physics UK

Smarter practice. Stronger understanding

SOLUTIONS

ATTEMPT CHECK CORRECT IMPROVE

OCR A A Level Physics: Non-uniform acceleration solutions

Matching solutions and teaching prompts for the class review

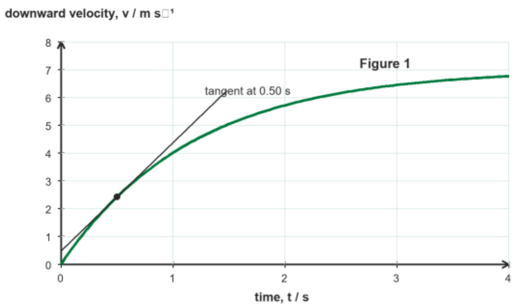
Specification points covered

- 3.2.1(a) Apply Newton's second law, F = ma.
- 3.2.1(c) Understand weight of an object, W = mg.
- 3.2.2(a) Define drag as a frictional force experienced by an object travelling through a fluid.
- 3.2.2(b) Explain factors which affect drag for an object travelling through air.
- 3.2.2(c) Describe the motion of falling objects in a uniform gravitational field in the presence of drag.
- 3.2.2(d) Define terminal velocity and use practical procedures to determine it in a fluid.

Teaching focus

Model the chain: velocity increases → drag increases → resultant force decreases → acceleration decreases. At terminal velocity, velocity stays the same; the resultant force and acceleration are zero.

1. Sensor pod in air



1. Define drag. [1 mark]

Answer / mark points: Drag is the frictional force experienced by an object travelling through a fluid.	
Teacher prompt / common error: The definition needs both friction and a fluid. Air is a fluid; drag is not an extra downward force.	

2. State the two vertical forces acting on the sensor pod just after it is released. Ignore any horizontal forces. [2 marks]

Answer / mark points: Weight acts vertically downwards. Drag due to the air acts vertically upwards, opposite to the motion.	
Teacher prompt / common error: Ask pupils to name forces on the pod, not the direction of motion. Do not credit 'gravity' as a force unless it is clearly stated as weight.	

3. Explain why the initial downward acceleration of the pod is approximately g. [1 mark]

Answer / mark points: Just after release, the downward weight is much greater than the upward drag. The resultant force is therefore approximately the weight, so a is approximately g downwards.	
Teacher prompt / common error: At release, drag is small because the downward velocity is zero. Weight is the dominant force.	

1. Sensor pod in air continued

4. Use Figure 1 to state the downward velocity of the pod at 1.0 s. [1 mark]

Answer / mark points: 4.0 m s^{-1} downwards (allow a sensible graph reading between 3.9 and 4.1 m s^{-1}).	
Teacher prompt / common error: Velocity is a vector, so the direction should be stated even though the vertical axis is labelled downward velocity.	

5. Draw a tangent to the curve at 0.50 s. Use it to determine the downward acceleration of the pod at this instant. [2 marks]

Answer / mark points: Gradient of a tangent at 0.50 s = 3.9 m s^{-2} downwards (allow 3.7–4.1 m s^{-2} from a suitable tangent).	
Teacher prompt / common error: Acceleration at one instant is the gradient of a tangent, not the average gradient from the origin. Check units carefully.	

6. Calculate the weight of the sensor pod. [1 mark]

Answer / mark points: $W = mg = 0.200 \times 9.81 = 1.962$ N = 1.96 N (3 s.f.).	
Teacher prompt / common error: Weight is a force in newtons: $W = mg$. Do not use $W = m / g$.	

7. Use your answer to question 5 to calculate the resultant force acting on the pod at 0.50 s. State its direction. [2 marks]

Answer / mark points: $F = ma = 0.200 \times 3.9 = 0.78$ N downwards (allow values consistent with the student's tangent).	
Teacher prompt / common error: Use the resultant force, not the weight. A stated direction is required.	

8. Calculate the magnitude of the drag force acting on the pod at 0.50 s. [2 marks]

Answer / mark points: Drag = weight − resultant force = 1.962 − 0.78 = 1.18 N upwards (3 s.f.).	
Teacher prompt / common error: At this instant the downward weight exceeds the upward drag. Use magnitudes after identifying the directions.	

1. Sensor pod in air continued

9. Explain why the downward acceleration of the pod decreases as its downward velocity increases. **[3 marks]**

Answer / mark points: As downward velocity increases, the drag force increases. The upward drag becomes closer to the downward weight, so the downward resultant force decreases. Therefore the downward acceleration decreases.

Teacher prompt / common error: Preferred language: downward velocity increases, drag increases, resultant force decreases, acceleration decreases. Do not accept ‘the velocity is accelerating’.

10. State what is meant by terminal velocity. Refer to the forces and the acceleration. **[2 marks]**

Answer / mark points: Terminal velocity is the constant velocity reached when drag equals weight. The resultant force and acceleration are then zero.

Teacher prompt / common error: A complete answer links constant velocity to balanced forces and zero acceleration. It does not mean that there are no forces.

11. The pod is redesigned with larger side fins. At its original terminal velocity, the drag is now greater than its weight. State and explain how the pod’s terminal velocity changes. **[2 marks]**

Answer / mark points: The terminal velocity decreases. At the original terminal velocity, drag is greater than weight so there is an upward resultant force. The downward velocity therefore decreases until drag again equals weight.

Teacher prompt / common error: At first there is an upward resultant force, so the downward velocity decreases. The new terminal velocity is lower, not higher.

12. On the axes in Figure 2, sketch a velocity–time graph for the redesigned pod. It is released from rest in the same conditions. Label the terminal velocity. **[2 marks]**

Answer / mark points: A curve starting at the origin with an initially steep positive gradient. It becomes less steep and levels off at a horizontal terminal-velocity line below 7.0 $m\ s^{-1}$.

Teacher prompt / common error: The line should be curved, not a straight deceleration line. Its horizontal section must be below the original terminal velocity.

2. Marble in a viscous liquid

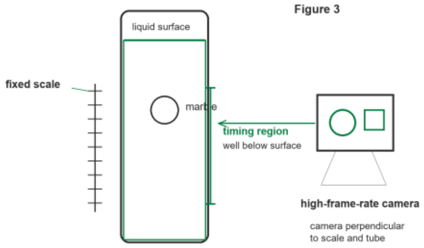


Figure 3

13. Explain why the timing region in Figure 3 begins well below the liquid surface. [1 mark]

Answer / mark points: It gives the marble time to reach terminal velocity before measurements are made in the timing region.
Teacher prompt / common error: This is about excluding the initial accelerating part of the motion, not simply making the measurement easier.

14. Table 1 gives total distances measured from video frames. (a) Calculate the average speed during the first 0.10 s. (b) Calculate the average speed from 0.30 s to 0.50 s. (c) Use the data to state the terminal velocity and explain your choice. [3 marks]

Answer / mark points: (a) $v = 0.040 / 0.10 = 0.40$ m s^{-1}. (b) $v = (0.500 - 0.260) / (0.50 - 0.30) = 1.20$ m s^{-1}. (c) Terminal velocity is 1.20 m s^{-1} because equal distances are travelled in equal time intervals from 0.30 s onwards, so the velocity stays the same.
Teacher prompt / common error: For terminal velocity, evidence must be a constant velocity. The equal distance in each equal 0.10 s interval gives that evidence.

15. Explain one advantage of using a high-frame-rate video camera instead of a hand-held stopwatch in this investigation. [2 marks]

Answer / mark points: A high-frame-rate camera provides a known, short time interval between frames and can be replayed or measured frame by frame. This reduces uncertainty from human reaction time.
Teacher prompt / common error: Expect a link between known short intervals or replay and reduced reaction-time uncertainty. ‘It is more accurate’ alone is not enough.

16. State one practical precaution that improves the accuracy of the distance measurements in Figure 3. Explain how it helps. [2 marks]

Answer / mark points: For example, place the camera perpendicular to the scale and tube. This reduces parallax error when reading the marble position. Allow a vertical, firmly clamped tube with clearly separated scale marks if explained.
Teacher prompt / common error: A named precaution must have an explanation. This is a distance-reading issue, so parallax is a useful focus.

3. Six-mark planning: verifying terminal velocity

17. A pupil wants to verify that a marble reaches a terminal velocity of 1.20 m s^{-1} as it falls through a transparent viscous liquid. Describe a suitable experiment using either a high-frame-rate camera or light gates. Explain how the measurements would show that the marble has reached terminal velocity. [6 marks]

Answer / mark points: Use a tall transparent tube of viscous liquid, held vertical and with a scale or equal markers beside it. Release a marble centrally and record it with a camera of known frame rate, or time several equal sections with light gates. Measure positions/times only after an initial section below the surface. Determine speeds for successive equal-distance sections using $v = \Delta s / \Delta t$. The marble is at terminal velocity where consecutive speeds are equal (or its displacement–time graph has a constant gradient); check that this value is 1.20 m s^{-1}. Repeat releases and calculate a mean, keeping the marble and liquid conditions the same. Use a tray beneath the tube or handle glassware safely.

Teacher prompt / common error: For 5–6 marks expect a connected method, a clear way to establish constant velocity, and a valid analysis. Insist on language such as ‘velocity stays the same’ and ‘acceleration is zero’; velocity does not ‘accelerate’.

Review language for the class

Use ‘downward velocity increases’ or ‘downward velocity decreases’. An object has an upward or downward acceleration. At terminal velocity, the velocity stays the same and the acceleration is zero; never write ‘the velocity is accelerating’.