M1 Momentum and Impulse: exam questions

10 questions · 35 marks · full mark schemes

Name _____ Date _____ Score / 35

- Momentum, impulse = change in momentum, conservation of momentum in direct collisions.
- Try every question before you look at the mark schemes. They start after the questions: M marks for method, A marks for accuracy, B marks for a correct result on its own.
- Online, with more practice: alevelmathrevision.com/alevel-frontend/units/m1/momentum-impulse-questions

1. **3 marks · warm-up**

Particle A of mass $3\ \text{kg}$ is moving with a speed of $4\ \text{m s}^{-1}$ along a smooth horizontal surface when it collides directly with a stationary particle B of mass $2\ \text{kg}$. The two particles coalesce (join together) to form a single particle C. Find the speed of C immediately after the collision.

2. **3 marks · standard**

A ball of mass $0.2\ \text{kg}$ strikes a vertical wall at right angles with a speed of $6\ \text{m s}^{-1}$ and rebounds in the opposite direction with a speed of $4\ \text{m s}^{-1}$. Calculate the magnitude of the impulse exerted by the wall on the ball.

3. 3 marks · standard

Two particles, P of mass $4\ \text{kg}$ and Q of mass $1\ \text{kg}$, move towards each other along a smooth horizontal line, each with speed $5\ \text{m s}^{-1}$. They collide and coalesce, and the combined particle moves at $3\ \text{m s}^{-1}$ in P's original direction of motion. Calculate the magnitude of the impulse exerted on particle Q during the collision.

4. 3 marks · standard

Two particles P and Q, of masses $2\ \text{kg}$ and $3\ \text{kg}$, are connected by a light inextensible string and are at rest on a smooth horizontal floor with the string slack. Q is projected directly away from P with speed $10\ \text{m s}^{-1}$. When the string becomes taut, both particles move with speed $6\ \text{m s}^{-1}$. Find the magnitude of the impulse transmitted through the string when it becomes taut.

5. 4 marks · standard

A particle of mass $2\ \text{kg}$ has its velocity changed from $(\mathbf{i} + 3\mathbf{j})\ \text{m s}^{-1}$ to $(4\mathbf{i} - \mathbf{j})\ \text{m s}^{-1}$ by an impulse $\mathbf{I}$. Calculate the magnitude of $\mathbf{I}$.

6. 4 marks · standard

Two particles, P of mass $4\ \text{kg}$ and Q of mass $1\ \text{kg}$, are moving towards each other in opposite directions on a smooth horizontal line. P has a speed of $5\ \text{m s}^{-1}$ and Q has a speed of $5\ \text{m s}^{-1}$. They collide and coalesce to form a single particle. Find the speed of the combined particle and state its direction of motion.

7. 3 marks · harder

A cart of mass $M\ \text{kg}$ is rolling on a smooth horizontal track at a speed of $10\ \text{m s}^{-1}$. A parcel of mass $5\ \text{kg}$ is dropped vertically into the cart. The speed of the cart and parcel becomes $8\ \text{m s}^{-1}$. Calculate the value of M.

8. 4 marks · harder

Three particles A, B, and C of masses $2\ \text{kg}$, $3\ \text{kg}$, and $1\ \text{kg}$ respectively lie at rest in a straight line on a smooth horizontal surface. A is projected towards B at $5\ \text{m s}^{-1}$. When A collides with B, they coalesce. The combined particle AB then collides with C and coalesces. Find the final speed of the combined particle ABC.

9. **4 marks · harder**

Particle A of mass $3m$ is moving with speed u and collides with particle B of mass m moving in the opposite direction with speed $2u$. As a result of the collision, A is brought to instantaneous rest. Find the speed and direction of B after the collision.

10. **4 marks · harder**

A particle A of mass $0.1\ \text{kg}$ falls from rest from a height of $2.45\ \text{m}$ above horizontal ground. It collides with the ground and does not rebound. Find the magnitude of the impulse exerted by the ground on A. (Take $g = 9.8\ \text{m s}^{-2}$)

Answers and worked solutions

Question 1

3 marks

1. M1 for applying the principle of conservation of linear momentum: $m_A u_A + m_B u_B = (m_A + m_B)v$.
2. M1 for substituting the values: $3(4) + 2(0) = (3+2)v$.
3. A1 for solving to find $v = \frac{12}{5} = 2.4\ \text{m s}^{-1}$.

Question 2

3 marks

1. M1 for establishing the change in velocity with correct signs, taking the rebound direction as positive: $v = 4$, $u = -6$.
2. M1 for applying $I = m(v-u) = 0.2(4-(-6))$.
3. A1 for calculating the magnitude as $0.2 \times 10 = 2\ \text{N s}$.

Question 3

3 marks

1. M1 for identifying the impulse on Q is equal to its change in momentum: $I = m_Q|v - u_Q|$.
2. M1 for substituting the velocities with consistent signs. Since Q's initial direction was negative, $u = -5$ and $v = 3$. Impulse magnitude $= 1|3-(-5)|$.
3. A1 for calculating $1 \times 8 = 8\ \text{N s}$.

Question 4

3 marks

1. M1 for identifying that the impulse in the string is equal to the change in momentum of either particle.
2. M1 for calculating the change in momentum for particle P: $I = 2(6-0)$. (Alternatively, for Q: $I = 3(10-6)$).
3. A1 for evaluating to $12\ \text{N s}$.

Question 5

4 marks

1. M1 for setting up $\mathbf{I} = m(\mathbf{v} - \mathbf{u}) = 2((4\mathbf{i} - \mathbf{j}) - (\mathbf{i} + 3\mathbf{j}))$.
2. M1 for finding the vector $\mathbf{I} = 2(3\mathbf{i} - 4\mathbf{j}) = 6\mathbf{i} - 8\mathbf{j}$.
3. M1 for finding the magnitude $|\mathbf{I}| = \sqrt{6^2 + (-8)^2}$.
4. A1 for evaluating to $10\ \text{N s}$.

Question 6

4 marks

1. M1 for setting up the conservation of momentum equation with opposite signs for velocities: $4(5) + 1(-5) = (4+1)v$.
2. M1 for simplifying to $20 - 5 = 5v \implies 15 = 5v$.
3. A1 for finding $v = 3\ \text{m s}^{-1}$.
4. A1 for stating the direction is the same as P's initial direction (since v is positive).

Question 7

3 marks

1. M1 for applying conservation of horizontal momentum, noting the parcel has no initial horizontal momentum: $10M + 5(0) = (M+5)8$.
2. M1 for expanding and rearranging: $10M = 8M + 40 \implies 2M = 40$.
3. A1 for finding $M = 20\ \text{kg}$.

Question 8

4 marks

1. M1 for setting up the overall conservation of momentum from start to finish, since momentum is conserved in both inelastic collisions.
2. M1 for writing $m_A u_A = (m_A + m_B + m_C)v$.
3. A1 for substituting values: $2(5) = (2+3+1)v \implies 10 = 6v$.
4. A1 for finding the final speed $v = \frac{5}{3}\ \text{m s}^{-1}$.

Question 9

4 marks

1. M1 for writing the conservation of momentum equation, taking A's initial direction as positive: $3m(u) + m(-2u) = 3m(0) + mv_B$.
2. M1 for simplifying: $3mu - 2mu = mv_B \implies mu = mv_B$.
3. A1 for finding $v_B = u$.
4. A1 for stating that B's direction is now reversed (it is now moving in A's initial direction).

Question 10

4 marks

1. M1 for finding the velocity on impact using $v^2 = u^2 + 2as$: $v^2 = 0 + 2(9.8)(2.45)$.
2. A1 for calculating $v^2 = 48.02 \implies v = 6.93\ \text{m s}^{-1}$.
3. M1 for setting up the impulse calculation: $I = m(v-u) = 0.1(0-(-6.93))$.
4. A1 for evaluating to $0.693\ \text{N s}$.

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