CAMBRIDGE IGCSE™ PHYSICS 0625 | TOPIC 1.6

FREE SAMPLE

Momentum

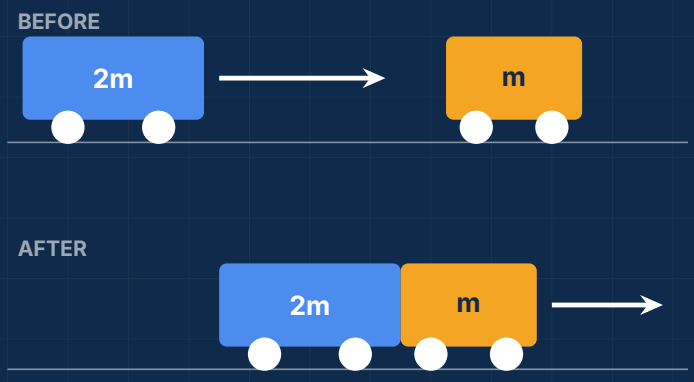
Free sample: knowledge organiser and Worksheet 1 with answers

Momentum p = mv | Impulse | Conservation of momentum | Collisions & explosions

F = Δp/Δt | Crumple zones & airbags | Exam-style questions

$$p = mv$$

$$F = \Delta p / \Delta t$$



total momentum before = total momentum after

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Knowledge organiser

MOMENTUM ON ONE PAGE

Key words

Momentum – mass $\times$ velocity. It is a vector: it has a direction.

Impulse – force $\times$ the time for which the force acts. It equals the change in momentum.

Conservation of momentum – when objects collide or push apart, the total momentum before $=$ the total momentum after, as long as no external resultant force acts.

Resultant force – the change in momentum per unit time.

Equations

$p = mv$ momentum, unit kg m/s

impulse $= F\Delta t = \Delta(mv)$ unit N s

$F = \dfrac{\Delta p}{\Delta t}$ F is the resultant force

$1\,\text{N s} = 1\,\text{kg m/s}$, because $1\,\text{N} = 1\,\text{kg m/s}^2$.

Δ means "change in": final value $-$ initial value.

Directions matter

Choose one direction as positive. Velocities and momenta the other way are negative.



A ball hits a wall at 5 m/s and bounces back at 5 m/s: its velocity changes from $+5$ to -5, a change of -10 m/s (size 10 m/s), **not** zero.

Collisions and explosions

Stick together: $m_1u_1 + m_2u_2 = (m_1 + m_2)v$

Push apart from rest: total momentum before $= 0$, so afterwards the two momenta are equal in size and opposite in direction.

The lighter object moves off faster.

Worked example: collision



They stick together. Before:
$2.0 \times 3.0 + 0 = 6.0\,\text{kg m/s}$.
After: $(2.0 + 1.0)\,v = 6.0$, so $v = 2.0$ m/s in the same direction.

Safety: making the time longer

To stop a moving person, their momentum must change by the same amount whatever happens. Crumple zones, airbags, seat belts, helmets and soft landing mats make the stopping **time longer**, so the force, $F = \Delta p/\Delta t$, is **smaller**.

Common mistakes

- Forgetting the minus sign when an object reverses.
- Using grams instead of kilograms.
- Adding speeds of objects moving in opposite directions.
- Thinking a bigger impact time means a bigger impulse: the impulse is fixed by the change in momentum.

Worked example: force

A 0.40 kg ball moving at 15 m/s is stopped in 0.020 s.

$\Delta p = 0.40 \times 15 = 6.0\,\text{kg m/s}$

$F = \Delta p/\Delta t = 6.0 \div 0.020 = 300\,\text{N}$

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Momentum and impulse

WORKSHEET 1
SUPPLEMENT

You will: define momentum and impulse, use $p = mv$ and impulse $= F\Delta t = \Delta(mv)$, and take account of direction when an object changes its velocity.

1 SUPPLEMENT Define **momentum** and state its unit. [2]

2 SUPPLEMENT Complete the table. Show your working in the space below it. [5]

Object	Mass	Velocity	Momentum
(a) cricket ball	0.16 kg	25 m/s	_____ kg m/s
(b) lorry	12 000 kg	15 m/s	_____ kg m/s
(c) runner	65 kg	8.0 m/s	_____ kg m/s
(d) car	1500 kg	_____ m/s	6000 kg m/s
(e) tennis ball	_____ kg	15 m/s	0.90 kg m/s

3 SUPPLEMENT Two identical cars, each of mass 1200 kg, travel along a straight road at 20 m/s. Car A moves east and car B moves west. Take east as the positive direction.

(a) State the momentum of each car. Include a sign or a direction in each answer. [2]

momentum of A = _____

momentum of B = _____

(b) A student adds the two momenta and gets zero. Explain why the total momentum is zero even though both cars are moving. [1]

4 SUPPLEMENT Impulse is measured in N s and momentum in kg m/s. Show that these units are the same. Use $F = ma$. [2]

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5 SUPPLEMENT A footballer kicks a ball of mass 0.43 kg that is at rest. Her foot exerts an average force of 250 N on the ball for 0.012 s.

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

.....

(b) Calculate the impulse on the ball. [2]

.....

impulse = _____

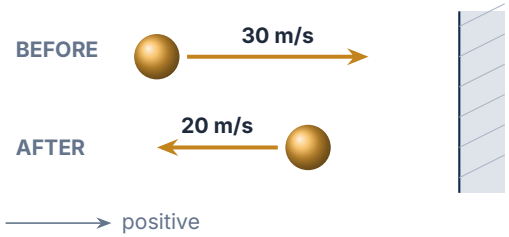
(c) Calculate the speed of the ball as it leaves her foot. [2]

.....

.....

speed = _____

6 SUPPLEMENT A tennis ball of mass 0.058 kg hits a wall at 30 m/s. It bounces straight back at 20 m/s. Take the direction towards the wall as positive.



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

.....

.....

change in momentum = _____

(b) State the size and direction of the impulse that the wall exerts on the ball. [1]

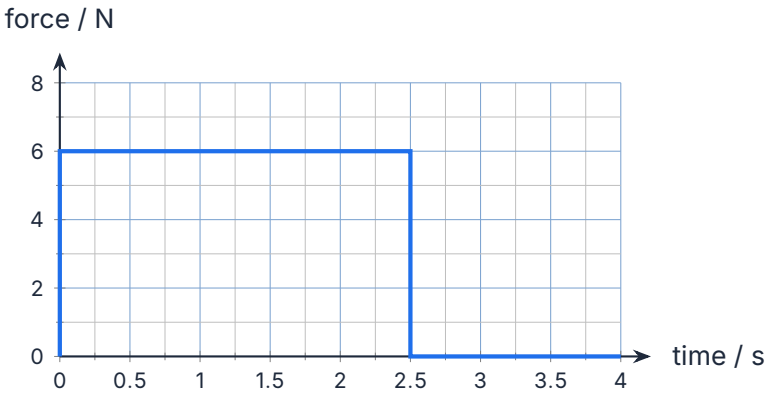
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(c) Explain why the change in momentum is larger than it would be if the ball had stopped dead at the wall. [1]

.....

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7 SUPPLEMENT A trolley of mass 3.0 kg is at rest on a smooth, level track. A constant resultant force pushes it along the track. The graph shows how the force varies with time.



(a) Calculate the impulse on the trolley. [2]

impulse = _____

(b) Calculate the speed of the trolley when the force stops acting. [2]

speed = _____

8 SUPPLEMENT A lorry of mass 9000 kg moves at 5.0 m/s. A car of mass 1000 kg moves at 30 m/s. A student says: *"The car is much faster, so it must have more momentum."* Use calculations to explain whether the student is correct. [2]

Exam tip Before every momentum calculation, choose a positive direction and write it down. A velocity in the opposite direction is negative. The *change* in a quantity is always final value − initial value.

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Answers: Worksheet 1

Mark codes: B1 independent mark C1 method mark, implied by a correct final answer A1 correct answer with unit. Accept answers that round correctly; allow error carried forward from earlier parts. Accept N s or kg m/s for momentum and impulse.

Worksheet 1 – Momentum and impulse

1 Momentum = mass × velocity B1; unit **kg m/s** (or N s) B1

2 **(a)** $0.16 \times 25 = 4.0$ B1
(b) $12\,000 \times 15 = 180\,000$ (1.8×10^5) B1
(c) $65 \times 8.0 = 520$ B1
(d) $v = p/m = 6000 \div 1500 =$ **4.0 m/s** B1
(e) $m = p/v = 0.90 \div 15 =$ **0.060 kg** B1

3 **(a)** A: $1200 \times 20 =$ **+24 000 kg m/s** (east) B1; B: **−24 000 kg m/s** (west) B1
(b) Momentum is a vector: the two momenta are equal in size but opposite in direction, so they cancel. B1

4 From $F = ma$, $1\,\text{N} = 1\,\text{kg m/s}^2$ C1; so $1\,\text{N s} = 1\,\text{kg m/s}^2 \times 1\,\text{s} = 1\,\text{kg m/s}$. A1

5 **(a)** Force × the time for which the force acts. B1
(b) 250×0.012 C1 = **3.0 N s** A1
(c) Impulse = change in momentum, so $0.43\,v = 3.0$ C1 $v =$ **7.0 m/s** A1

6 **(a)** Before: $0.058 \times 30 = +1.74$ kg m/s; after: $0.058 \times (-20) = -1.16$ kg m/s C1
$\Delta p = -1.16 - 1.74$ C1 = **−2.9 kg m/s** (2.9 kg m/s away from the wall) A1
(b) **2.9 N s**, away from the wall (in the negative direction) B1
(c) The ball must lose all its forward momentum *and* gain momentum in the opposite direction (stopping alone would be a change of only 1.74 kg m/s). B1

7 **(a)** 6.0×2.5 C1 = **15 N s** A1
(b) $3.0\,v = 15$ C1 $v =$ **5.0 m/s** A1

8 Lorry: $9000 \times 5.0 = 45\,000$ kg m/s; car: $1000 \times 30 = 30\,000$ kg m/s C1. The student is **wrong**: the lorry has more momentum because momentum depends on mass as well as velocity. A1

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Get the full pack

You have just used Worksheet 1. The full Momentum pack contains:

- **Worksheet 1:** Momentum and impulse
- **Worksheet 2:** Conservation of momentum
- **Worksheet 3:** Force, momentum and safety
- **Multiple-choice practice:** 10 Paper 2-style questions
- **Practical skills:** an Alternative to Practical (Paper 6) question
- **Exam-style questions:** a 40-mark paper
- **Revision checklist** and knowledge organiser

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