

# Acceleration

## Mark Scheme



[www.scienceexamssorted.co.uk](http://www.scienceexamssorted.co.uk)

1. Whether it is a skydiver in freefall or a car braking at a junction, acceleration is the fundamental measure of how an object's velocity changes.

a) A car travels along a straight road. It accelerates from a speed of 10 m/s to 25 m/s in exactly 5 seconds. What is the acceleration of the car?

|                                        |                      |
|----------------------------------------|----------------------|
| <b>C – is the only correct answer.</b> | <b>1 mark</b>        |
|                                        | <b>Total: 1 mark</b> |

b) A motorcycle is travelling around a circular track at a constant, steady speed of 40 mph. Even though the speed is constant, the motorcycle is accelerating.

|                                        |                      |
|----------------------------------------|----------------------|
| <b>C – is the only correct answer.</b> | <b>1 mark</b>        |
|                                        | <b>Total: 1 mark</b> |

c) The velocity time graph below shows the velocity of a runner during the first part of a race. Using the graph, what is the acceleration of the runner?

|                                        |                      |
|----------------------------------------|----------------------|
| <b>A – is the only correct answer.</b> | <b>1 mark</b>        |
|                                        | <b>Total: 1 mark</b> |

d) A cyclist is travelling at 12 m/s. They apply the brakes and come to a complete stop in 3 seconds.

|                                        |                      |
|----------------------------------------|----------------------|
| <b>B – is the only correct answer.</b> | <b>1 mark</b>        |
|                                        | <b>Total: 1 mark</b> |

e) A cheetah starts from rest and accelerates to a top speed of 20 m/s over a distance of 50 m.

|                                        |                      |
|----------------------------------------|----------------------|
| <b>A – is the only correct answer.</b> | <b>1 mark</b>        |
|                                        | <b>Total: 1 mark</b> |

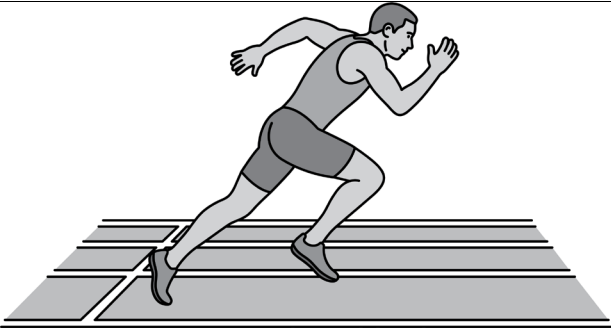
f) The graph below shows how the velocity of a rocket changes during a launch.

|                                        |                      |
|----------------------------------------|----------------------|
| <b>B – is the only correct answer.</b> | <b>1 mark</b>        |
|                                        | <b>Total: 1 mark</b> |

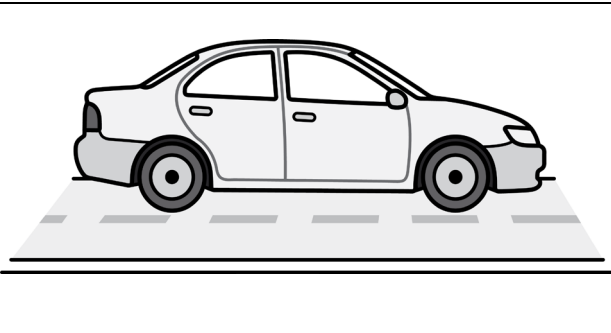
(Total for Question 1 is 6 marks)

2. For each of the scenarios below, use the equation  $\text{acceleration} = \text{change in velocity divided by the time taken}$  ( $a = \frac{\Delta V}{t}$ ).

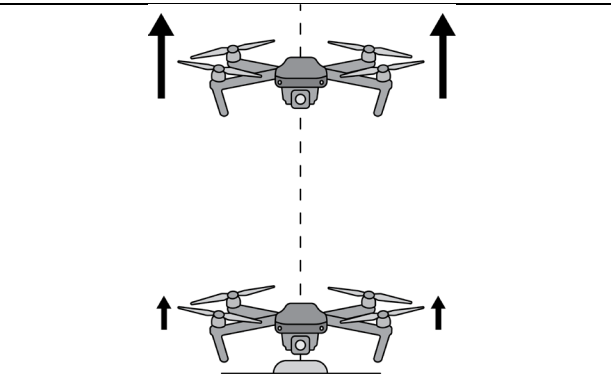
- a) The sprinter in the figure starts from rest and reaches a top speed of 10.5 m/s in a time of 3.0 seconds. Calculate the acceleration of the sprinter.

|                                                                                   |                                                                                   |
|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
|  | $a = \frac{\Delta V}{t}$ $a = 10.5 \div 3$ $a = 3.5$ $\text{Unit} = \text{m/s}^2$ |
|                                                                                   | Award 1 mark for the correct figure.                                              |
|                                                                                   | Award 1 mark for the correct unit.                                                |

- b) The car in Diagram B is travelling at 22 m/s. The driver hits the brakes and the car comes to a complete stop in 4.0 seconds. Calculate the **deceleration** of the car.

|                                                                                    |                                                                                   |
|------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
|  | $a = \frac{\Delta V}{t}$ $a = -22 \div 4$ $a = -5.5$ $\text{Unit} = \text{m/s}^2$ |
|                                                                                    | Award 1 mark for the correct figure.                                              |
|                                                                                    | Award 1 mark for the correct unit.                                                |

- c) The drone in the figure below accelerates from an initial velocity of 2 m/s to a final velocity of 14 m/s. The drone has an acceleration of 1.5 m/s<sup>2</sup>. Calculate the time taken for this acceleration.

|                                                                                     |                                                                                 |
|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
|  | $t = \frac{\Delta V}{a}$ $t = 12 \div 1.5$ $t = 8$ $\text{Unit} = \text{m/s}^2$ |
|                                                                                     | Award 1 mark for the correct figure.                                            |
|                                                                                     | Award 1 mark for the correct unit.                                              |

(Total for Question 2 is 6 marks)

3. For each of the scenarios below, use the equation  $v^2 - u^2 = 2as$ .

- a) A rocket starts from rest and reaches a velocity of 50 m/s after travelling a distance of 100 m.  
Calculate the acceleration of the rocket.

|                                                  |                |
|--------------------------------------------------|----------------|
| acceleration = $\frac{50^2 - 0^2}{2 \times 100}$ | 1 mark         |
| acceleration = <b>12.5</b>                       | 1 mark         |
| Unit: <b>m/s<sup>2</sup></b>                     | 1 mark         |
|                                                  | Total: 3 marks |

- b) A cyclist is travelling at 15 m/s. They hit the brakes and come to a stop over a distance of 25 m.  
Calculate the **deceleration** of the cyclist.

|                                                 |                |
|-------------------------------------------------|----------------|
| acceleration = $\frac{0^2 - 15^2}{2 \times 25}$ | 1 mark         |
| deceleration = <b>4.5</b>                       | 1 mark         |
| Unit: <b>m/s<sup>2</sup></b>                    | 1 mark         |
|                                                 | Total: 3 marks |

- c) A train accelerates uniformly at 1.5 m/s<sup>2</sup>. Its velocity increases from 20 m/s to 40 m/s.  
Calculate the **distance** the train travels while it is accelerating.

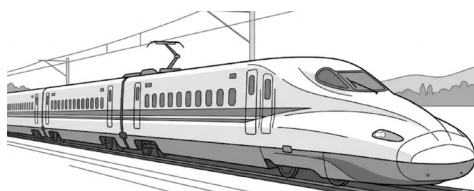
|                                                   |                |
|---------------------------------------------------|----------------|
| acceleration = $\frac{40^2 - 20^2}{2 \times 1.5}$ | 1 mark         |
| deceleration = <b>400</b>                         | 1 mark         |
| Unit: <b>m</b>                                    | 1 mark         |
|                                                   | Total: 3 marks |

- d) A bullet is fired from a rifle. It accelerates from rest at 45,000 m/s<sup>2</sup> through a barrel that is 0.6 m long.  
Calculate the **final velocity** of the bullet as it leaves the barrel.

|                                                               |                |
|---------------------------------------------------------------|----------------|
| $v^2 - u^2 = 2as$<br>$v^2 - 0^2 = 2 \times 45,000 \times 0.6$ | 1 mark         |
| $v^2 = 54,000$<br>$v = \sqrt{54000} \quad v = \mathbf{232.4}$ | 1 mark         |
| Unit: <b>m/s</b>                                              | 1 mark         |
|                                                               | Total: 3 marks |

(Total for Question 3 is 12 marks)

4. A high-speed passenger train is travelling along a straight, level track.



- a) State what is meant by the term acceleration.

|                                         |               |
|-----------------------------------------|---------------|
| A statement that conveys the following: |               |
| <u>The rate of change of velocity.</u>  | 1 mark        |
|                                         | Total: 1 mark |

- b) The train departs from a station. It starts from rest and accelerates to a velocity of 60 m/s. It takes the train 120 seconds to reach this velocity. Calculate the **acceleration** of the train.

|                                         |                |
|-----------------------------------------|----------------|
| acceleration = $\frac{60^2 - 0^2}{120}$ | 1 mark         |
| deceleration = 0.5                      | 1 mark         |
| Unit: m/s <sup>2</sup>                  | 1 mark         |
|                                         | Total: 3 marks |

- c) Later in the journey, the train is travelling at a high speed when it approaches another station. The driver applies the brakes, producing a resultant braking force of 300,000 N. Calculate the **deceleration** of the train as it brakes.

|                              |                |
|------------------------------|----------------|
| $F = m \times a$             |                |
| $300,000 = 400,000 \times a$ | 1 mark         |
| $a = 0.75$                   | 1 mark         |
|                              | Total: 2 marks |

- d) A passenger notices that the train takes a very long time, and travels a very long distance, before it finally comes to a complete stop.

|                                                                                                                                 |                |
|---------------------------------------------------------------------------------------------------------------------------------|----------------|
| An explanation to include the following:                                                                                        |                |
| A train has a much larger mass than a car.                                                                                      | 1 mark         |
| Because $a = F \div m$ much larger mass results in a much lower deceleration (meaning it takes longer/travels further to stop). | 1 mark         |
|                                                                                                                                 | Total: 2 marks |

(Total for Question 4 is 8 marks)

5. A student is riding an electric scooter along a flat cycle path.



The student and scooter have a combined mass of 85,000 g and are travelling at a speed of 18 km/h.

A dog suddenly runs in front of the student. The student applies the brakes and comes to a complete stop. The braking distance of the scooter is exactly 5 metres.

- a) Calculate the **resultant braking force** required to stop the scooter in this distance.  
You must show all of your working and ensure your units are correct.

|                                                                                                                                                                                                                                                                                                                                                                                              |         |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| <p><b>Convert units:</b></p> <p><b>Marking note:</b> this step doesn't necessarily need to be done first but it does need to happen at some point in the student's calculation.</p> <p><b>Mass:</b> <math>85,000 \text{ g} \div 1000 = 85 \text{ kg}</math></p> <p><b>Distance in m:</b> <math>18 \text{ km} \times 1000 = 18,000 \text{ m}</math></p> <p><b>Time in seconds:</b> 3600 s</p> | 2 marks |
| <p><b>Speed:</b></p> <p><math>18,000 \div 3600 = 5 \text{ m/s}</math></p>                                                                                                                                                                                                                                                                                                                    | 1 mark  |
| <p><b>Find the time using the average speed:</b></p> <p>Time = distance <math>\div</math> average speed</p> <p><math>T = 5 \div 2.5</math></p> <p><math>T = 2 \text{ seconds}</math></p>                                                                                                                                                                                                     | 1 mark  |
| <p><b>Calculate deceleration:</b></p> <p>deceleration = <math>\frac{0^2 - 5^2}{2}</math></p> <p>deceleration = <math>2.5 \text{ m/s}^2</math></p>                                                                                                                                                                                                                                            | 1 mark  |
| <p><b>Calculate braking force:</b></p> <p><math>F = m \times a</math></p> <p><math>F = 85 \times 2.5</math></p> <p>Force = 212.5 N</p>                                                                                                                                                                                                                                                       | 1 mark  |
| Total: 6 marks                                                                                                                                                                                                                                                                                                                                                                               |         |

- b) The student rides the scooter again on a different day when it is raining heavily. The figure below shows this.



Explain how the wet weather will affect the scooter's braking distance and their overall stopping distance.

|                                                                                                                     |                |
|---------------------------------------------------------------------------------------------------------------------|----------------|
| An explanation to include the following:                                                                            |                |
| The wet surface decreases friction (between the tyres and the path), which increases the braking distance.          | 1 mark         |
| <b>Allow:</b> 1 mark for stating friction decreases causing braking distance to increase.                           |                |
| Because stopping distance = thinking distance + braking distance, the overall stopping distance will also increase. | 1 mark         |
| <b>Allow:</b> 1 mark for correctly concluding that overall stopping distance increases.                             |                |
|                                                                                                                     | Total: 2 marks |

- c) When a car driver brakes very sharply, its passengers are held in their seat by a seatbelt.

Using Newton's first law of motion, state what would happen to the student if the electric scooter brakes too sharply, and why this happens.

|                                                                                                                                                                                                                                                                                                       |                |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| An explanation to include the following:                                                                                                                                                                                                                                                              |                |
| The student would fall/fly forwards over the handlebars.                                                                                                                                                                                                                                              | 1 mark         |
| With one of following points in their explanation(or both):                                                                                                                                                                                                                                           |                |
| <ul style="list-style-type: none"> <li>Because (according to Newton's first law) an object in motion will stay in motion unless acted upon by a resultant force.</li> <li>The scooter stops, but there is no resultant force (like a seatbelt) pulling the student backwards to stop them.</li> </ul> |                |
|                                                                                                                                                                                                                                                                                                       | Total: 2 marks |

(Total for Question 5 is 10 marks)

6. A historical reenactor is using an English longbow. The figure below shows the bowman.



The archer pulls the bowstring back and holds the arrow stationary. When the string is released, it accelerates the arrow forwards. As the arrow leaves the string, it reaches a top speed of 180 km/h.

- a) Convert the arrow's speed into m/s.

|                                          |                          |                |
|------------------------------------------|--------------------------|----------------|
| An explanation to include the following: |                          |                |
| 180 km = 180,000 m                       | 3600 seconds as the time | 1 mark         |
| 180,000 ÷ 3600                           |                          |                |
| Speed = <b>50 m/s</b>                    |                          | 1 mark         |
|                                          |                          | Total: 2 marks |

- b) The distance the string accelerates the arrow is 75 cm.

Use the equation  $v^2 - u^2 = 2as$  to calculate the uniform acceleration of the arrow while it is still on the string. You must show your working.

|                                       |  |                |
|---------------------------------------|--|----------------|
| Distance = 75 cm = 0.75 m             |  |                |
| $50^2 - 0^2 = 2 \times a \times 0.75$ |  | 1 mark         |
| $a = 2500 \div 1.5$                   |  | 1 mark         |
| $a = \mathbf{1666.7}$                 |  | 1 mark         |
| Unit: <b>m/s<sup>2</sup></b>          |  | 1 mark         |
|                                       |  | Total: 4 marks |

- c) The heavy arrow has a mass of 60 g.

Calculate the **resultant force** exerted on the arrow by the bowstring.

|                             |  |                |
|-----------------------------|--|----------------|
| Mass = 60 g = 0.06 kg       |  | 1 mark         |
| $F = m \times a$            |  |                |
| $F = 0.06 \times 1666.7$    |  | 1 mark         |
| $F = \mathbf{100\text{ N}}$ |  | 1 mark         |
|                             |  | Total: 3 marks |

(Total for Question 6 is 9 marks)

7. A student drops a heavy, rough stone into a deep, clear lake.

a) State the name of the downward force and the upward force acting on the stone as it sinks.

|                                                           |                |
|-----------------------------------------------------------|----------------|
| <b>Downward force:</b> weight                             | 1 mark         |
| <b>Upward force:</b> water resistance or drag or friction | 1 mark         |
|                                                           | Total: 2 marks |

b) The stone has a mass of 3.5 kg. At one point as the stone sinks the upward force acting against the stone is 12.4 N. Gravitational field strength ( $g$ ) = 9.8 N/kg.

Calculate the acceleration of the stone at this exact moment.

You must show your working.

|                                                                                                                  |                |
|------------------------------------------------------------------------------------------------------------------|----------------|
| <b>Calculate weight:</b><br>$W = m \times g$<br>$W = 3.5 \times 9.8$<br>$W = 34.3 \text{ N}$                     | 1 mark         |
| <b>Calculate resultant force:</b><br>$F = 34.3 - 12.4$<br>$F = \mathbf{21.9 \text{ N}}$                          | 1 mark         |
| <b>Calculate acceleration:</b><br>$F = m \times a$<br>$21.9 = 3.5 \times a$<br>$a = 21.9 \div 3.5$<br>$a = 6.26$ | 1 mark         |
| Unit: <b><math>\text{m/s}^2</math></b>                                                                           | 1 mark         |
|                                                                                                                  | Total: 4 marks |

As the stone sinks deeper, its downward speed continues to increase.

Eventually, the stone reaches its **terminal velocity**.

c) Explain why the acceleration of the stone decreases as it sinks, and why it reaches terminal velocity

|                                                                                                                                                         |                |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| <b>An explanation to include the following:</b>                                                                                                         |                |
| As the speed of the stone increases, the upward force of water resistance increases.                                                                    | 1 mark         |
| This reduces the overall downward resultant force, which causes the acceleration to decrease.                                                           | 1 mark         |
| Eventually, the upward water resistance exactly equals/balances the downward weight, making the resultant force zero (so it falls at a constant speed). | 1 mark         |
|                                                                                                                                                         | Total: 2 marks |

(Total for Question 7 is 8 marks)