

3.6 Momentum

Name: _____ Class: _____ Date: _____

Total: 15 marks

KEY WORDS coefficient of restitution • conservation of momentum
 • oblique impact • momentum and impacts • moment

Objective

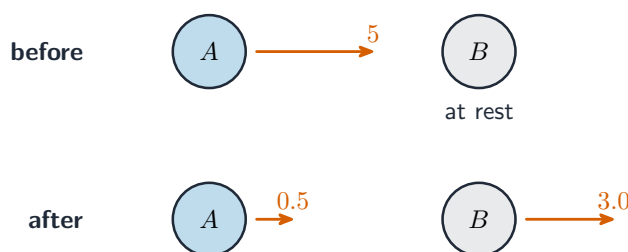
Build the skills to answer exam questions on **momentum and impacts** – conservation of momentum, the **coefficient of restitution** e , and **oblique impact**. Take $g = 10 \text{ m s}^{-2}$.

You must be able to:

- apply conservation of momentum to a collision
- use $e = \frac{\text{speed of separation}}{\text{speed of approach}}$
- resolve velocities for an oblique impact

1 Key knowledge and worked examples

■ Restitution



$$e = \frac{\text{speed of separation}}{\text{speed of approach}} = \frac{3.0 - 0.5}{5} = 0.5$$

e compares how fast the bodies separate with how fast they approached ($0 \leq e \leq 1$)

A (2 kg, 5 m s⁻¹) hits stationary B (3 kg), $e = 0.5$: momentum $2(5) = 2v_A + 3v_B$; restitution $v_B - v_A = 0.5(5) = 2.5$. Solve: $v_A = 0.5$, $v_B = 3.0 \text{ m s}^{-1}$.

■ **Key knowledge: A rebound from a smooth wall**

Resolve velocity into components parallel and perpendicular to the wall. Only the perpendicular component is reversed and scaled by restitution for a smooth fixed wall.

■ **Worked example: A rebound from a smooth wall**

A particle approaches a wall with perpendicular speed 6 and parallel speed 8 m s^{-1} . With $e = 0.5$, its outgoing components are -3 perpendicular and 8 parallel. Hence outgoing speed is $\sqrt{3^2 + 8^2} = \sqrt{73} \text{ m s}^{-1}$. The parallel component is unchanged because there is no tangential impulse.

2 Practice

2.1 State the range of possible values of the coefficient of restitution e . [1]

2.2 Two balls approach at a combined closing speed of 8 m s^{-1} with $e = 0.25$. Find their separation speed. [2]

3 Exam-style questions

3.1 A perfectly elastic collision has a coefficient of restitution: [1]

- ☐ **A** 0
B 0.5
C 1
D 2

3.2 A sphere P of mass 3 kg moving at 4 m s^{-1} collides directly with a sphere Q of mass 1 kg moving towards it at 2 m s^{-1} . The coefficient of restitution is 0.5.

(a) Write the momentum and restitution equations. [3]

(b) Find the velocities of P and Q after impact. [4]

3.3 A ball is dropped from a height of 2 m onto the floor, with coefficient of restitution 0.8 between ball and floor. Find the height of the first bounce. [4]

Solutions

Each answer shows the steps, then the **result**.

2.1

- $0 \leq e \leq 1$

2.2

- separation = $e \times$ approach = $0.25 \times 8 = 2 \text{ m s}^{-1}$

3.1 C

- A perfectly elastic collision has $e = 1$

3.2

(a)

- take P 's direction positive: momentum $3(4) + 1(-2) = 3v_P + 1v_Q$, i.e. $3v_P + v_Q = 10$;
restitution $v_Q - v_P = 0.5(4 - (-2)) = 3$

(b)

- from the two equations: $v_Q = v_P + 3$; $3v_P + v_P + 3 = 10 \Rightarrow 4v_P = 7 \Rightarrow v_P = 1.75 \text{ m s}^{-1}$;
 $v_Q = 4.75 \text{ m s}^{-1}$

3.3

- speed hitting floor: $v = \sqrt{2g(2)} = \sqrt{40} = 6.32 \text{ m s}^{-1}$; rebound speed = $ev = 0.8(6.32) = 5.06 \text{ m s}^{-1}$; bounce height = $\frac{(ev)^2}{2g} = \frac{25.6}{20} = 1.28 \text{ m}$