

Momentum conservation, impulse and collision types

Physics grades 11-12 (A Level · IB · Class 11-12) · Worksheet

Name: _____ Date: _____ Class: _____

These twenty problems cover momentum, impulse, $F = \Delta p / \Delta t$, force-time graphs and collisions. Early problems build the formulas, middle problems use conservation in one dimension, and the final problems add two dimensions, a ballistic pendulum, continuous flow and a proof for elastic collisions.

They suit A Level, IB physics and CBSE Class 11 students. Choose a positive direction first and write the signs of all velocities.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB A.2

Problem 1 Key relationships (easy)

Write each relationship.

1. Momentum in terms of mass and velocity, with its unit.
2. Impulse in terms of force and time, and in terms of momentum.
3. The condition for momentum to be conserved.
4. How an elastic collision differs from an inelastic one.

Problem 2 Motorbike momentum (easy)

Chiamaka and her motorbike have a total mass of 210 kg and travel at 54 km/h.

1. Convert the speed to m/s.
2. Calculate the momentum.
3. Calculate the momentum at twice the speed.

Problem 3 Pushing a cart (easy)

A farm worker pushes a 85 kg cart from rest with a steady resultant force of 70 N for 6.0 s.

1. Calculate the impulse.
2. State the change in momentum.
3. Calculate the final speed of the cart.

Problem 4 Same unit, two names (easy)

1. Show that the newton second is equivalent to the kilogram metre per second.
2. A van of mass 2.5 tonnes travels at 36 km/h. Calculate its momentum in kg m/s.

Problem 5 Catching a volleyball (easy)

A volleyball of mass 0.27 kg falls at 6.0 m/s and a player stops it in 0.15 s.

1. Calculate the change in momentum.
2. Calculate the average force on the ball.

Problem 6 Jumping off a raft (easy)

Kofi in Accra, mass 60 kg, jumps horizontally at 2.5 m/s from a raft of mass 90 kg that is at rest on calm water. Ignore water resistance.

1. Calculate Kofi's momentum.
2. Calculate the recoil speed of the raft.

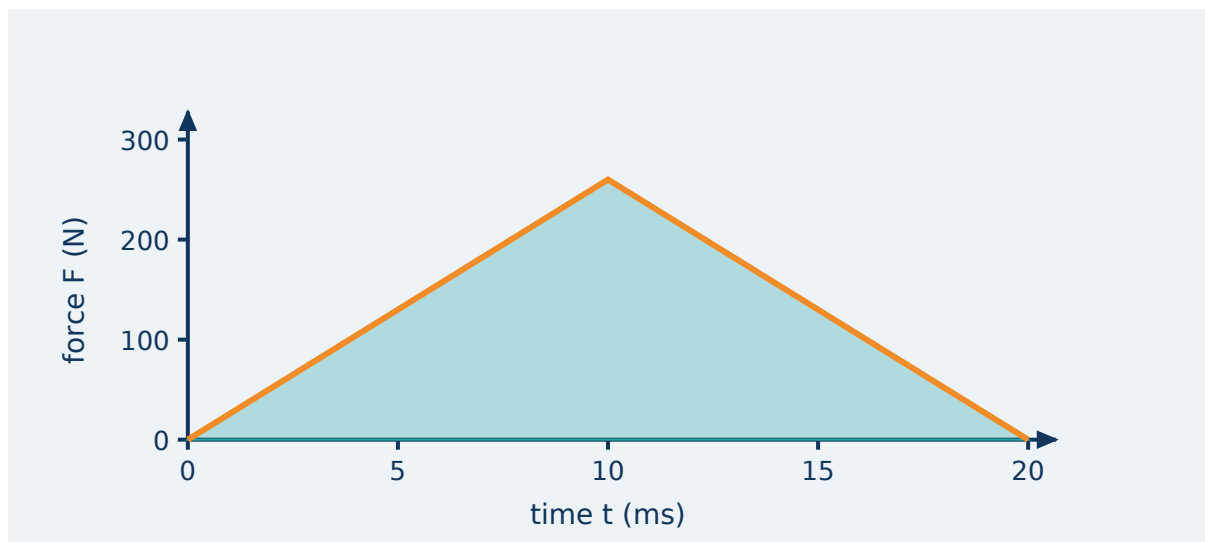
Problem 7 Railway wagons (medium)

A loaded wagon of 12 000 kg rolls at 2.0 m/s into a stationary wagon of 8000 kg. They couple together.

1. Calculate their common speed.
2. Calculate the kinetic energy before and after.
3. State the energy lost.

Problem 8 Basketball bounce (medium)

A basketball of mass 0.40 kg lands at 5.0 m/s downwards. The graph shows the contact force.



Contact force on a basketball during a bounce.

1. Calculate the impulse as the area under the graph.
2. Calculate the average force during contact.
3. Calculate the upward speed after the bounce. Take upward as positive.

Problem 9 Cycling into soft sand (medium)

A cyclist and bicycle of total mass 75 kg ride at 6.0 m/s into soft sand and stop in 0.80 s.

1. Calculate the average force from the sand.
2. Calculate the average force if the same cyclist stopped in 0.050 s against a wall.
3. Explain why the longer time is safer.

Problem 10 Rain on a shed (medium)

Rain falls at 12 m/s onto a flat roof of area 40 m² at a rate of 25 mm per hour. The water has density 1000 kg/m³ and stops on impact.

1. Calculate the mass of rain landing on the roof each second.
2. Calculate the average force on the roof.

Problem 11 Gliders on an air track (medium)

A glider of mass 0.60 kg moves at 5.0 m/s and collides elastically and head-on with a stationary glider of mass 0.20 kg.

1. Use $v_1 = (m_1 - m_2)u \div (m_1 + m_2)$ and $v_2 = 2 m_1 u \div (m_1 + m_2)$ to find both final velocities.
2. Verify that momentum is conserved.
3. Verify that the relative speeds of approach and separation are equal.

Problem 12 Model rocket (medium)

Diego in Texas launches a model rocket of mass 0.80 kg. During a short burn it ejects 0.050 kg of gas downwards at 120 m/s relative to the ground. Ignore gravity and drag during the burn.

1. Calculate the momentum of the gas.
2. Calculate the speed of the rocket after the burn.

Problem 13 Bullet and ball (medium)

A bullet of mass 0.0040 kg travels at 500 m/s. A ball of mass 0.50 kg travels at 4.0 m/s.

1. Calculate the momentum of each.
2. Calculate the kinetic energy of each.
3. Explain which is more damaging to a target and which needs the larger impulse to stop.

Problem 14 Checking glider data (medium)

Two gliders collide on an air track. Glider A (0.30 kg) moves at +0.80 m/s and glider B (0.20 kg) moves at -0.60 m/s. After impact A moves at -0.32 m/s and B at +1.08 m/s.

1. Calculate the total momentum before and after.
2. Calculate the total kinetic energy before and after.
3. State whether the collision was elastic.

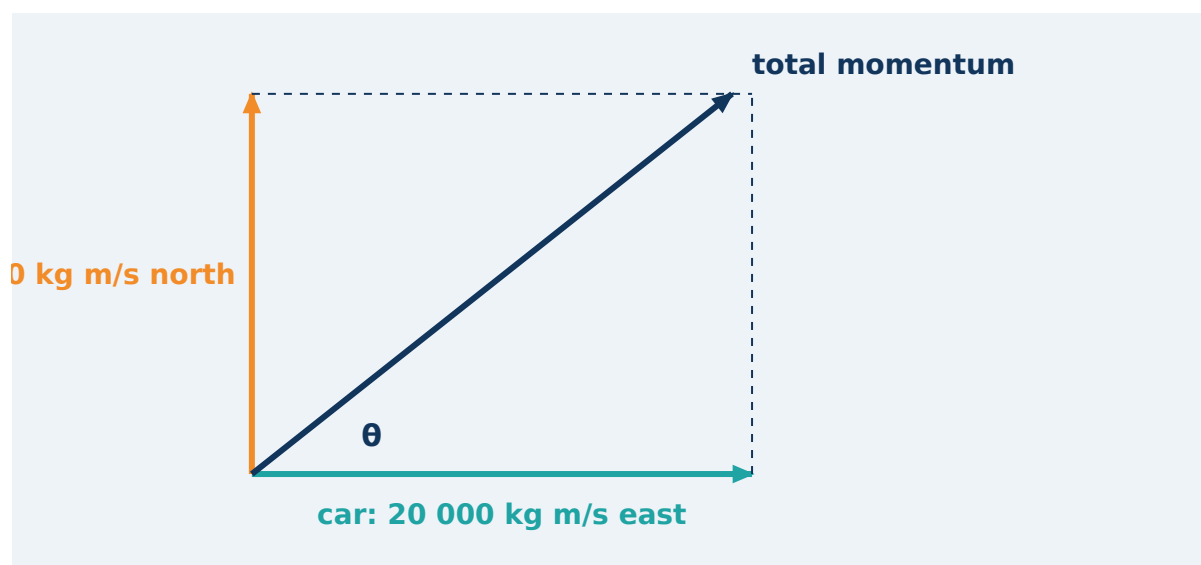
Problem 15 Catching a fast ball (medium)

A fielder in Mumbai catches a ball of mass 0.16 kg moving at 25 m/s.

1. Calculate the average force if the hand stops the ball in 0.010 s.
2. Calculate the average force if the hand moves back and stops it in 0.060 s.
3. Explain the difference using impulse.

Problem 16 Crossroads collision (hard)

A car of mass 1000 kg travels east at 20 m/s. A van of mass 2000 kg travels north at 10 m/s. They collide at a junction and lock together.

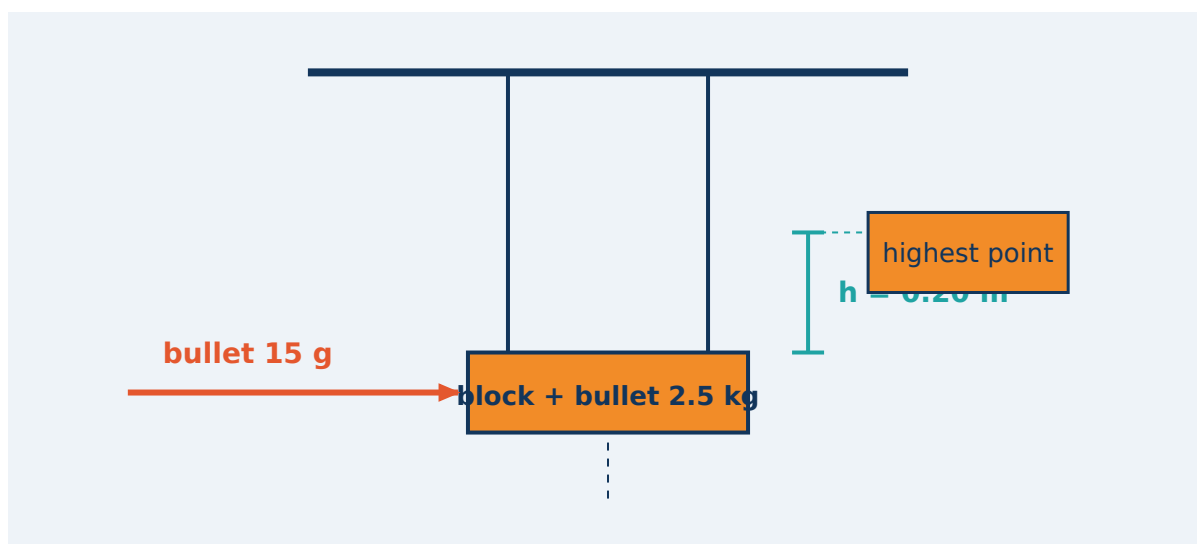


The two momenta are perpendicular, so the total is found with Pythagoras.

1. Calculate the momentum of each vehicle.
2. Calculate the speed of the wreckage.
3. Calculate its direction.
4. Calculate the kinetic energy lost.

Problem 17 Ballistic pendulum (hard)

A bullet of mass 15 g is fired into a block hanging on strings. The block and bullet together have mass 2.5 kg and swing up through a height of 0.20 m. Use $g = 9.81 \text{ N/kg}$.



The bullet embeds in the block, which then swings up to a height of 0.20 m.

1. Calculate the speed of the block just after the impact.
2. Calculate the speed of the bullet before the impact.
3. Calculate the fraction of kinetic energy lost in the impact.

Problem 18 Grain on a conveyor (hard)

Grain falls vertically onto a horizontal belt at 40 kg/s. The belt moves at a constant 2.0 m/s.

1. Calculate the horizontal momentum given to the grain each second.
2. State the horizontal force the belt must exert on the grain.
3. Calculate the power the motor must supply to the belt for this force.
4. Calculate the kinetic energy given to the grain each second, and explain the difference from part 3.

Problem 19 Force readings in a kick (hard)

A footballer kicks a stationary ball of mass 0.45 kg. A sensor records the contact force every 2.0 ms.

t (ms)	0	2	4	6	8	10	12
F (N)	0	500	1000	1500	1000	500	0

1. Use the trapezium rule to find the impulse.
2. Calculate the speed of the ball as it leaves the foot.
3. Calculate the average force during contact.
4. Compare the peak force with the average force.

Problem 20 Elastic collision proof (hard)

A ball of mass 0.20 kg moves at +6.0 m/s and hits a block of mass 1.0 kg moving at -2.0 m/s. The collision is elastic and head-on.

1. Show that for an elastic head-on collision $u_1 - u_2 = v_2 - v_1$.

2. Use that result and momentum conservation to find both velocities after the collision.
3. Verify that the kinetic energy is conserved.