5.5 Successive impacts and wall rebounds

Name: _____ Class: _____ Date: _____ **Total: 23 marks**

KEY WORDS restitution • separation speed

Successive impacts and wall rebounds

Objective

Chain collisions: solve each impact completely, carry speeds into the next, handle rebounds from fixed walls (speed scaled by e, direction reversed), and equate only what the question ties together (objectives 4.1–4.3).

1 Key knowledge and worked examples

Chains. A fixed wall collision multiplies the speed by the wall's restitution and reverses direction – no momentum equation (the wall is immovable). Between two moving particles, momentum + restitution as usual. Work stage by stage with a signed diagram; "same speed" or "at rest" conditions close the algebra.

Worked example – matching a rebound (WME02 June 2025 Q5d). After the collision of Q5, Q moves at $\frac{2(1+e)u}{3}$ and P at $\frac{(2-e)u}{3}$ with $e = \frac{1}{3}$, so $v_Q = \frac{8}{9}u$ and $v_P = \frac{5}{9}u$. Q hits a wall with restitution f and rebounds matching P's speed: $f \cdot \frac{8}{9}u = \frac{5}{9}u$, so $f = \frac{5}{8}$.

2 Practice

2.1 A ball hits a smooth wall at $8\ \mathrm{m\,s^{-1}}$ perpendicularly with $e = 0.4$. Find its rebound speed. [1]

2.2 A 1 kg ball moving right at 6 m s^{-1} hits a wall ($e = \frac{1}{3}$) and rebounds into a stationary 2 kg ball, with which it collides with restitution $\frac{1}{2}$. Find the 2 kg ball's speed after. [5]

2.3 Three particles A, B, C in a line: A (m) at $3u$ hits B (m) at rest with $e = \frac{1}{2}$; B then hits C (2m) at rest with $e = \frac{1}{4}$. Find C's final speed. [6]

3 Exam-style questions

3.1 *(Edexcel IAL WME02 June 2025 Q5d.)* Following the collision of question 3.1 on the collisions sheet (masses $2m$ and m, restitution $e = \frac{1}{3}$): Q now moves towards a fixed vertical wall at right angles to its motion and rebounds with coefficient of restitution f. Given that immediately after the rebound Q has the same speed as P, find f. [3]

3.2 *(Original.)* Two balls P (1 kg) and Q (2 kg) lie in a line on a smooth floor between two parallel walls. P is projected at 12 $\mathrm{m\,s^{-1}}$ towards Q; they collide with $e = \frac{1}{2}$; Q then hits the far wall with $e = \frac{1}{3}$ and rebounds to collide with P again. Find the speeds of both balls after the second P–Q collision, given it has restitution $\frac{1}{3}$. [8]

Solutions

2.1 $0.4 \times 8 = 3.2\ \mathrm{m\,s^{-1}}$.

2.2 The ball rebounds at $6 \times \frac{1}{3} = 2\ \mathrm{m\,s^{-1}}$, leftward, so -2 with right positive. Momentum: $1(-2) = v_1 + 2v_2$; restitution with approach speed 2: $\frac{1}{2} = \frac{v_2 - v_1}{2}$, so $v_2 = v_1 + 1$. Substituting: $-2 = v_1 + 2(v_1 + 1) = 3v_1 + 2$, so $v_1 = -\frac{4}{3}$ and $v_2 = -\frac{1}{3}$: the 2 kg ball moves off at $\frac{1}{3}\ \mathrm{m\,s^{-1}}$ to the left.

2.3 First collision (A into B): $3u = v_A + v_B$ and $\frac{1}{2}(3u) = v_B - v_A$: $v_B = \frac{9}{4}u$, $v_A = \frac{3}{4}u$. Second (B into C): $\frac{9}{4}u = v'_B + 2v_C$ and $\frac{1}{4} \cdot \frac{9}{4}u = v_C - v'_B$: $v_C - v'_B = \frac{9u}{16}$. Adding: $3v_C = \frac{36u}{16} + \frac{9u}{16} = \frac{45u}{16}$, so $v_C = \frac{15u}{16}$.

3.1 After the first collision: $v_Q = \frac{2(1+\frac{1}{3})u}{3} = \frac{8}{9}u$ and $v_P = \frac{(2-\frac{1}{3})u}{3} = \frac{5}{9}u$. Rebound: $f \cdot \frac{8}{9}u = \frac{5}{9}u$, so $f = \frac{5}{8}$.

3.2 First collision: $12 = v_P + 2v_Q$ and $\frac{1}{2}(12) = v_Q - v_P$ give $v_Q = 10$, $v_P = -2$ (P rebounds left at 2). Q hits the far wall and rebounds at $10 \times \frac{1}{3} = \frac{10}{3}$ leftward. Q (leftward at $\frac{10}{3}$) now catches P (leftward at 2): approach speed $= \frac{10}{3} - 2 = \frac{4}{3}$. Right positive, momentum: $1(-2) + 2(-\frac{10}{3}) = v'_P + 2v'_Q$, i.e. $-\frac{26}{3} = v'_P + 2v'_Q$. Restitution: the separation speed after is $\frac{1}{3} \times \frac{4}{3} = \frac{4}{9}$ with P separating leftward faster, so $v'_Q - v'_P = \frac{4}{9}$, i.e. $v'_P = v'_Q - \frac{4}{9}$. Substituting: $-\frac{26}{3} = 3v'_Q - \frac{4}{9}$, so $3v'_Q = -\frac{74}{9}$ and $v'_Q = -\frac{74}{27} = -2.74$; $v'_P = -\frac{86}{27} = -3.19\ \mathrm{m\,s^{-1}}$. Both continue leftward: P at $3.19\ \mathrm{m\,s^{-1}}$, Q at $2.74\ \mathrm{m\,s^{-1}}$.

Local review guidance: wall rebounds as pure speed scaling before any momentum work; each collision solved completely with a signed diagram; "same speed" conditions applied to the correct stage. This is authored classroom guidance.