

Newton's Laws

Mark Scheme



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1. Newton's three laws of motion provide the essential rules for predicting how forces will affect an object, whether it is resting in equilibrium, accelerating under a resultant force, or colliding with another object.

- a) A car is travelling along a straight motorway at a constant velocity of 25 m/s.
Which statement correctly describes the forces acting on the car?

B – is the only correct answer.	1 mark
	Total: 1 mark

- b) A heavy truck collides with a small, stationary car.
Which statement correctly describes the forces exerted during the impact?

C – is the only correct answer.	1 mark
	Total: 1 mark

- c) According to Newton's Second Law, the acceleration of an object is directly proportional to the resultant force acting on it.

C – is the only correct answer.	1 mark
	Total: 1 mark

- d) A planet orbits a star at a constant speed in a circular path.

According to Newton's First Law, why must there be a resultant force acting on the planet?

D – is the only correct answer.	1 mark
	Total: 1 mark

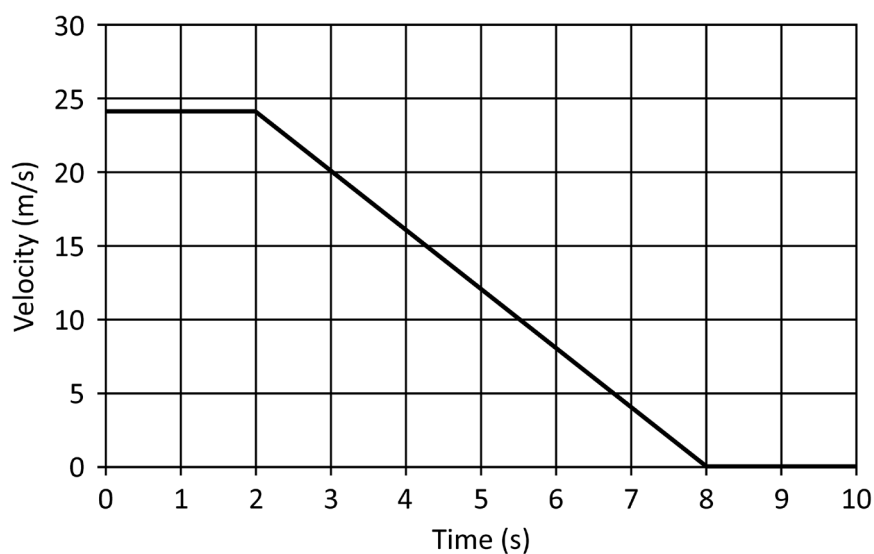
- e) Which of the following is the correct definition of inertial mass?

C – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 5 marks)

2. A car is travelling along a straight road at a constant velocity.
The driver sees a hazard ahead and applies the brakes to stop the car.

The velocity-time graph below shows the motion of the car.



- a) State the time at which the driver first applied the brakes.

2 seconds	1 mark
	Total: 1 mark

- b) Calculate the deceleration of the car while it is braking.

Change in velocity = 24 m/s	1 mark
Time taken = 6 seconds	1 mark
$a = \frac{\Delta v}{t}$ $a = \frac{24}{6}$ $a = 4 \text{ m/s}^2$	1 mark
	Total: 3 marks

- c) The total mass of the car and the driver is 1400 kg.
Calculate the resultant braking force required to stop the car.

Force = mass $\times$ acceleration	1 mark
Force = 1400 $\times$ 4	1 mark
Force = 5600 N	1 mark
	Total: 3 marks

d) State which of Newton's Laws you used to complete the calculation in part (c).

Newton's second law	1 mark
	Total: 1 mark

e) A second, identical car is travelling on the same road at the same speed.

However, this car is towing a heavy trailer.

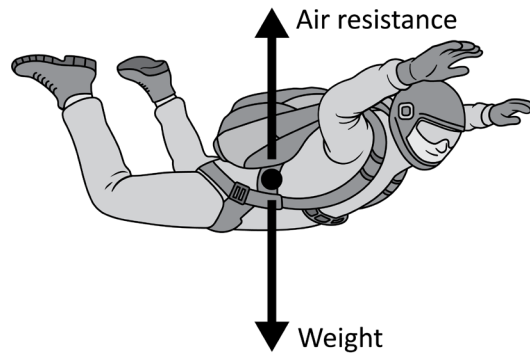
The driver of the second car applies the exact same braking force as the first car.

Explain how towing the heavy trailer will affect the acceleration and the stopping distance of the car.

An explanation to include:	
Towing a trailer increases the total mass of the vehicle.	1 mark
Allow 1 mark for identifying the increase in mass.	
Because $a = F \div m$ (and the force is constant), a larger mass results in a smaller deceleration.	1 mark
Allow 1 mark for linking the larger mass to a lower deceleration. Must mention acceleration/deceleration, not just 'it slows down slower'	
Because it is decelerating slower, the car will travel further before stopping / the stopping distance increases.	1 mark
Award 1 mark for concluding that stopping distance increases.	
	Total: 3 marks

(Total for Question 2 is 11 marks)

3. A skydiver jumps from a plane. The figure below shows the forces acting on the skydiver shortly after jumping.



- a) State what is happening to the speed of the skydiver at this exact moment.

Explain your answer using Newton's First Law.

An explanation to include the following:	
The speed is increasing / the skydiver is accelerating.	1 mark
Award: 1 mark for stating they are accelerating / speeding up.	
Because the downward force (weight) is greater than the upward force (air resistance), there is a resultant force acting downwards (which causes acceleration).	1 mark
Award: 1 mark for explaining there is a resultant force downwards.	
	Total: 2 marks

- b) As the skydiver continues to fall, their speed increases.

Describe what happens to the upward force of air resistance as their speed increases.

The air resistance <u>increases</u> .	1 mark
	Total: 1 mark

- c) Eventually, the skydiver reaches a constant top speed called terminal velocity.

Explain why the skydiver reaches terminal velocity and stops accelerating.

An explanation to include the following:	
As the skydiver speeds up, the air resistance keeps increasing.	1 mark
Until the upward force of air resistance exactly equals the downward force of weight.	1 mark
Award: 1 mark for stating air resistance becomes equal to/balances the weight.	
The resultant force is now zero, so they fall at a constant speed (Newton's 1st law).	1 mark
Award: 1 mark for stating the resultant force becomes zero.	
	Total: 3 marks

- d) The downward force on the skydiver is their weight.
This is caused by the Earth pulling downwards on the skydiver.

According to Newton's Third Law, there must be an equal and opposite reaction force.

Identify this reaction force.

The skydiver pulling upwards on the Earth (with a gravitational force).	1 mark
	Total: 1 mark

- e) A different skydiver, who has a much larger mass, jumps from the plane.

Explain why the heavier skydiver will reach a higher terminal velocity than the first skydiver.

An explanation to include:	
The heavier skydiver has a greater downward weight force.	1 mark
Allow: 1 mark for identifying the heavier skydiver has a larger weight.	
Therefore, they need a greater upward force of air resistance to balance their weight and reach a zero resultant force.	1 mark
Allow: 1 mark for stating they therefore need a larger force of air resistance to achieve balance/equilibrium.	
Because air resistance increases with speed, they must fall at a faster/higher speed to generate enough air resistance to balance their weight.	1 mark
Allow: 1 mark for linking this to needing a higher speed to generate that larger air resistance.	
	Total: 3 marks

(Total for Question 3 is 10 marks)

4. A large space rocket is launched vertically upwards from a launchpad.

Explain the forces acting on the rocket during its launch and explain why its acceleration increases as it travels upwards.

In your answer you should refer to:

- Newton's laws
- The forces acting on the rocket
- Why the acceleration is not constant.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	The student correctly identifies some forces (e.g., thrust, weight) or states a simple rule for example $F = m \times a$, but does not logically link them to the rocket's changing motion.
Level 2	3 - 4	The student identifies the relevant forces and explains the initial acceleration using Newton's Laws, but the explanation for why the acceleration increases may be incomplete or lack physical terminology.
Level 3	5 - 6	The student correctly identifies the forces acting on the rocket and successfully applies Newton's laws to explain both the initial acceleration and why the acceleration increases (linking to changing mass and/or changing air resistance).

Indicative content:	
Applying Newton's third law at the launch: • The rocket engines push the exhaust gases downwards. • According to Newton's third law, the gases exert an equal and opposite force pushing the rocket upwards (this is the thrust). Applying Newton's first and second laws during the initial acceleration: • The upward thrust is greater than the downward forces (weight and air resistance). • Because the forces are unbalanced, there is an upward resultant force. • According to Newton's first/second Law ($F = m \times a$), this resultant force causes the rocket to accelerate upwards. Explaining the increasing acceleration: • As the rocket burns fuel, its overall mass decreases significantly. • Because $a = F \div m$, a decreasing mass with a constant thrust will result in a greater acceleration. • As mass decreases, weight ($W = m \times g$) also decreases, which increases the overall upward resultant force. • As the rocket gets higher, the atmosphere becomes thinner, so air resistance decreases. This also increases the overall upward resultant force, further increasing acceleration.	
	Total: 6 marks

(Total for Question 4 is 6 marks)

5. An athlete is competing in a 100 m sprint.

a) The athlete has a mass of 75 kg.

Use the graph to calculate the acceleration of the athlete during the first 3 seconds of the race.

Acceleration = change in speed $\div$ time	1 mark
Change in speed = 9 m/s	1 mark
Time taken = $9 \div 3$	
Time taken = 3 seconds	1 mark
	Total: 3 marks

b) State the equation that links acceleration (a), mass (m), and resultant force (F).

Resultant force = mass $\times$ acceleration or $F = m \times a$	1 mark
	Total: 1 mark

c) Calculate the resultant force acting on the athlete during the first 3 seconds of the race.

$F = 75 \times 3$	1 mark
$F = 225 \text{ N}$	1 mark
	Total: 2 marks

d) Look at the graph between 3 seconds and 6 seconds.

The athlete is still applying the exact same forward driving force with their legs.

Explain why the athlete's acceleration decreases between 3 seconds and 6 seconds.

An explanation to include:	
As the athlete's speed increases, the air resistance acting against them also increases.	1 mark
This reduces the overall resultant force, which (because $a = F \div m$) causes the acceleration to decrease.	1 mark
	Total: 2 marks

e) State the resultant force acting on the athlete at 8 seconds.

Give a reason for your answer.

Resultant force = 0 (N)	1 mark
Reason: At 8 seconds, the graph is flat, meaning the athlete is travelling at a constant speed. According to Newton's first law, constant speed means the forces are balanced / resultant force is zero.	1 mark
	Total: 2 marks

(Total for Question 5 is 10 marks)

6. A helicopter is hovering perfectly still at a constant altitude.
The diagram shows the vertical forces acting on the helicopter.

A student looks at the diagram and states:

"The Earth pulls down on the helicopter with gravity, and the rotors push up with an equal and opposite thrust force. Therefore, these two forces are a Newton's third law action-reaction pair."

The student's statement is **incorrect**.

Explain why the student is wrong. In your answer, you should:

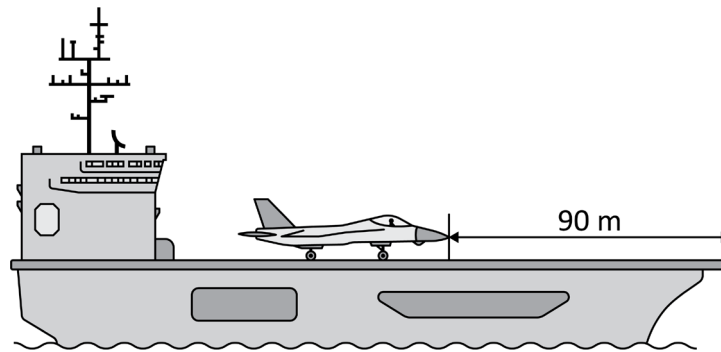
- explain why the two forces mentioned by the student are **not** a Newton's Third Law pair.
- identify the true Newton's third law pair for the downward **weight** force.
- identify the true Newton's third law pair for the upward **lift thrust** force.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Simple, fragmented statements. The student states that Third Law pairs must be the same type of force or act on different objects, but cannot correctly identify the true pairs for this scenario.
Level 2	3 - 4	A mostly correct explanation. The student identifies why the student is wrong, and correctly identifies at least one of the true Newton's Third Law pairs. May lack some specific terminology.
Level 3	5 - 6	A detailed, coherent, and logically structured explanation. The student clearly explains why the student is wrong (referencing forces acting on the same object) and correctly identifies both true Newton's Third Law pairs with the correct force types and interacting objects.

Indicative content:	
Why the student is wrong (the misconception): • The student is describing Newton's first law (balanced forces / equilibrium keeping the helicopter hovering). • A Newton's third law pair must consist of forces acting on two different objects. The weight and the lift thrust are both acting on the same object (the helicopter). • A Newton's third law pair must also be the exact same type of force. Weight (gravity) and Lift (a mechanical contact force with the air) are different types of forces. The true pair for weight: • Action: The Earth pulls down on the helicopter (gravitational force). • Reaction: The helicopter pulls up on the Earth (gravitational force). The true pair for the Lift Thrust: • Action: The rotor blades push down on the air (contact/mechanical force). • Reaction: The air pushes up on the rotor blades/helicopter which is contact or mechanical force).	
	Total: 6 marks

(Total for Question 6 is 6 marks)

7. A fighter jet is launched from the deck of an aircraft carrier using a steam catapult. The figure below shows the jet leaving the aircraft carrier.



The fighter jet has a mass of 2.4×10^4 kg.

It starts from rest and must reach a take-off velocity of 75 m/s by the time it reaches the end of the 90 m runway.

- a) Calculate the acceleration required for the jet to reach take-off velocity.

$v^2 - u^2 = 2as$	1 mark
$75^2 - 0^2 = 2 \times a \times 90$	1 mark
$a = 5625 \div 180$	
$a = 31.25 \text{ m/s}^2$	1 mark
	Total: 3 marks

- b) During the launch, the jet's own engines provide a constant forward thrust of 150,000 N.

Calculate the additional force that the steam catapult must apply to the jet to achieve the required acceleration.

$F = m \times a$	1 mark
$F = 2.4 \times 10^4 \times 31.25$	1 mark
Total force = engine thrust + catapult force	
$750,000 = 150,000 + C$	
$C = 750,000 - 150,000$	1 mark
$C = 600,000 \text{ N}$	1 mark
	Total: 4 marks

(Total for Question 7 is 7 marks)