Cambridge IGCSE · Physics 0625 · Notes

Momentum

Read online at **pastopic.com/cambridge/physics-0625/notes/momentum**

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Read first: **Motion**, **Forces**

What you need to know

The whole of this topic is **Extended** (Supplement) content: it is tested on Papers 2 and 4, not on the Core papers. By the end of it you should be able to:

1. **Extended only:** define **momentum** as mass × velocity, and recall and use $p = mv$.
2. **Extended only:** define **impulse** as force × the time for which the force acts, and recall and use impulse $= F\Delta t = \Delta(mv)$: the impulse on an object equals its change in momentum.
3. **Extended only:** use the **principle of conservation of momentum** to solve simple problems in one dimension (along a straight line): collisions, objects that join together and objects that push apart.
4. **Extended only:** define the **resultant force** as the change in momentum per unit time, and recall and use $F = \dfrac{\Delta p}{\Delta t}$.

Understand it

Momentum

A lorry and a bicycle both moving at 5 m/s are very different things to stop. A bullet is tiny but hard to stop because it is so fast. **Momentum** combines both ideas: how much mass is moving, and how fast.

$$p = mv \qquad (p \text{ in kg m/s},\ m \text{ in kg},\ v \text{ in m/s}).$$

A 0.25 kg ball moving at 12 m/s has momentum $0.25 \times 12 = 3.0$ kg m/s. A stationary object has **zero** momentum, because its velocity is zero.

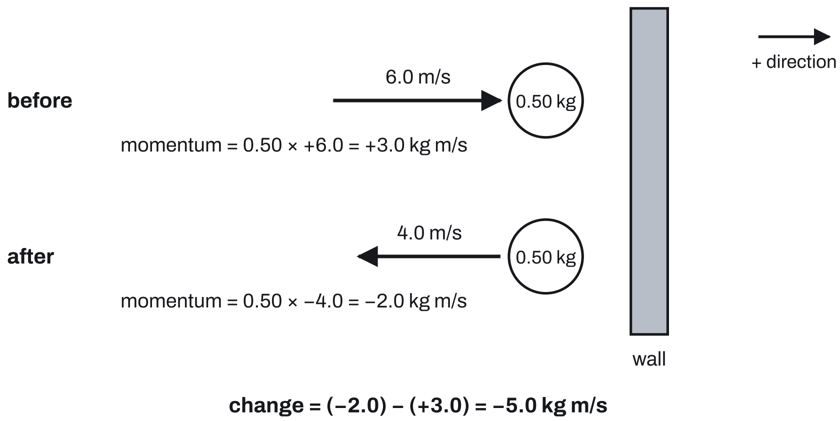
Momentum uses **velocity**, not speed, so it is a **vector**: it has a direction. Along a straight line, pick one direction as **positive** (say, to the right) and the other as **negative**. A 2.0 kg trolley moving left at 3.0 m/s has momentum -6.0 kg m/s. Forgetting the signs is the source of most wrong answers in this topic.

Changing momentum: rebounds

The **change in momentum** is final momentum minus initial momentum:

$$\Delta p = mv - mu,$$

where u is the velocity before and v the velocity after. When an object **bounces back**, its velocity changes sign, so the change is **bigger** than either momentum on its own.



For the ball in the diagram: $\Delta p = 0.50 \times (-4.0) - 0.50 \times 6.0 = -2.0 - 3.0 = -5.0$ kg m/s. The size of the change is 5.0 kg m/s, pointing **away from the wall**. Subtracting the speeds $(6.0 - 4.0)$ would give only 1.0 kg m/s, which is wrong: the ball first has to be stopped (losing 3.0) and then sent back (2.0 more).

Impulse

What changes an object's momentum is a force acting for some time. The **impulse** of a force is

$$\text{impulse} = F\Delta t \qquad (\text{unit: N s}),$$

and it is exactly equal to the change in momentum it causes:

$$F\Delta t = \Delta(mv) = mv - mu.$$

A resultant force of 20 N pushing a trolley for 0.50 s gives an impulse of $20 \times 0.50 = 10$ N s, so the trolley's momentum goes up by 10 kg m/s, whatever its mass. The units **N s** and **kg m/s** are the same thing, so either is correct for impulse or momentum.

The same impulse can come from a big force for a short time or a small force for a long time: 1000 N for 0.010 s and 10 N for 1.0 s both give 10 N s.

Force is the rate of change of momentum

Divide both sides by the time:

$$F = \frac{\Delta p}{\Delta t}.$$

The **resultant force** on an object is its **change in momentum per unit time** (per second). This is the same law as $F = ma$ from the Forces note: $\dfrac{mv - mu}{t} = m \times \dfrac{v-u}{t} = ma$. But $F = \dfrac{\Delta p}{\Delta t}$ is often quicker, because you don't need the acceleration, and it also works for a stream of moving material (water from a hose, gas from a rocket).

If a car's momentum rises from 4000 kg m/s to 7000 kg m/s in 5.0 s, the resultant force on it is $\dfrac{7000 - 4000}{5.0} = 600$ N.

Streams of material. For a jet of water or gas, work per second: the force is the momentum change of the material that moves in one second,

$$F = (\text{mass per second}) \times (\text{change in velocity}).$$

If 12 kg of water leaves a nozzle every second and its speed rises from 2.0 m/s to 7.0 m/s, the force is $12 \times (7.0 - 2.0) = 60$ N.

Why longer stopping times are safer

To stop something, you must take away all its momentum, so the change in momentum is fixed. From $F = \dfrac{\Delta p}{\Delta t}$, making the stopping **time longer** makes the **force smaller**. That is the idea behind:

- **bending your knees** when you land from a jump;
- **moving your hands back** as you catch a fast ball;
- **airbags, seat belts and crumple zones** in cars, **cycle helmets** and **crash mats**, which all squash or stretch so that the collision lasts longer.

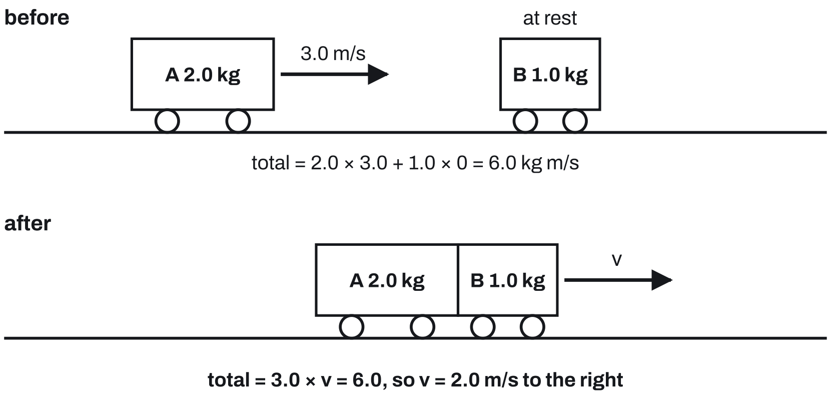
None of these changes the change in momentum (or the impulse): they spread it over a longer time, so the average force on your body is smaller. The same idea explains the other direction: a smaller force needs a **longer** time to give the same change in momentum.

Conservation of momentum

When two objects collide, they push on each other with **equal and opposite** forces for the **same** time. So they receive equal and opposite impulses: whatever momentum one gains, the other loses. Added together, the total does not change.

The principle of conservation of momentum: when no outside (external) resultant force acts, the total momentum of a set of objects stays the same:

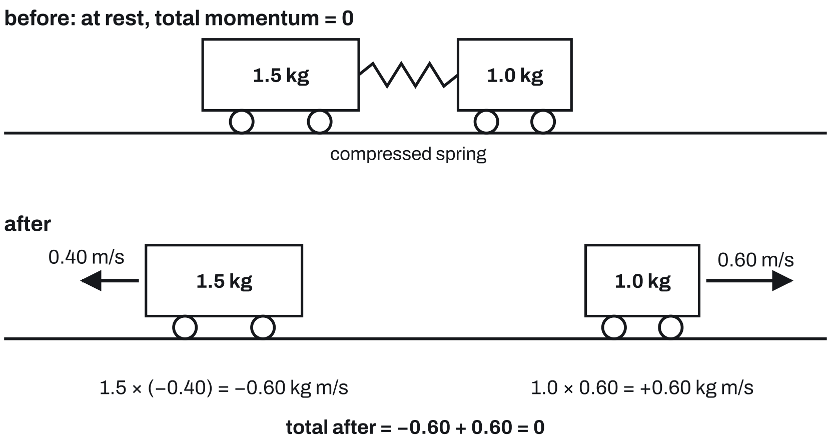
$$\text{total momentum before} = \text{total momentum after}.$$



In the diagram, trolley A (2.0 kg, 3.0 m/s) hits trolley B (1.0 kg, at rest) and they stick together. Before: $2.0 \times 3.0 + 1.0 \times 0 = 6.0$ kg m/s. After: $(2.0 + 1.0)v = 3.0v$. So $3.0v = 6.0$ and $v = 2.0$ m/s to the right. The combined mass moves more slowly than A did, but carries the same total momentum.

Explosions and pushing apart

If objects start **at rest**, the total momentum is **zero**, and it stays zero after they push apart. So they must move in **opposite directions** with momenta of the same size.



In the diagram, $1.5 \times 0.40 = 0.60$ kg m/s to the left and $1.0 \times 0.60 = 0.60$ kg m/s to the right: the total is $-0.60 + 0.60 = 0$. The **lighter** trolley moves **faster**. The same happens when a gun recoils as it fires a bullet, a cannon rolls back as it fires a ball, and a rocket moves forwards as it pushes hot gas backwards: the gas and the rocket have momenta of the same size in opposite directions.

Momentum is always conserved in these events, but **kinetic energy is usually not**: in a collision some is transferred to heat and sound, and in an explosion or a spring release kinetic energy is created from another store. Don't use kinetic energy to find a velocity after a collision; use momentum.

Key facts and formulas

The 0625 papers have no formula sheet, so learn every equation.

Formula	Status
Extended only: momentum $p = mv$ (a vector, in kg m/s)	Learn it
Extended only: change in momentum $\Delta p = mv - mu$, with signs for direction	Learn it
Extended only: impulse $= F\Delta t = \Delta(mv)$, in N s	Learn it
Extended only: resultant force $F = \dfrac{\Delta p}{\Delta t}$	Learn it
Extended only: conservation: total momentum before $=$ total momentum after (no external force)	Learn it
Extended only: stream of material: $F =$ mass per second $\times$ change in velocity	Learn it
1 N s $= 1$ kg m/s	Learn it
$F = ma$ and $a = \dfrac{v-u}{t}$ (from Forces and Motion)	Learn it

How to do it

In the Paper 2 and 4 questions we have tagged for this topic (54 different questions, 2021–2025; 2 more are repeats on other papers), the types came up this often. 14 of the 54 questions mix two or three types, so the counts add up to more than 54.

Question type	Questions
Conservation of momentum: collisions and explosions	17
Force or time from the change in momentum	17
Change in momentum and impulse	16
Definitions, equations and statements	16
Calculating momentum with $p = mv$	4
Explaining why a longer time means a smaller force	3

1. Conservation of momentum: collisions and explosions (17 questions)

1. **Choose a positive direction** (usually right, or the first object's direction) and give every velocity a sign.
2. **Total momentum before**: add mu for each object, with signs. An object at rest contributes 0.
3. **Total momentum after**: write mv for each object, with the unknown as a letter. Objects that **stick together** move as one mass: $(m_1 + m_2)v$.
4. **Set them equal** (state "momentum before = momentum after") and solve.
5. **Give the direction** from the sign of your answer.

For example, a 0.50 kg trolley at 0.40 m/s hits a stationary 0.30 kg trolley and they stick: $0.50 \times 0.40 = 0.80v$, so $v = 0.25$ m/s in the same direction.

Variations you will meet:

- **Objects moving towards each other.** One momentum is negative. A 0.60 kg trolley at 0.50 m/s right meeting a 0.40 kg trolley at 0.25 m/s left: total $= 0.30 - 0.10 = 0.20$ kg m/s to the right (Worked example 2).
- **Both move after, separately.** Put one unknown in: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$. If an object bounces back, its velocity after is negative, and the answer may come out negative, meaning "backwards".
- **Find a mass.** The unknown is a mass instead of a velocity. If the objects stick together, the combined mass comes out first: subtract the known mass to get the one asked for.
- **Start from rest (explosions, springs, recoil).** Total momentum is 0, so $m_1v_1 = m_2v_2$ in size, in opposite directions. The same holds when part of a moving object is thrown off (a space vehicle dropping a stage): total momentum before (whole object) $=$ momentum of the part $+$ momentum of the rest.
- **A bullet or ball that sticks in a block.** Use the combined mass after. Convert grams to kilograms first.
- **"Show that" the speed is about ….** Write the conservation equation in symbols, then numbers, and give the answer to one more significant figure than printed.
- **Multiple-choice ideas.** Momentum is conserved in all collisions and explosions with no external force; kinetic energy usually is not. A rocket's momentum and the gas's momentum are equal in size but **opposite**, so the total stays zero; saying they are simply "equal" is wrong. The two objects in a collision have equal and opposite changes in momentum (and receive equal and opposite impulses).
- **Impulse on each object.** Find the change in momentum of **one** object, using **its own** mass and velocities. The impulse on the other object is the same size, in the opposite direction.
- **Explain how momentum is conserved** when air rushes out of a balloon or gas from a rocket: the gas gains momentum backwards and the balloon gains the same amount forwards, so the total stays at zero.

2. Force or time from the change in momentum (17 questions)

1. **Find the change in momentum** $\Delta p = mv - mu$ (watch for rebounds; convert g to kg and ms to s).
2. **Use** $F = \dfrac{\Delta p}{\Delta t}$ (or $F\Delta t = \Delta p$). Rearrange for what you want:
   - force: $F = \dfrac{\Delta p}{\Delta t}$;
   - time of contact: $\Delta t = \dfrac{\Delta p}{F}$;
   - a velocity: $v = u + \dfrac{F\Delta t}{m}$.
3. **Give the unit** (N, s or m/s) and the direction if asked.

For example, a 0.060 kg ball stopped from 30 m/s in 0.0040 s: $\Delta p = 0.060 \times 30 = 1.8$ kg m/s, so $F = 1.8 \div 0.0040 = 450$ N.

Variations you will meet:

- **Only the momenta are given.** "Momentum rises from 4000 to 7000 kg m/s in 5.0 s": $F = 3000 \div 5.0 = 600$ N.
- **Times in ms or minutes.** 9.5 ms $= 0.0095$ s; 1.0 minute $= 60$ s. Examiners often see answers 1000 times too big or too small from this.

- **The force slows an object to rest** (braking, a rough surface): Δp is the whole starting momentum. Use the momentum **after** any collision if the question follows on from one. A **smaller** resistive force takes a **longer** time to stop it.
- **Find the starting speed** from the force and stopping time: $u = \dfrac{F\Delta t}{m}$.
- **A stream of water or gas**: force $=$ mass per second $\times$ change in velocity. A rocket that ejects gas at 2000 m/s at 30 kg per second gets a force of 6.0×10^4 N. To find the largest mass that force could lift, set it equal to a weight: $m = F \div g$.
- **You may use $F = ma$ instead**, with $a = \dfrac{v-u}{t}$; it gives the same answer. But don't divide kinetic energy by time: that is power, not force.

3. Change in momentum and impulse (16 questions)

1. **Choose a positive direction.**
2. **Write u and v with signs.** A ball that bounces back has v negative.
3. $\Delta p = mv - mu = m(v-u)$. The impulse is the same number, in N s.
4. **Give the size** (and direction if asked).

For example, a 0.20 kg ball hits a wall at 8.0 m/s and bounces back at 6.0 m/s: $\Delta p = 0.20 \times (-6.0 - 8.0) = -2.8$, so the impulse is 2.8 N s, away from the wall.

Variations you will meet:

- **Force and time given**: impulse $= F\Delta t$ directly, for example 150 N for 0.020 s gives 3.0 N s. Then the speed afterwards is $\Delta p \div m$ for an object that started at rest.
- **Impulse on the wall (or bat)** is the same size as the impulse on the ball, in the opposite direction.
- **Final momentum from an impulse that reverses the motion.** Start with $+p$; the impulse is $-F\Delta t$; the final momentum is $p - F\Delta t$. If that is negative, the object is going back the other way, and its size is the answer.
- **Change in velocity from force and time**: $\Delta v = \dfrac{F\Delta t}{m}$.
- **Speed changes in the same direction**: $\Delta p = m(v-u)$ with both positive, for example a 25 kg object going from 4.0 m/s to 10 m/s receives 150 N s.
- **Acceleration during a rebound**: $a = \dfrac{v-u}{t}$ with the signs, so a ball going from $+15$ m/s to -10 m/s in 0.050 s has an acceleration of size 500 m/s².
- **An object that started at rest** (a golf ball hit off the tee): the impulse is just its final momentum, mv.

4. Definitions, equations and statements (16 questions)

1. **Momentum**: mass × **velocity** (not speed), $p = mv$.
2. **Impulse**: force × the time for which it acts, $F\Delta t$; it equals the change in momentum. It is **not** the change in momentum divided by time.
3. **Resultant force**: the change in momentum per unit time, $F = \dfrac{\Delta p}{\Delta t}$.

4. **Conservation of momentum**: with no external resultant force, total momentum before $=$ total momentum after.

Variations you will meet:

- **Which equation is right?** Look for $Ft = mv - mu$, impulse $= Ft$, impulse $=$ change in momentum, $F = \dfrac{\Delta p}{t}$. Reject impulse $=$ force × distance (that's work), force $= \Delta p \times t$, and impulse $=$ change in kinetic energy.
- **Which change gives a bigger change in momentum?** $\Delta p = F\Delta t$, so a bigger force for the same time (or the same force for longer). Doubling the force and halving the time leaves it unchanged.
- **When is momentum changing?** Whenever there is a resultant force, an impulse, or a change in speed or direction (speeding up **or** slowing down).
- **Scalar or vector?** Momentum and impulse are **vectors**.
- **"State an equation that defines impulse"**: impulse $= F\Delta t$ (force × time).

5. Calculating momentum with p = mv (4 questions)

1. Convert the mass to kg (grams ÷ 1000) and the velocity to m/s.
2. Multiply: $p = mv$.
3. Unit **kg m/s** (or N s), and the direction if the velocity has one.

Variations you will meet:

- **Velocity from another topic first**, for example from distance ÷ time, or from energy ($\frac{1}{2}mv^2 = mgh$ gives $v = \sqrt{2gh}$), then $p = mv$.
- **"State the momentum of a stationary object"**: zero, **because** its velocity is zero. Say why, not just "it is not moving" if the question already said so.
- **"Show that the momentum is about …"**: write $p = mv$ first, then the numbers.

6. Explaining why a longer time means a smaller force (3 questions)

1. The change in momentum is **fixed** (the object has to be brought to rest, or its motion changed by a set amount).
2. Use $F = \dfrac{\Delta p}{\Delta t}$: a **longer** time gives a **smaller** average force.
3. Link it to the situation: bending the knees, moving the hands back, a crumple zone, a crash mat.

Variations you will meet:

- **"Which effect does bending her knees have?"** A smaller force from the ground. Not a smaller change in momentum, not a smaller impulse, and not less kinetic energy lost: those stay the same.
- **A smaller resistive force**: the time to stop gets **longer**, for the same change in momentum.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

Extended only. A hockey ball of mass 0.16 kg moves at 12 m/s towards a player. She hits it and it moves straight back at 18 m/s. The stick is in contact with the ball for 8.0 ms.

(a) Define momentum. **[1]**

(b) Calculate the change in momentum of the ball. **[3]**

(c) Calculate the average force of the stick on the ball. **[2]**

(a) Momentum is mass × velocity. **B1**

(b) Take the direction the ball moves after the hit as positive: $u = -12$ m/s and $v = +18$ m/s. **C1**

$\Delta p = mv - mu = 0.16 \times 18 - 0.16 \times (-12)$ **C1** $= 2.88 + 1.92 = 4.8$ kg m/s **A1** (in the direction of the hit).

(c) 8.0 ms $= 0.0080$ s. $F = \dfrac{\Delta p}{\Delta t}$ **C1** $= \dfrac{4.8}{0.0080} = 600$ N **A1**.

Example 2

Extended only. Trolley P, of mass 0.60 kg, moves to the right at 0.50 m/s. Trolley Q, of mass 0.40 kg, moves to the left at 0.25 m/s. They collide and stick together.

(a) Calculate the velocity of the trolleys after the collision, and state its direction. **[4]**

(b) Calculate the impulse on trolley Q during the collision. **[2]**

(c) State the impulse on trolley P during the collision. **[1]**

(a) Take right as positive. Momentum before $= 0.60 \times 0.50 + 0.40 \times (-0.25) = 0.30 - 0.10 = 0.20$ kg m/s. **C1**

Momentum after $= (0.60 + 0.40)v = 1.00v$. **C1**

Momentum before $=$ momentum after: $1.00v = 0.20$ **C1**, so $v = 0.20$ m/s to the right. **A1**

(b) Impulse on Q $=$ change in momentum of Q **C1** $= 0.40 \times 0.20 - 0.40 \times (-0.25) = 0.080 + 0.10 = 0.18$ N s, to the right **A1**.

(c) 0.18 N s to the left (equal and opposite to the impulse on Q). **B1** (Check: $0.60 \times 0.20 - 0.60 \times 0.50 = -0.18$ N s.)

Example 3

Extended only. A toy cannon of mass 1.5 kg stands at rest on a smooth floor. It fires a ball of mass 50 g forwards at 24 m/s.

(a) State the total momentum of the cannon and ball before firing. Explain your answer. **[1]**

(b) Calculate the velocity of the cannon just after firing. **[3]**

(c) The ball takes 0.030 s to travel along the barrel. Calculate the average force on the ball. **[2]**

(a) Zero, because both are at rest (velocity zero, so $mv = 0$). **B1**

(b) 50 g $= 0.050$ kg. Momentum of ball $= 0.050 \times 24 = 1.2$ kg m/s forwards. **C1**

Total momentum after $=$ total before $= 0$, so $0.050 \times 24 + 1.5v = 0$ **C1**, and $v = -\dfrac{1.2}{1.5} = -0.80$ m/s: 0.80 m/s **backwards**. **A1**

(c) $F = \dfrac{\Delta p}{\Delta t}$ **C1** $= \dfrac{1.2}{0.030} = 40$ N **A1**.

Example 4

Extended only. A student of mass 60 kg jumps down from a wall. She hits the ground at 5.0 m/s and comes to rest.

(a) Calculate the change in her momentum as she stops. **[2]**

(b) Calculate the average resultant force on her if she lands with straight legs and stops in 0.050 s, and if she bends her knees and stops in 0.40 s. **[2]**

(c) Explain why bending her knees is safer. **[2]**

(a) $\Delta p = mv - mu = 0 - 60 \times 5.0$ **C1**, so the change is 300 kg m/s (upwards, opposite to her motion). **A1**

(b) Straight legs: $F = \dfrac{300}{0.050} = 6000$ N. Bent knees: $F = \dfrac{300}{0.40} = 750$ N. **B1 B1**

(c) Her change in momentum is the same either way. **B1** Bending her knees makes the time to stop longer, and $F = \dfrac{\Delta p}{\Delta t}$, so the force on her is smaller. **B1**

Common mistakes

- **Ignoring direction.** Momentum is a vector. When objects move towards each other, or a ball bounces back, one velocity is **negative**. Adding momenta that point opposite ways, or subtracting speeds for a rebound, is the most common error in the reports.
- **Using speed for momentum**, or writing "momentum is mass × speed". It is mass × **velocity**.
- **Mixing up impulse and force.** Impulse is force × time (N s), and equals the change in momentum. It is not change in momentum ÷ time; that is the force.
- **Stopping at the change in momentum** when the question wants the final momentum, or taking the momentum before the impact when the change was asked for. Read what is wanted.
- **Forgetting to combine the masses** after objects stick together, or finding the combined mass and forgetting to subtract the known one when asked for the other object's mass.
- **Using the wrong object's numbers.** For the impulse on one object, use that object's mass and its own velocities before and after. Equating the momentum of one piece to the momentum of the other, when the whole object was moving before, is another slip.
- **Units.** Convert grams to kilograms and ms to s before substituting. Give momentum in kg m/s or N s; impulse in N s, not N.
- **Using $F = ma$ or kinetic energy the wrong way.** Dividing kinetic energy by time does not give a force. When the material flows (water, gas), use mass per second × change in velocity.
- **Writing only numbers.** In a "show that", write $p = mv$ or "momentum before = momentum after" in words or symbols first; numbers alone don't show the physics.
- **Repeating the question** in an explanation. "Trolley B is stationary" is given; the explanation is "its velocity is zero, so $mv = 0$".
- **Confusing momentum with moment**, or saying bending the knees reduces the change in momentum. It reduces the **force**.

How to get the marks

- **Write the equation first** ($p = mv$, $F\Delta t = \Delta(mv)$, $F = \Delta p/\Delta t$, or "momentum before = momentum after"). The first mark is often for the equation or substitution, even if the answer goes wrong later.
- **Conservation answers**: a mark for each side's momentum with the right signs, a mark for setting them equal, then the answer with a **direction** when the question has a "direction" line.
- **"Define"**: momentum $=$ mass × velocity; impulse $=$ force × time for which it acts; resultant force $=$ change in momentum per unit time. A correct equation with symbols named also earns the mark.
- **"Show that"**: write the equation in symbols, then the numbers, then a value with one more significant figure than printed (for example 0.412 when the question says "about 0.4").
- **"Explain"**: name the physics, not just the result. For a longer stopping time: "same change in momentum, longer time, so smaller force, because $F = \Delta p/\Delta t$".
- **Accuracy**: give 2 or 3 significant figures (3 if asked), and keep full values until the end.

- **Units**: kg m/s or N s for momentum and impulse; N for force. A missing unit where the answer line has none loses a mark.
- **Multiple choice**: work it out first. Wrong options use the usual slips: ignoring a rebound, using the momentum instead of its change, forgetting to convert grams or ms, or multiplying instead of dividing by the time.

Quick check

1. **Extended only.** Calculate the momentum of a 1200 kg car travelling at 15 m/s.
2. **Extended only.** A 0.30 kg ball hits a wall at 10 m/s and bounces straight back at 4.0 m/s. Calculate the impulse on the ball.
3. **Extended only.** A 2.0 kg trolley moving at 3.0 m/s hits a stationary 1.0 kg trolley. Afterwards the 2.0 kg trolley moves on at 1.0 m/s in the same direction. Calculate the velocity of the 1.0 kg trolley.
4. **Extended only.** A resultant force of 250 N acts for 4.0 s on a 500 kg boat that starts at rest. Calculate the boat's final speed.
5. **Extended only.** A fire hose sprays 8.0 kg of water each second. The water enters the nozzle at 3.0 m/s and leaves at 18 m/s. Calculate the force the water exerts on the hose.

Answers

1. $p = mv = 1200 \times 15 = 18\,000$ kg m/s.
2. Take the direction towards the wall as positive: $\Delta p = 0.30 \times (-4.0) - 0.30 \times 10 = -1.2 - 3.0 = -4.2$ kg m/s. The impulse is 4.2 N s, away from the wall.
3. Momentum before $= 2.0 \times 3.0 + 0 = 6.0$ kg m/s. After: $2.0 \times 1.0 + 1.0v = 6.0$, so $v = 4.0$ m/s in the same direction.
4. $\Delta p = F\Delta t = 250 \times 4.0 = 1000$ kg m/s. $v = \frac{1000}{500} = 2.0$ m/s.
5. $F =$ mass per second × change in velocity $= 8.0 \times (18 - 3.0) = 120$ N (backwards on the hose, opposite to the water's motion).

Past questions to try

- **0625/43/M/J/25 Q2**: momentum of a space vehicle, then conservation of momentum when it ejects its nose cone (Extended).
- **0625/41/M/J/24 Q2**: two trolleys pushed apart by a spring, then kinetic energy (Extended).
- **0625/43/O/N/22 Q2**: the change in momentum of a tennis ball that reverses, the definition of impulse and the contact time (Extended).
- **0625/42/F/M/24 Q2**: defining impulse and the force on a rocket from its exhaust gases (Extended).