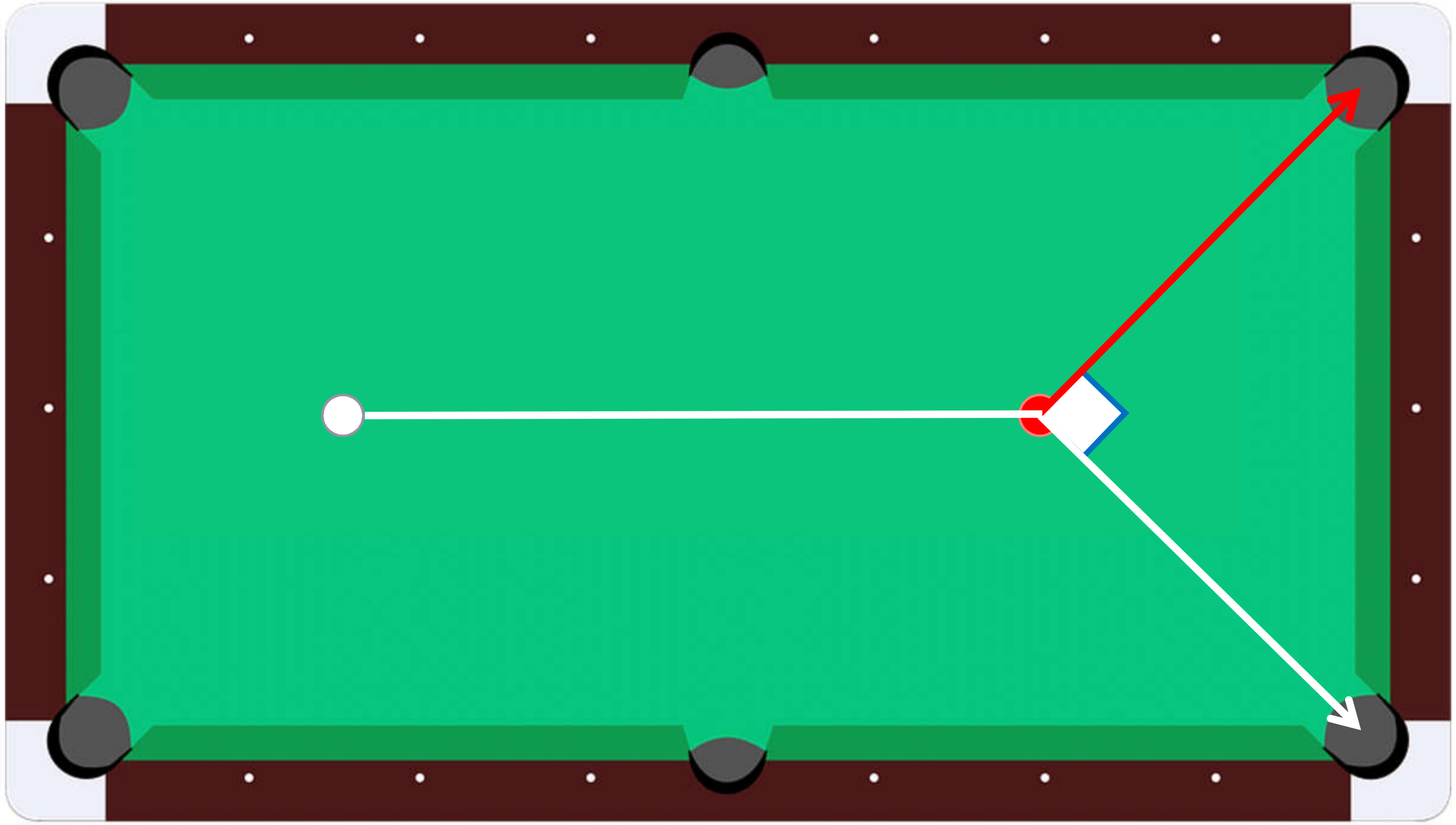
<u>Newton's third law states:</u>

$$F_{AB} = F_{BA}$$

Since the bodies are in contact for a short time, **t,** the change in momentum is given by:

$$\rho_A = F_{BA} \quad t = - F_{AB} \quad t$$ and $$\rho_B = F_{AB} \quad t$$ ∴ $$\rho_A + \quad \rho_B = 0$$

Collisions in two dimensions



$mass_{red}$ = 1.0 kg
$mass_{white}$ = 1.0 kg
speed, u_{white} = 0.5 ms^{-1}

Calculate the speed the balls move off with after the collision.

Initial momentum of white ball in y-direction = (final component of white ball in y direction) + (final component of red ball in y direction)

$$mu = mv_y + mv_y$$
$$mu = 2mv_y$$
$$v_y = v \cos 45°$$

Substituting this gives:

$$0.5 = 2v \cos 45°$$
$$v = \frac{0.5}{2 \cos 45°} = \mathbf{0.354\ ms^{-1}}$$

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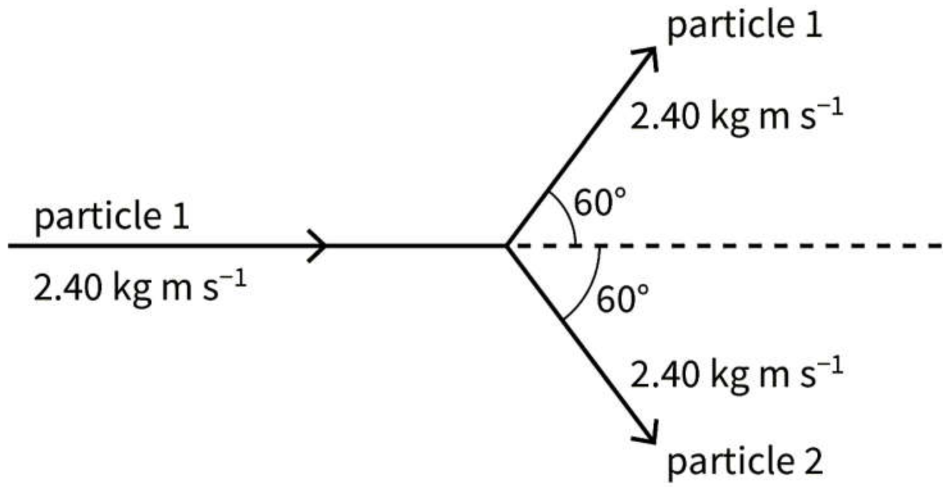
Collisions in two dimensions



The picture shows the momentum vectors for two particles, 1 and 2, before and after a collision. **Show that momentum is conserved in this collision.**

Tips:

1. Consider momentum in the y direction, before and after the collision.
2. Consider momentum in the x direction, before and after the collision.
3. Are the components of momentum in the y direction equal and opposite?
4. Are the magnitudes of momentum (before and after the collision) in the x direction equal?

Y – direction:

Before collision, momentum = 0

After collision:

ρ_1 = 2.40 sin 60° = 2.08 kg ms^{-1} upwards

ρ_2 = 2.40 sin 60° = 2.08 kg ms^{-1} downwards

Momentums are equal and opposite

x – direction:

Before collision, momentum = 2.40 kg ms^{-1}

After collision:

ρ_1 = 2.40 cos 60° = 1.20 kg ms^{-1} to the right

ρ_2 = 2.40 cos 60° = 1.20 kg ms^{-1} to the right

Total momentum = (1.20 + 1.20) = 2.40 kg ms^{-1} to the right

Momentum is conserved in both x and y directions ∴ momentum is conserved.

Elastic collisions

Object A:

mass = ***m***

velocity = ***v***

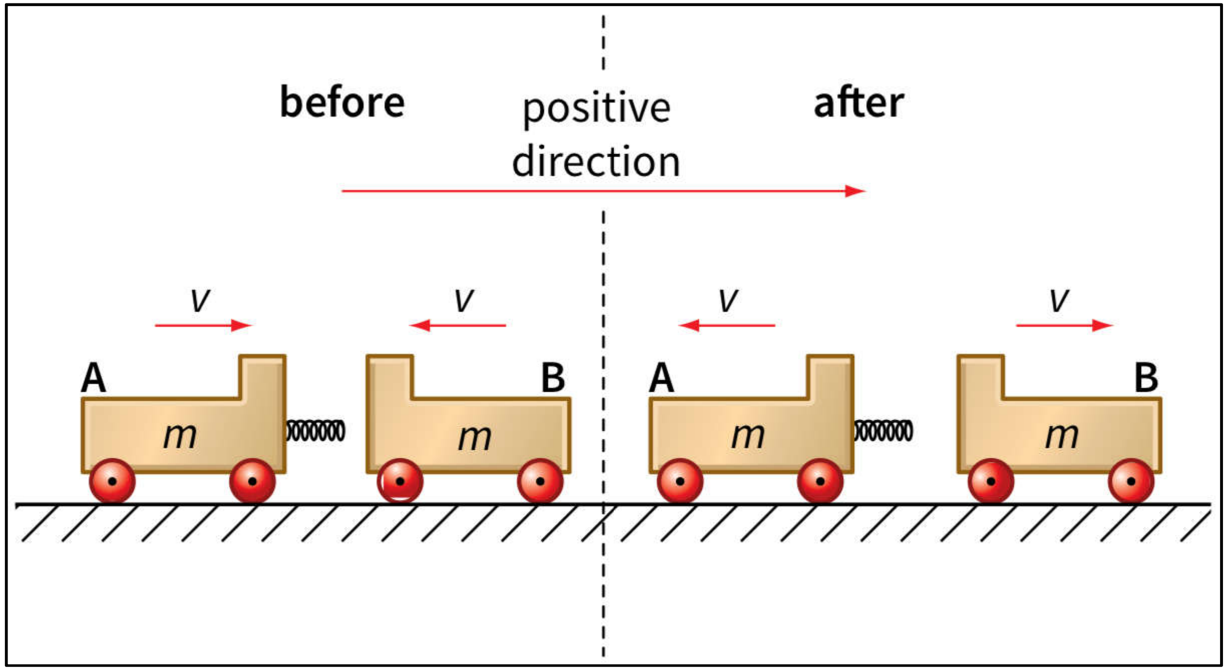
momentum = ***mv***

Object B:

mass = ***m***

velocity = **– *v***

momentum = **– *mv***



After collision:

Both objects have their velocities reversed.

Total momentum after collision

= (–mv) + mv

= **0**

Total momentum before collision

= $\rho_A + \rho_B$

= mv + (–mv)

= **0**

Total kinetic energy before collision

= $k.e._A + k.e._B$

= $½mv^2 + ½mv^2$

= $\mathbf{mv^2}$

Total kinetic energy after collision

= $½mv^2 + ½mv^2$

= $\mathbf{mv^2}$

In a perfectly elastic collision, relative speed of approach = relative speed of separation

Inelastic collisions

Object A:

mass = ***m***

velocity = ***v***

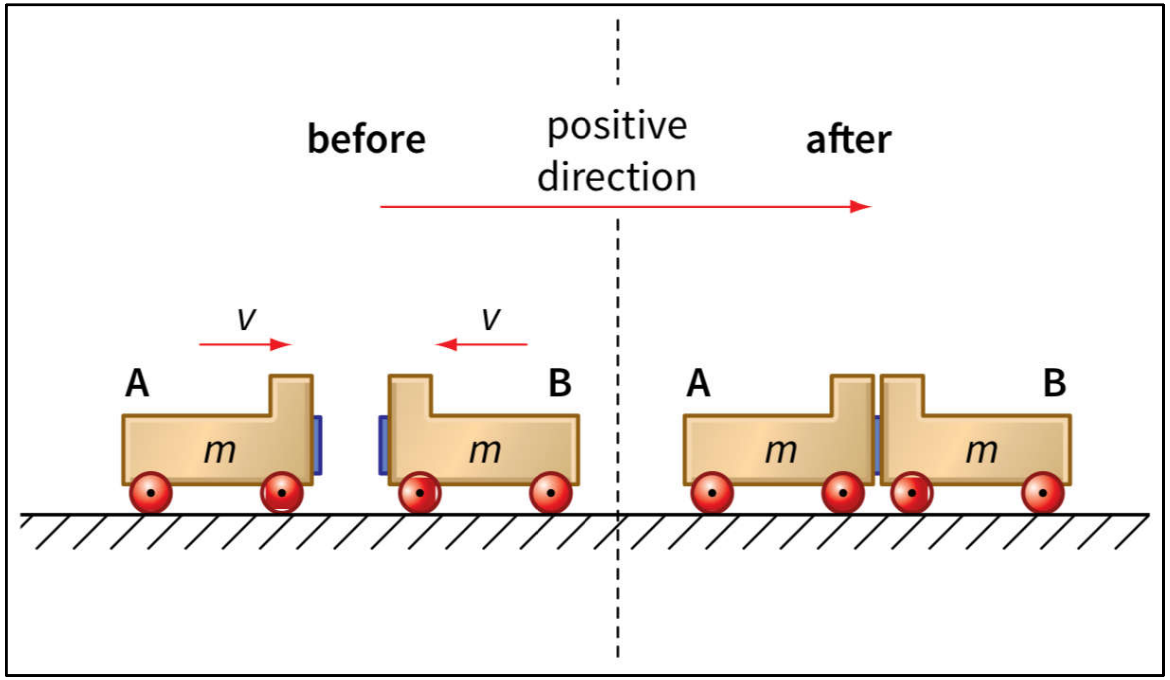
momentum = ***mv***

Object B:

mass = ***m***

velocity = **– *v***

momentum = **– *mv***



After collision:

Both objects have their velocities reversed.

Total momentum after collision

$= (-mv) + mv$

$= 0$

Total momentum before collision

$= \rho_A + \rho_B$

$= mv + (-mv)$

$= 0$

Total kinetic energy before collision

$= k.e._A + k.e._B$

$= \frac{1}{2}mv^2 + \frac{1}{2}mv^2$

$= \mathbf{mv^2}$

Total kinetic energy after collision

$= \frac{1}{2}mv^2 + \frac{1}{2}mv^2$

$= \mathbf{0}$

Velocity of the combined trolleys = 0 ms^{-1}

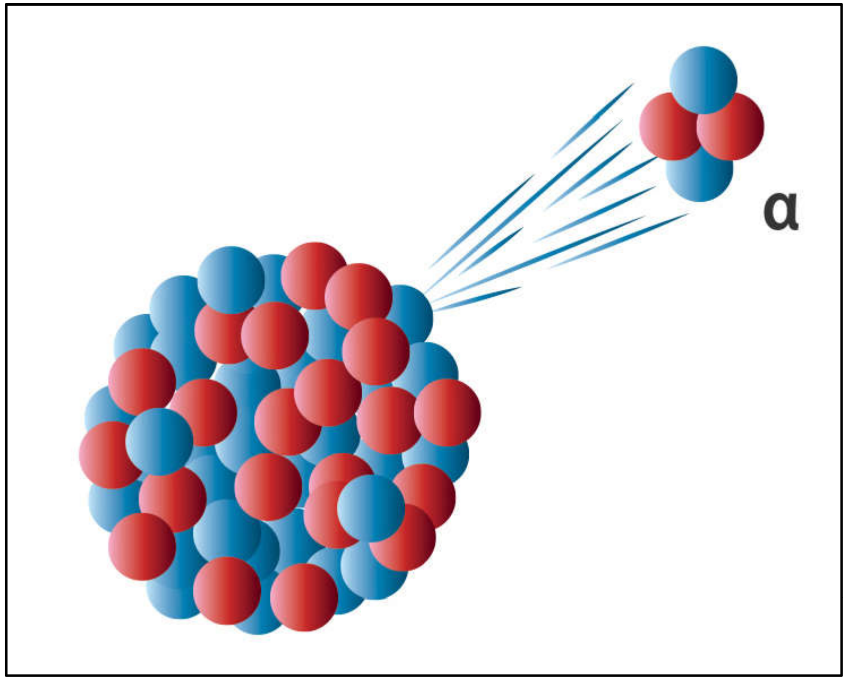
Explosions

Energy:

During an explosion, potential energy will be converted to kinetic energy.

Momentum:

There is no change in the total momentum of the system during this interaction.



Before interaction:

Before the interaction, the initial momentum = 0

After interaction:

After the interaction, the final momentum also = 0

In the case of the alpha particle being emitted, the momentum of the alpha particle in one direction = the momentum of the recoiling daughter nucleus in the other direction.

$$\rho_\alpha = - \rho_{nucleus}$$

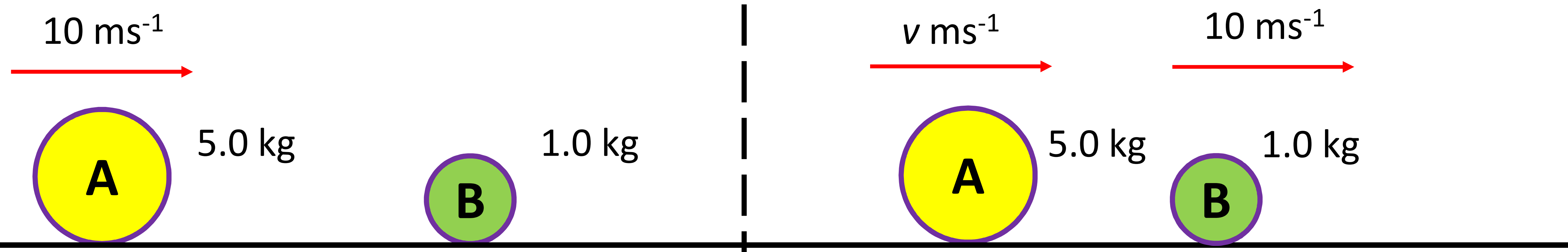
d) understand that, while momentum of a system is always conserved in interactions between bodies, some change in kinetic energy may take place

1. **Determine the final velocity of the large ball after the impact.**
2. **Calculate the kinetic energy 'lost' in the impact.**

Before | **After**

Determine the final velocity of the large ball after the impact.

$$m_a u_a + m_b u_b = m_a v_a + m_b v_b$$
$$(5.0 \times 10) + (1.0 \times 0) = (5 \times v) + (1 \times 10)$$
$$5v = (5.0 \times 10) - (1 \times 10)$$
$$5v = 50 - 10$$
$$\mathbf{v = 8.0\ ms^{-1}}$$



1. **Determine the final velocity of the large ball after the impact.**
2. **Calculate the kinetic energy 'lost' in the impact.**

Calculate the kinetic energy 'lost' in the impact.

Total kinetic energy before the collision:

$= \frac{1}{2} mv^2 + \frac{1}{2} mv^2$

$= \frac{1}{2} (5.0)(10^2) + 0$

$= \mathbf{250\ J}$

Total kinetic energy after the collision:

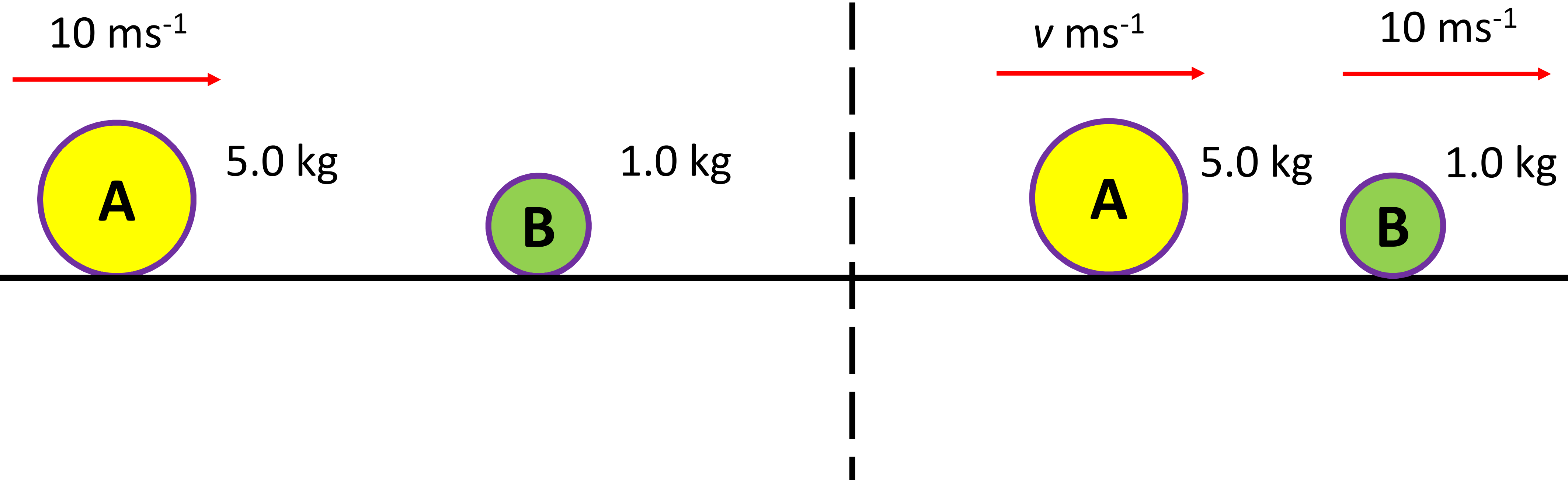
$= \frac{1}{2} mv^2 + \frac{1}{2} mv^2$

$= \frac{1}{2} (5.0)(8.0^2) + \frac{1}{2} (1.0)(10^2)$

$= \mathbf{210\ J}$

k.e. lost = 250 – 210 = 40 J

Lost kinetic energy will transfer to internal heat energy and sound energy



Assignment

When a bullet of mass 6g was fired into a wood block of mass 375g on a smooth surface, the wood block moves at a velocity of 12m/s.

Calculate

1. Velocity of the bullet?
2. KE before and after the collision?
3. Nature of the collision (Elastic/Inelastic) and WHY?