1.3 Momentum and moments (P)

Name: _____ Class: _____ Date: _____ **Total: 23 marks**

Objective

Build the skills to answer exam questions on **momentum and moments** : momentum $p = mv$, conservation of momentum in collisions, force as the rate of change of momentum, safety features, Newton's third law, and moments.

You must be able to:

- calculate momentum and use conservation of momentum
- calculate force from the change in momentum and the time taken
- explain how safety features reduce the force in a collision
- plan an experiment to test conservation of momentum

1 Key knowledge and worked examples

Momentum

idea	equation or rule
momentum	$p = m \times v$ (unit kg m/s)
conservation of momentum	total momentum before = total momentum after, if no external force acts
force and momentum	$F = (mv - mu) \div t$: force = change in momentum ÷ time
Newton's third law	when A pushes on B, B pushes back on A with an equal and opposite force
moment	force × perpendicular distance from the pivot (unit N m); balanced when clockwise moments = anticlockwise moments

Worked example 1: momentum. Find the momentum of a 0.15 kg ball moving at 20 m/s.

1. Known: $m = 0.15$ kg; $v = 20$ m/s.
2. Rule: $p = mv$.
3. Numbers: 0.15×20.
4. Result: 3.0 **kg m/s**.

Worked example 2: force. A 60 kg person slows from 15 m/s to rest in 0.20 s. Find the force.

1. Known: change in momentum $60 \times 15 = 900$ kg m/s; $t = 0.20$ s.
2. Rule: F = change in momentum $\div t$.
3. Numbers: $900 \div 0.20$.
4. Result: 4500 **N**.

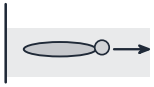
Answer shapes: take one direction as positive; a velocity the other way is negative.

2 Practice

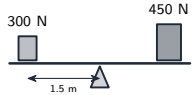
2.1 Calculate the momentum of a 1500 kg car moving at 12 m/s. [2]



2.2 State Newton's third law, and give an example. [2]

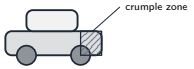


2.3 A child of weight 300 N sits 1.5 m from the pivot of a see-saw. Calculate the distance from the pivot at which a 450 N adult must sit to balance it. [2]



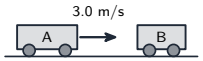
3 Exam-style questions

3.1 Explain how the crumple zone of a car reduces the force on the passengers in a crash. [3]



3.2 Trolley A (2.0 kg) moves at 3.0 m/s and hits trolley B (1.0 kg), which is at rest. The trolleys stick together and move off together.

(a) Calculate the momentum of trolley A before the collision. [2]



(b) Calculate the velocity of the two trolleys after the collision. [3]

(c) The collision lasts 0.10 s. Calculate the force on trolley B. [3]

(d) Describe how to use trolleys and light gates to test whether momentum is conserved in this collision. [6]

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Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

- 1500×12
- **18 000** kg m/s

2.2

- if body A exerts a force on body B, B exerts an equal and opposite force on A
- e.g. a swimmer pushes the wall backwards and the wall pushes the swimmer forwards

2.3

- child's moment $300 \times 1.5 = 450$ N m
- $450 \div 450 =$ **1.0** m on the other side

3.1

- the crumple zone crushes, so the car takes longer to stop
- the change in momentum is the same
- force = change in momentum ÷ time, so a longer time gives a smaller force

3.2

(a) $2.0 \times 3.0 =$ **6.0** kg m/s

(b) total momentum after = 6.0 kg m/s; total mass 3.0 kg; $v = 6.0 \div 3.0 =$ **2.0** m/s

(c) B's change in momentum $= 1.0 \times 2.0 = 2.0$ kg m/s; $F = 2.0 \div 0.10 =$ **20** N

(d) points to include:

- measure the masses of both trolleys on a balance (K)
- use a level runway (or slightly tilted to cancel friction) (App)
- fix a card of known length to trolley A; place one light gate before the collision and one after (K)
- push A towards B; the light gates time the card; velocity = card length ÷ time (K)
- calculate total momentum before ($m_A v_A$) and after ($(m_A + m_B)v$) (An)
- repeat with different masses or speeds; compare before and after; small differences are due to friction (An)

Levels: **5–6** a full, logical answer with correct physics and correct terms; **3–4** several correct points, partly linked; **1–2** one or two relevant points.