

Elastic and inelastic collisions with centre of mass

AP Physics 1 (algebra-based) · Test answers (mark scheme)

Award marks for correct method as well as for the final answer, and allow follow-through from an earlier wrong value. Penalise a missing unit or sign once only. The written answers can be worded differently if the physics idea is clear.

Level: AP Physics 1 (algebra-based) · **Curriculum:** AP P1 Unit 4

Question 1 Core ideas (2 marks)

- The net external force on the system is zero (or negligible during the collision).
- The mass-weighted average position of the objects; $v_{\text{cm}} = (m_1 v_1 + m_2 v_2) \div (m_1 + m_2)$.

Marking: one mark for each part.

Question 2 Classify the events (2 marks)

- Inelastic: kinetic energy is transformed (perfectly inelastic as far as the putty is concerned).
- Elastic.

Marking: one mark for each classification, with a reason.

Question 3 Trolleys that couple (3 marks)

- $1.2 + 0.45 = 1.5 v$, so $v = \mathbf{1.1 \text{ m/s}}$.
- Before: $1.2 + 0.1125 = 1.3125 \text{ J}$. After: $\frac{1}{2} \times 1.5 \times 1.1^2 = 0.9075 \text{ J}$. Loss = **0.41 J** (0.405 J).

Marking: (a) 1 mark momentum equation, 1 mark answer; (b) 1 mark.

Question 4 An elastic collision (3 marks)

- $v_1 = (0.30 - 0.10) \times 4.0 \div 0.40 = \mathbf{2.0 \text{ m/s}}$; $v_2 = 2 \times 0.30 \times 4.0 \div 0.40 = \mathbf{6.0 \text{ m/s}}$.
- Before: $\frac{1}{2} \times 0.30 \times 16 = 2.4 \text{ J}$. After: $\frac{1}{2} \times 0.30 \times 4.0 + \frac{1}{2} \times 0.10 \times 36 = 0.6 + 1.8 = 2.4 \text{ J}$.

Marking: (a) 1 mark each velocity; (b) 1 mark for both totals.

Question 5 Centre of mass (3 marks)

- a. $x_{\text{cm}} = (4.0 \times 0.10 + 2.0 \times 0.70) \div 6.0 = 1.8 \div 6.0 = \mathbf{0.30 \text{ m}}$.
b. Take right as positive: $p = 4.0 \times 1.5 - 2.0 \times 3.0 = 0$, so $v_{\text{cm}} = \mathbf{0}$.

Marking: (a) 1 mark substitution, 1 mark answer; (b) 1 mark.

Question 6 Third law and conservation (2 marks)

At every instant the two objects exert equal and opposite forces on each other for the same contact time. The impulses $F \Delta t$ are therefore equal and opposite, so the changes in momentum are equal and opposite and the total momentum of the pair is unchanged.

Marking: 1 mark equal and opposite forces for the same time; 1 mark equal and opposite impulses or changes in momentum.

Question 7 Identify the collision (3 marks)

- a. $3.0 - 1.0 = 2.0 = 1.5 \times 0.20 + 1.0 v$, so $v = \mathbf{+1.7 \text{ m/s}}$.
b. Before: $3.0 + 0.5 = 3.5 \text{ J}$. After: $0.03 + 1.445 = \mathbf{1.475 \text{ J}}$.
c. Kinetic energy is lost but the carts separate: **inelastic**.

Marking: one mark for each part.

Question 8 Paragraph argument (2 marks)

The statement is incorrect. Momentum and kinetic energy are conserved under different conditions: momentum needs only zero net external force, so it is conserved in every isolated collision. Kinetic energy is conserved only if no energy is transformed to thermal energy, sound or deformation. A perfectly inelastic collision loses kinetic energy but still conserves momentum.

Marking: 1 mark for stating that momentum is still conserved with the condition; 1 mark for explaining where kinetic energy goes.