A-LEVEL PHYSICS • EXERCISE SHEET

3.1 Momentum and Newton's laws of motion

Name: _____ Class: _____ Date: _____ **Total: 18 marks**

Objective

Build the skills to answer exam questions on **momentum and Newton's laws** — $F = ma$, momentum, impulse, and the three laws.

You must be able to:

- recall and use $F = ma$ and **weight** $= mg$
- use **momentum** $p = mv$ and force as $F = \Delta p/\Delta t$
- state and apply **Newton's three laws**

1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

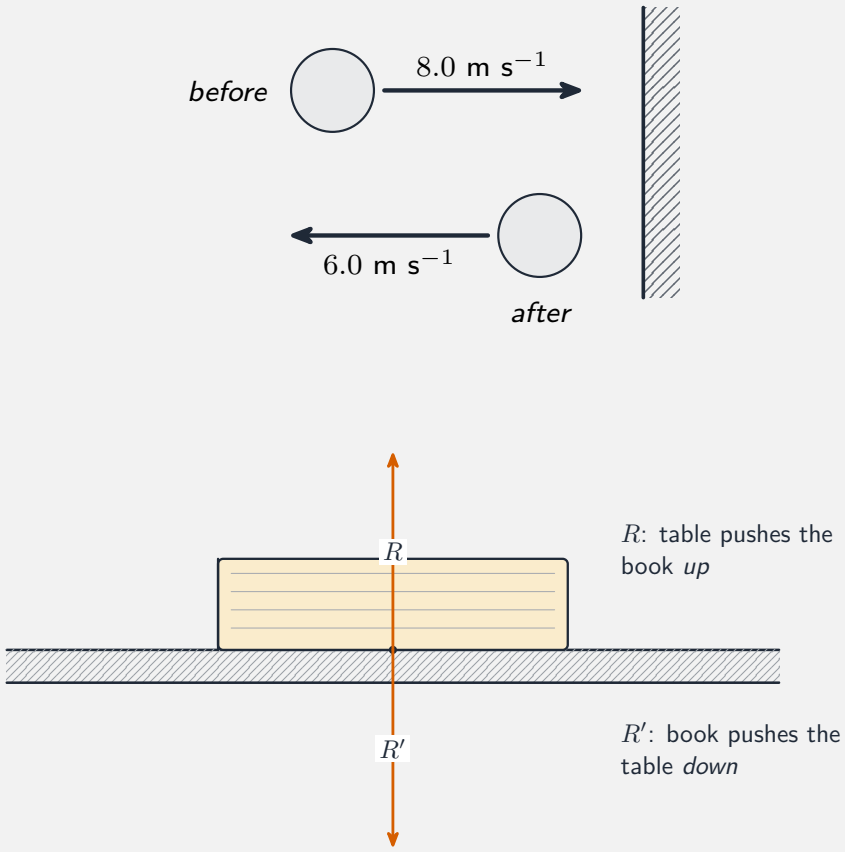
Newton's laws and F = ma

- **1st law:** with **zero resultant force**, an object stays at rest or moves at constant velocity.
- **2nd law:** resultant force = rate of change of momentum; for constant mass, $F = ma$.
- **3rd law:** if A pushes B, B pushes A with an **equal, opposite** force (a different object, same type).

Weight is the pull of gravity: $W = mg$ (with $g = 9.81$ m s^{-2}). **Mass** is the amount of matter (in kg) and is the **same everywhere**; **weight** is the force mg and **changes** with g —an object weighs less on the Moon (smaller g) even though its mass is unchanged.

Momentum and impulse

Momentum $p = mv$ (a vector, unit kg m s^{-1} = N s). In a collision the average force is $F = \dfrac{\Delta p}{\Delta t}$ —assign each direction a sign.



Newton third-law force pairs

Worked example. A 0.20 kg ball hits a wall at 8.0 m s^{-1} and rebounds at 6.0 m s^{-1} in 0.050 s. Take the rebound direction as positive ($u = -8.0$, $v = +6.0$):

$$\Delta p = m(v-u) = 0.20\,(6.0-(-8.0)) = 2.8 \text{ kg m s}^{-1}, \quad F = \frac{2.8}{0.050} = 56 \text{ N}.$$

2 Practice

Now apply the methods above.

2.1 State **Newton's first law** of motion. [1]

2.2 Calculate the **momentum** of a 1500 kg car travelling at 20 m s^{-1}. [2]

2.3 A resultant force of 5.0 N acts on a 2.0 kg mass. Find its **acceleration**. [2]

2.4 Calculate the **weight** of a 60 kg person ($g = 9.81$ m s^{-2}). [1]

3 Exam-style questions

3.1 The unit kg m s^{-1} is the unit of which quantity? [1]

- **A** force
- **B** momentum
- **C** energy
- **D** power

3.2 State **Newton's third law**, and give **one** example of a force pair. [2]

3.3 A 0.20 kg ball hits a wall at 8.0 m s^{-1} and rebounds straight back at 6.0 m s^{-1}. The contact lasts 0.050 s. Calculate the **average force** on the ball. [4]

3.4 Using Newton's second law, explain why a **longer** contact time gives a **smaller**

average force for the same change in momentum. [2]

3.5 An object is taken from the Earth to the Moon, where g is smaller. State what happens to its **mass** and to its **weight**. [2]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **3.1 Momentum and Newton's laws** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/22 N25 —Q1 (momentum and impulse)
- 9702/24 J25 —Q2 (Newton's laws)
- 9702/11 N25 —Q11 (force and momentum)
- 9702/24 J25 —Q3 (momentum calculation)

Solutions

2.1 An object stays at **rest** or moves with **constant velocity** unless a **resultant (external) force** acts on it.

2.2 $p = mv = 1500 \times 20 = 3.0 \times 10^4$ kg m s^{-1}.

2.3 $a = F/m = 5.0/2.0 = 2.5$ m s^{-2}.

2.4 $W = mg = 60 \times 9.81 = 590$ N.

3.1 B —momentum.

3.2 When object A exerts a force on B, B exerts an **equal and opposite** force on A (same type, different bodies); example: a rocket pushes gas down, the gas pushes the rocket up (or foot/ground, etc.).

3.3 Take rebound as positive: $u = -8.0$, $v = +6.0$; $\Delta p = 0.20\,(6.0 - (-8.0)) = 2.8$ kg m s^{-1}; $F = \Delta p/\Delta t = 2.8/0.050 = 56$ N.

3.4 $F = \Delta p/\Delta t$; for the same Δp, a larger Δt gives a smaller F (the force is inversely proportional to the contact time).

3.5 The **mass stays the same**; the **weight decreases**, because g is smaller on the Moon.