

Elastic and inelastic collisions with centre of mass

AP Physics 1 (algebra-based) · Worksheet

Name: _____ Date: _____ Class: _____

These 20 problems build the skills used in AP Physics 1 unit 4 collision questions: choosing a system, writing a signed momentum equation, comparing kinetic energy, and following the centre of mass. They run from simple classification to multi-step calculations. The last five problems are in the style of the free-response section, with a derivation, an experimental design, a graph-based timeline and a written argument. Draw a before-and-after sketch for every problem and check each answer with a second method.

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

Problem 1 Sorting collisions (easy)

Classify each event as elastic, inelastic or perfectly inelastic, and say which quantity is conserved in all three cases.

1. Two lumps of modelling clay collide and stick.
2. Two hard steel balls collide and bounce with no loss of kinetic energy.
3. A van hits a barrier and the front crumples; the van rebounds slowly.

Problem 2 Balancing point of two masses (easy)

Find the centre of mass position for each pair on a metre rule.

1. 3.0 kg at $x = 0$ and 1.0 kg at $x = 0.80$ m.
2. 2.0 kg at $x = -1.0$ m and 6.0 kg at $x = 3.0$ m.

Problem 3 Carts that stick (easy)

In a school lab in Lagos, Chiamaka rolls a 0.80 kg cart at 1.5 m/s into a 0.40 kg cart at rest. The carts stick together.

1. Calculate the total momentum before the collision.
2. Calculate the speed of the joined carts.

Problem 4 Choosing the system (easy)

Two toy trucks collide on a smooth table. Truck A has momentum that changes a lot in the collision.

1. Explain why the momentum of truck A alone is not conserved.
2. Explain why the momentum of the pair of trucks is conserved.

Problem 5 Energy lost when carts stick (easy)

Use the data of the carts in the Chiamaka problem (0.80 kg at 1.5 m/s hits 0.40 kg at rest, final speed 1.0 m/s).

1. Calculate the kinetic energy before and after.
2. Calculate the kinetic energy lost and the percentage lost.

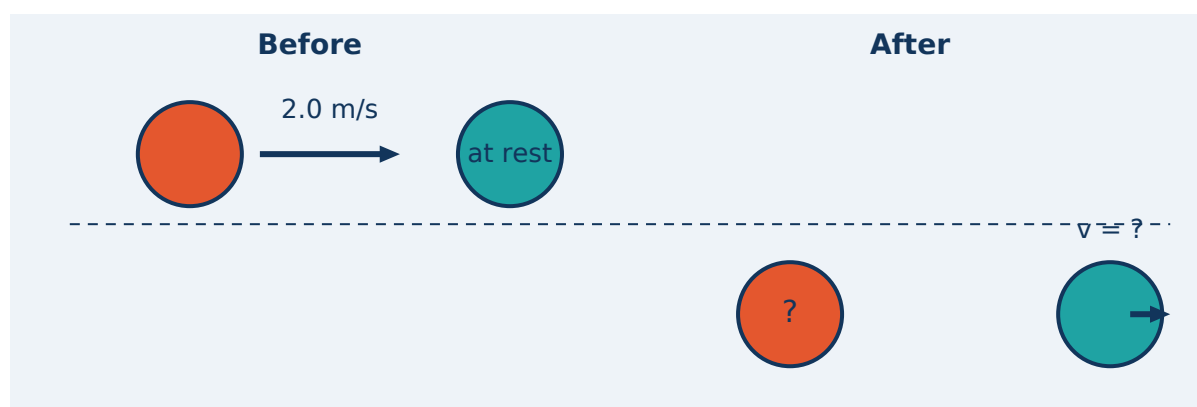
Problem 6 Centre of mass velocity (easy)

A 2.0 kg cart moves at +4.0 m/s and a 3.0 kg cart moves at −2.0 m/s on the same track.

1. Calculate the velocity of the centre of mass.
2. State what the velocity of the centre of mass is after they collide, if no outside force acts.

Problem 7 Curling takeout (medium)

In Winnipeg, Noah slides a 19 kg curling stone at 2.0 m/s head-on into an identical stationary stone. Assume an elastic collision.



Two identical stones.

1. Calculate the velocity of each stone after the collision.
2. Calculate the velocity of the centre of mass before and after.

Problem 8 Crash test at the proving ground (medium)

In Texas, Diego watches a 1200 kg test car at 20 m/s hit an 800 kg stationary car. The two interlock.

1. Calculate their speed immediately after the impact.
2. Calculate the kinetic energy transformed.
3. Suggest where this energy goes.

Problem 9 Find the unknown cart (medium)

In Lahore, Bilal rolls a 0.50 kg cart at 2.4 m/s into a second cart of unknown mass at rest. They stick and move at 1.5 m/s.

1. Write the momentum equation.
2. Calculate the mass of the second cart.

Problem 10 Reading a velocity graph (medium)

The graph shows two carts colliding. Cart A has mass 2.0 kg.



Velocity against time for the collision.

1. Read the velocities of both carts before and after the collision.
2. Calculate the mass of cart B.
3. Decide whether the collision is elastic. Support your answer with kinetic energy values.

Problem 11 Heavy hits light (medium)

At a school in Singapore, Mei sends a 2.0 kg trolley at 3.0 m/s into a 1.0 kg trolley at rest. Springs make the collision elastic.

1. Calculate both velocities after the collision.
2. Show that the speed of approach equals the speed of separation.

Problem 12 Head-on trolleys stop dead (medium)

In Accra, Kofi's 20 kg trolley moves at 1.5 m/s towards a 30 kg trolley moving at 1.0 m/s the other way. They hook together.

1. Calculate the final velocity.
2. Calculate the kinetic energy lost.

Problem 13 Equal and opposite impulses (medium)

Return to the carts of the Chiamaka problem (0.80 kg from 1.5 m/s to 1.0 m/s; 0.40 kg from rest to 1.0 m/s). The contact lasts 0.050 s.

1. Calculate the change in momentum of each cart.
2. Calculate the average force on each cart.

Problem 14 Three masses on a light rod (medium)

Masses of 1.0 kg, 2.0 kg and 3.0 kg are fixed at positions 0, 0.30 m and 0.90 m on a light

rod.

1. Calculate the position of the centre of mass.
2. Suggest where you could place a pivot so the rod balances horizontally.

Problem 15 Checking recorded data (medium)

A student records a collision on a track: a 0.50 kg cart at 0.80 m/s hits a 0.25 kg cart at rest. Afterwards the speeds are 0.27 m/s (first cart, forward) and 1.06 m/s (second cart).

1. Calculate the total momentum before and after.
2. Calculate the total kinetic energy before and after.
3. State what kind of collision this is, allowing for measurement error.

Problem 16 Sticking to a heavy cart (hard)

A cart of mass m_1 and speed u hits a stationary cart of mass m_2 and they stick.

1. Derive an expression for the final speed in terms of m_1 , m_2 and u .
2. Show that the fraction of kinetic energy retained is $m_1 \div (m_1 + m_2)$.
3. The second cart is nine times heavier and $u = 5.0$ m/s. Calculate the final speed and the percentage of kinetic energy lost.

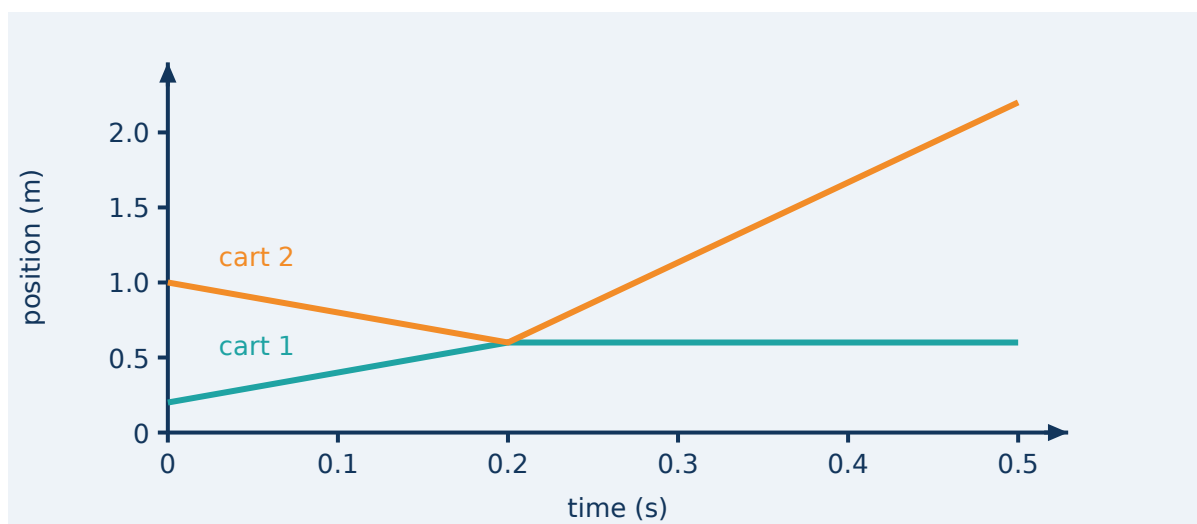
Problem 17 Designing a test of momentum conservation (hard)

A teacher gives you two dynamics carts, a level track, a balance, two photogates with a timer, and a hook-and-loop strip for one end of each cart. Design an experiment to test whether momentum is conserved when the carts stick together.

1. List the measurements and say how you obtain each speed.
2. Describe how you analyse the data and what result supports conservation of momentum.
3. Identify one systematic error and say how to reduce it.

Problem 18 Timeline of a point collision (hard)

A 1.5 kg cart at $x = 0.20$ m moves at +2.0 m/s towards a 0.50 kg cart at $x = 1.00$ m moving at -2.0 m/s. Treat the carts as points. The collision is elastic.



Positions of both carts against time.

1. Calculate the time and the position of the collision.
2. Calculate both velocities after the collision.
3. Calculate the position of the centre of mass at $t = 0.50$ s in two different ways.

Problem 19 Partly inelastic bounce (hard)

A 2.0 kg cart at +3.0 m/s meets a 1.0 kg cart at -1.5 m/s. After the collision the 2.0 kg cart moves at +0.50 m/s.

1. Calculate the velocity of the 1.0 kg cart after the collision.
2. Calculate the kinetic energy lost.
3. Calculate the ratio of the speed of separation to the speed of approach and comment.

Problem 20 Evaluating a claim (hard)

Two 1500 kg cars travel towards each other at 10 m/s on a straight road in Leeds. They collide head-on and stop together. A student writes: "Momentum was destroyed in the crash because the cars stopped."

1. Calculate the total momentum before and after and the kinetic energy transformed.
2. Write a short paragraph that evaluates the student's claim, using the idea of a system and internal forces.