

Terminal velocity and changing forces

AQA GCSE Combined Science Trilogy 8464 and Separate Physics 8463 | Paper 2 | Foundation and Higher

Worked answers | 28 parts / 44 marks per pathway | Alternative final pages

Specification points covered

8463 4.5.1.3 and 4.5.1.4 / 8464 6.5.1.3 and 6.5.1.4: weight and collinear resultants

8463 4.5.6.1.5 / 8464 6.5.4.1.5: acceleration and terminal velocity

8463 4.5.6.2.1 and 4.5.6.2.2 / 8464 6.5.4.2.1 and 6.5.4.2.2: Newton's First and Second Laws

Section 6: Separate Physics graph pathway; section 5 is the matched Combined data pathway

An automated greenhouse drops seed-pod sensors through a 24 m test shaft. Engineers compare fixed outer shells before choosing a landing design. Air is still. Ignore upthrust; only weight and air resistance act during a fall. Each trial has a fixed orientation and no contact with the shaft.

Original PhysicsUK practice, not an official AQA resource. Common pages 1–5 plus Combined page 6 OR Separate page 7. Each route: 28 parts, 44 marks; all tasks are both-tier. Assign only one final pathway. Credit equivalent correct wording and consistent follow-through. Graph answers have reading tolerances. Do not describe a velocity as “accelerating”.

1 Preparing a release

Unless a question states otherwise, a sensor has total mass 100 g, including its shell. At the instant it is released from rest, air resistance is zero in this model.

1(a) What is meant by the weight of an object? **[1 mark]**

Answer / mark points: The force acting on it due to gravity. [1] Weight is not mass.

1(b) What is meant by acceleration? **[1 mark]**

Answer / mark points: The rate of change of velocity/change in velocity per unit time. [1] It is not the velocity itself.

1(c) Convert the sensor's mass to kg and calculate its weight. **[2 marks]**

Answer / mark points: 100 g = 0.100 kg. [1]

$W = mg = 0.100 \times 9.8 = 0.980$ N, downwards. [1]

1(d) Calculate the resultant force and acceleration at the instant of release. Include directions. **[2 marks]**

Answer / mark points: Only weight acts in the model: resultant = 0.980 N downwards. [1]

$a = F/m = 0.980/0.100 = 9.8$ m s⁻² downwards. [1] Drag becomes significant later.



2 Comparing stages of the fall

Figure 1 gives three snapshots of the SAME 100 g sensor. The labelled arrows are forces on the actual sensor, not three different sensors in one fall. Drag means air resistance. Use the force VALUES, not measured arrow lengths.

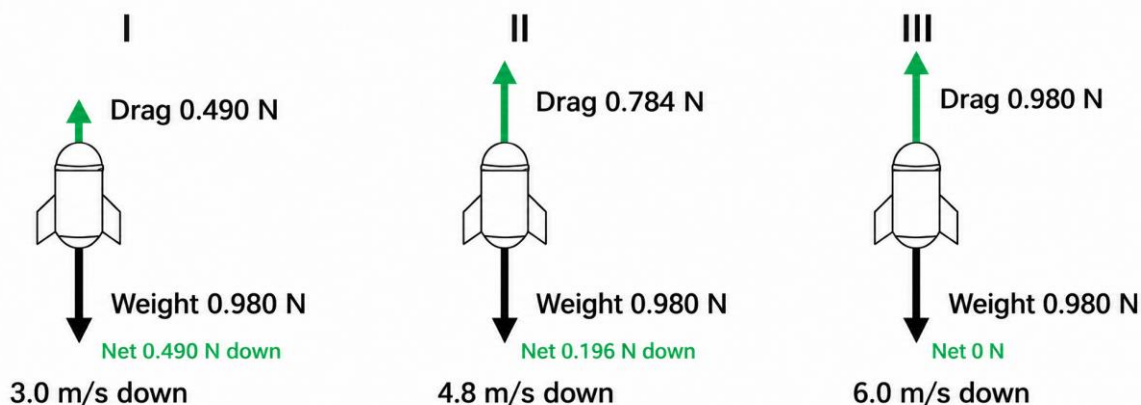


Figure 1

2(a) Calculate the resultant force in snapshot I, including its direction. [1 mark]

Answer / mark points: $0.980 - 0.490 = 0.490$ N downwards. [1 for magnitude and direction]

2(b) Calculate the acceleration in snapshot I, including its direction. [1 mark]

Answer / mark points: $a = 0.490/0.100 = 4.90$ m s⁻² downwards. [1]

2(c) Calculate the resultant force in snapshot II, including its direction. [1 mark]

Answer / mark points: $0.980 - 0.784 = 0.196$ N downwards. [1 for magnitude and direction]

2(d) Calculate the acceleration in snapshot II, including its direction. [1 mark]

Answer / mark points: $a = 0.196/0.100 = 1.96$ m s⁻² downwards. [1]

2(e) For snapshot III, state the resultant force and acceleration, then describe the sensor's velocity. [2 marks]

Answer / mark points: Resultant = 0 N and acceleration = 0 m s⁻². [1 for both]

Velocity remains constant at 6.0 m s⁻¹ downwards. [1] It is not stationary.

2(f) The acceleration is smaller in II than in I. Explain why this does NOT mean that the sensor is slowing down. [2 marks]

Answer / mark points: The resultant and acceleration are still downwards, in the same direction as the motion. [1]

Downward velocity still increases, but at a smaller rate. [1] Decreasing acceleration is not the same as decreasing speed.



3 Choosing an outer shell

Table 1 gives rounded drag measurements for original shell A and wider shell B at three downward speeds. Both complete sensors have mass 100 g. The shells stay fixed in shape; there is no parachute opening. Use the supplied evidence rather than assuming a drag equation.

Table 1

Downward speed / m s^{-1}	Drag on A / N	Drag on B / N
2.0	0.327	0.550
4.0	0.653	0.980
6.0	0.980	1.300

3(a) At 4.0 m s^{-1} , calculate the resultant force and acceleration for shell A. Include directions. **[2 marks]**

Answer / mark points: Resultant = $0.980 - 0.653 = 0.327 \text{ N}$ downwards. [1]
 $a = 0.327/0.100 = 3.27 \text{ m s}^{-2}$ downwards. [1] Accept 3.3 m s^{-2} .

3(b) Use Table 1 to identify the terminal velocity of each design. Explain how you know. **[2 marks]**

Answer / mark points: A: 6.0 m s^{-1} downwards, where drag equals weight, 0.980 N . [1]
 B: 4.0 m s^{-1} downwards, where drag also equals 0.980 N . [1] Terminal velocity is not the largest drag value.

3(c) The sensor must land at no more than 4.5 m s^{-1} . Which shell meets this speed criterion after a long enough fall? Justify your answer using both designs. **[2 marks]**

Answer / mark points: Choose B: terminal speed 4.0 m s^{-1} is below 4.5 m s^{-1} . [1]
 A reaches 6.0 m s^{-1} , above the limit. [1] This checks only the supplied speed criterion, not full engineering safety.



3 Choosing an outer shell continued

Use Table 1 on the previous page. The original complete sensor has mass 100 g unless a new mass is stated.

3(d) In a new trial, shell B is already moving DOWN at 6.0 m s^{-1} . Calculate the resultant force and describe the immediate change in its speed. **[2 marks]**

Answer / mark points: $1.300 - 0.980 = 0.320 \text{ N}$ upwards. [1]

It slows down because the resultant is opposite its downward motion. [1] It does not instantly start moving upwards.

3(e) An internal payload increases shell A's total mass to 150 g without changing its outer shape. At 6.0 m s^{-1} drag is still 0.980 N. Calculate the resultant and predict whether its new terminal speed is above or below 6.0 m s^{-1} . **[2 marks]**

Answer / mark points: Weight = $0.150 \times 9.8 = 1.470 \text{ N}$; resultant = $1.470 - 0.980 = 0.490 \text{ N}$ downwards. [1]

Terminal speed is higher: it still speeds up at 6.0 m s^{-1} and needs greater drag to balance its greater weight. [1] Allow correct follow-through.

3(f) The team claims that a difference in terminal speed is caused by shell shape. State TWO other conditions that should be kept the same when comparing A and B. **[2 marks]**

Answer / mark points: Any two, one mark each: complete sensor mass; air conditions/density or still-air conditions; release from rest under the same conditions; enough common fall distance to reach terminal motion; controlled orientation for each design. [2 max]

Do not credit "same outer shape": that is the variable being tested.

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4 Explaining the changing motion

Use the greenhouse sensor to correct the statements below. Its mass and gravitational field strength stay constant throughout each fall.

4(a) Rewrite this sentence correctly: "The sensor's velocity is accelerating downwards." Describe what happens to its velocity during the early fall. **[1 mark]**

Answer / mark points: The sensor's downward velocity increases. [1] Accept speed increases while moving downwards. The object accelerates; its velocity changes.

4(b) A trainee says, "At terminal velocity the sensor has zero velocity because the resultant is zero." Correct both parts of the motion description. **[2 marks]**

Answer / mark points: The sensor still has a non-zero downward velocity. [1]
Its velocity is constant/its acceleration is zero because the resultant is zero. [1] Do not say that all forces are zero.

4(c) A log says that the sensor's weight is "used up" during the fall. Explain why its weight stays constant in this test. **[1 mark]**

Answer / mark points: Its mass and g remain constant, so $W = mg$ stays constant. [1 for the linked explanation] Weight is not a store that is used up.

4(d) Why is air resistance zero at release but greater later in the fall? **[2 marks]**

Answer / mark points: At release the sensor is at rest relative to the still air. [1]
As its speed relative to the air increases, air resistance increases. [1] Do not say that its weight causes air resistance directly.

4(e) The sensor is falling steadily. A trainee says "no forces act". Use the model to correct this statement. **[1 mark]**

Answer / mark points: Non-zero weight downwards and air resistance upwards act and balance; only their resultant is zero. [1 for the correction]

4(f) Write a linked explanation of how shell A goes from release to terminal velocity. Refer to changing forces, acceleration and velocity. **[3 marks]**

Answer / mark points: Initially weight is greater than drag, so there is a downward resultant/acceleration and downward velocity increases. [1]
As speed increases, drag increases while weight stays constant, so resultant force and acceleration decrease. [1]
Eventually drag equals weight: resultant and acceleration are zero, and the sensor continues at constant non-zero downward velocity. [1]
Do not credit "velocity accelerates" or "weight decreases".

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5 Combined Science data pathway

Combined Science Trilogy 8464: complete this page after sections 1–4, then stop. Separate Physics pupils use section 6 instead. Table 2 is a model based on rounded measurements for a 100 g sensor with shell A. It represents steady terminal motion from 3.0 s. The sensor has not yet landed.

Table 2

Time / s	Downward velocity / m s ⁻¹
0	0
1.0	4.8
2.0	5.8
3.0	6.0
4.0	6.0

5(a) Use Table 2 to calculate the change in downward velocity from 0 to 1.0 s. **[1 mark]**

Answer / mark points: $4.8 - 0 = 4.8 \text{ m s}^{-1}$ downwards. [1]

5(b) Calculate the average acceleration from 0 to 1.0 s. **[1 mark]**

Answer / mark points: $(4.8 - 0)/(1.0 - 0) = 4.8 \text{ m s}^{-2}$ downwards. [1]

5(c) Calculate the average acceleration from 1.0 to 2.0 s. **[1 mark]**

Answer / mark points: $(5.8 - 4.8)/(2.0 - 1.0) = 1.0 \text{ m s}^{-2}$ downwards. [1]

5(d) Calculate the average acceleration from 3.0 to 4.0 s. **[1 mark]**

Answer / mark points: $(6.0 - 6.0)/(4.0 - 3.0) = 0 \text{ m s}^{-2}$. [1]

5(e) Use the values from 3.0 to 4.0 s to explain why the sensor has not stopped. **[2 marks]**

Answer / mark points: Its velocity is 6.0 m s^{-1} downwards at both times, not zero. [1]
Zero change in velocity/zero acceleration means it continues at that constant velocity. [1]

5(f) Compare the average accelerations during 0–1.0 s and 1.0–2.0 s. Explain the difference using the forces. **[2 marks]**

Answer / mark points: It decreases from 4.8 to 1.0 m s^{-2} , while downward velocity still increases. [1]
Increasing drag with constant weight gives a smaller downward resultant and hence smaller acceleration. [1]

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6 Separate Physics graph pathway

Separate Physics 8463: complete this page INSTEAD of section 5. Figure 2 represents the same model trial for a 100 g sensor with shell A, based on rounded measurements. It is horizontal from 3.0 s; the sensor has not yet landed. Use the plotted points for average-acceleration calculations.

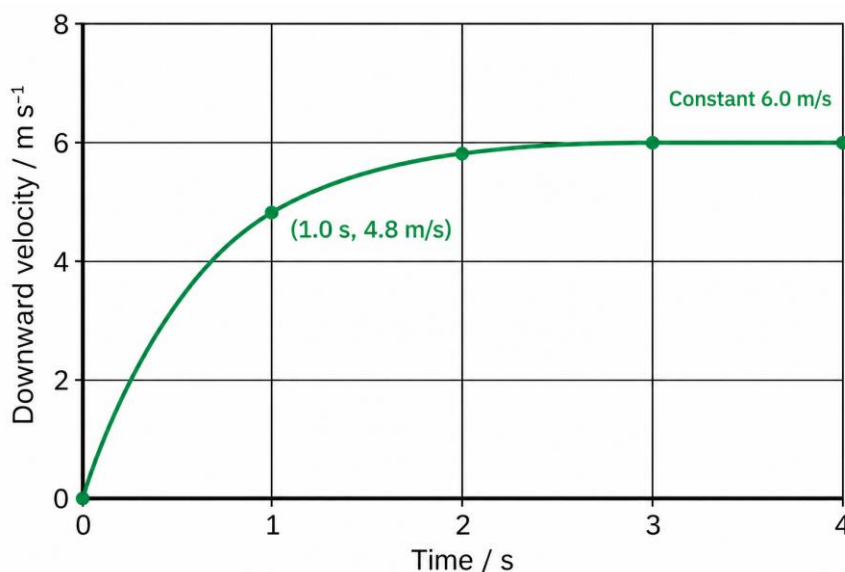


Figure 2

6(a) Read the downward velocity at 1.0 s from Figure 2. **[1 mark]**

Answer / mark points: About 4.8 m s⁻¹ downwards. [1; accept 4.6–5.0 from the graph]

6(b) Read the terminal velocity from Figure 2. Include its direction. **[1 mark]**

Answer / mark points: 6.0 m s⁻¹ downwards. [1; accept 5.9–6.1]

6(c) Use the plotted points to calculate the average acceleration from 0 to 1.0 s. **[1 mark]**

Answer / mark points: $(4.8 - 0)/1.0 = 4.8 \text{ m s}^{-2}$ downwards. [1; allow consistent reading follow-through]

6(d) Use the plotted points to calculate the average acceleration from 1.0 to 2.0 s. **[1 mark]**

Answer / mark points: $(5.8 - 4.8)/(2.0 - 1.0) = 1.0 \text{ m s}^{-2}$ downwards. [1; allow consistent graph readings] This is an average, not an instantaneous tangent gradient.

6(e) State the acceleration from 3.0 to 4.0 s and explain what this part of the graph shows about velocity. **[2 marks]**

Answer / mark points: Acceleration = 0 m s⁻² because the gradient is zero. [1]
Velocity is constant at 6.0 m s⁻¹ downwards, not zero. [1]

6(f) Explain why the curve becomes less steep before it is horizontal. Link the gradient to the changing forces. **[2 marks]**

Answer / mark points: The decreasing gradient means decreasing positive/downward acceleration; velocity still increases. [1]
Drag increases with speed while weight stays constant, reducing the downward resultant and therefore acceleration. [1]

Review and improve

Check force directions and distinguish increasing velocity from decreasing acceleration. Timing is estimated and untrials.

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