2.1 Motion

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Course	DP IB Physics
Section	2. Mechanics
Topic	2.1 Motion
Difficulty	Medium

To be used by all students preparing for DP IB Physics HL
Students of other boards may also find this useful

1

The correct answer is **C** because:

- Air resistance on a projectile decreases its horizontal and vertical velocity
  - Since the horizontal component of the velocity is always constant, this is responsible for the horizontal distance of the projectile
- The question focuses on horizontal distance, rather than the height of the projectile
- A smaller angle of release for a projectile experiencing air resistances means it would reach a similar horizontal distance to a projectile without air resistance released at the same angle
  - In other words, the effects of air resistance would increase the larger the initial angle (and flight time)

A is incorrect as	a projectile with a rougher surface will slow down more than one that is smooth. Smoother surfaces are more aerodynamic
B is incorrect as	the larger the surface to volume ratio, the more air resistance will affect an object. For example, a badminton shuttle experiences more air resistance than a gold ball, because of the holes in it
D is incorrect as	air resistance decreases with **increasing** altitude because the air becomes less dense the higher up it is from the Earth's surface. Therefore, a lower altitude would have more air resistance than a higher one

2

The correct answer is **C** because:

- Acceleration is the **gradient** of a velocity-time graph
- If the car stops accelerating at some point in its motion, this is indicated by a gradient that is 0
    - This would be a horizontal line on the velocity-time graph
- Since the graph is never horizontal, this therefore means the car must always be accelerating

A is incorrect as	the velocity of the car is 0 m s^{-1} at some point (the graph crosses the *t* axis). This means it is no longer moving and the car is stationary
B is incorrect as	the velocity is positive, then negative. This implies a change in direction so the car must be moving backwards than forwards (or vice versa, depending on which direction is taken as positive)
D is incorrect as	the velocity of the car is negative after time *t* because it is in the negative part of the graph. The acceleration is the gradient of the velocity-time graph, and after time *t*, its acceleration is negative. Therefore, the acceleration and velocity are in the **same** negative direction (i.e., the car is 'speeding up')

3

The correct answer is **B** because:

- If an object is falling at constant speed, this means it has reached its **terminal** speed
- This means the drag force on the object upwards is **equal** to its weight downwards
- The weight, W of an object is calculated by:
    - $W = mg$ where m is the mass of the object and g is the acceleration due to gravity ≈ 10 m s^{-2}
- Converting the mass of the object from g to kg:
    - $5.6 \text{ g} = 5.6 \times 10^{-3}$ kg
- Therefore, the drag force is equal to
    - $W = (5.6 \times 10^{-3}) \times 10 = 0.056$ N

A is incorrect as	there is still a non-zero drag force is an object is moving at constant speed. This is outlined in Newton's first law. If there was no drag force, the object would keep accelerating
C is incorrect as	the mass of the object has not been converted from g to kg
D is incorrect as	2 times the weight has been considered as the drag force, instead of the drag force being equal to the weight

Remember to always covert units of mass into kg when using the $W = mg$ equation (unless W is in kN). Although it may look like the question gives the value '5.6 g' where g could be the acceleration due to gravity, note that it specifically says the 'object of **mass** 5.6 g' which implies that the 'g' is the unit 'grams' and not 'g' for the acceleration due to gravity. If the wording had been 'object of **weight** 5.6 g' then this would imply a force and therefore g would refer to the acceleration due to gravity.

Since paper 1 is a non-calculator paper, always assume g to be 10 m s^{-2}. In paper 2, $g = 9.81$ m s^{-2} should be used instead (as given in the data booklet).

4

The correct answer is **A** because:

- We need to calculate the time taken for the stone to hit the ground
- For the stone:
  - $s = 30$ m
  - $u = -25$ m s^{-1}
  - v = not given
  - $a = 10$ m s^{-2}
  - $t = ?$
- Therefore, the equation of motion to use is:
  - $s = ut + \frac{1}{2}at^2$
- Substituting in the values gives:
  - $30 = -25t + \frac{1}{2} \times 10 \times t^2$
  - $5t^2 - 25t - 30 = 0$
- Dividing through by 5 to simplify gives:
  - $t^2 - 5t - 6 = 0$
- Factorising gives the value for t as:
  - $(t - 6)(t + 1) = 0$
  - $t = 6$ s
- Extra height of balloon from its initial position in $t = 6$ s:
  - Distance = speed × time
  - Extra height = 25 × 6 = 150 m
- Therefore, the total height of the balloon when the stone hits the ground is:
  - Total height = initial height + extra height
  - Total height = 30 + 150 = 180 m

B is incorrect as	the other answer for *t* from the quadratic is *t* = –1 s, not 1 s. This value is ignored because we cannot have negative time (yet?)
C is incorrect as	the initial height has not been added onto the extra height from the time taken for the stone to fall
D is incorrect as	this has assumed the balloon just doubled in height

Factorising quadratics is expected knowledge from GCSE maths, this can be very common in SUVAT equations with $s = ut + \frac{1}{2}at^2$ to calculate the time, *t*.

5

The correct answer is **B** because:

- The displacement of an object is how far it is from its **initial** position by the end of its trajectory
- Since the object starts and ends at position W, this means its displacement is 0
    - This eliminates options **C** and **D**
- The distance of the object is how much ground its covered in its trajectory
- Since the object travels in a full circle, the distance its covered is equal to the circumference of the circle
- The circumference is defined by the equation
    - $2\pi r$ where r is the radius of the circle
- The radius, r of the circle is **half** the distance from Z to X (or W to Y)
    - Radius = $\frac{6}{2}$ = 3 km
- Therefore, the distance travelled, or circumference is
    - Distance = $2\pi \times 3 = 6\pi$

A is incorrect as	the value for distance has been calculated using the equation πr^2 which is the area of a circle, rather than its circumference. This would give $\pi(3)^2 = 9\pi$
C is incorrect as	displacement and distances have been considered the wrong way around
D is incorrect as	the displacement has been confused with distance and the value for distance has been calculated using the equation πr^2 which is the area of a circle, rather than its circumference

6

The correct answer is **C** because:

- The acceleration is the **gradient** of a velocity-time graph
- The acceleration of the object:
  - Increases from zero
  - Reaches a maximum
  - Decreases to zero
- Therefore, the corresponding velocity-time graph should have a gradient that:
  - Increases from zero
  - Reaches a maximum
  - Decreases to zero
- This is shown by graph **C**

A is incorrect as	this graph has a constant gradient, which would correspond to an acceleration–time graph that is a horizontal line
B is incorrect as	this graph has a gradient that decreases to 0 then increases again (negatively). This is the opposite to the acceleration–time graph given in the question
D is incorrect as	this graph has a gradient that decreases to zero then increases positively again. This is the opposite to the acceleration–time graph given in the question

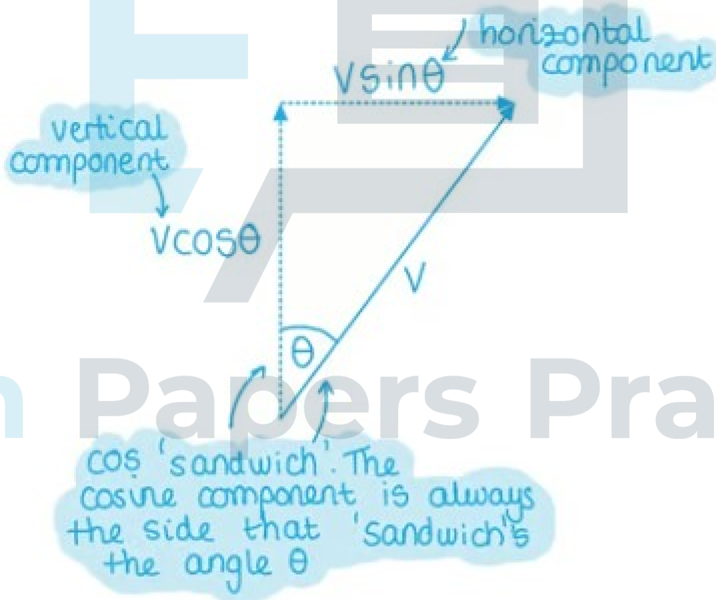
7

The correct answer is **D** because:

- Considering the horizontal direction:
  - $s = 15$ m
  - $u = 3 \sin \theta$
  - $v = 3 \sin \theta$ (since air resistance can be ignored, acceleration is 0 m s^{-2}, therefore, the initial horizontal velocity is equal to the final horizontal velocity)
  - $a = 0$ m s^{-2}
  - $t = 10$ s
- Therefore, we need the SUVAT equation linking s, u, a and t
  - $s = ut + \frac{1}{2}at^2$
- Substituting in the values gives:
  - $15 = (3 \sin \theta) \times 10 = 30 \sin \theta$
- Rearranging for θ gives:
  - $\theta = \sin^{-1}\left(\frac{15}{30}\right) = \sin^{-1}(0.5)$
- Since the question says sin 30 = 0.5, this means $\sin^{-1}(0.5) = 30°$
  - Therefore, $\theta = 30°$

During projectile motion, remember to consider the vertical and horizontal motion separately. In this case, we have been given the **horizontal** distance, therefore, this is an indication to consider the horizontal velocity and acceleration. In projectile motion, the object can be considered to have a **constant** horizontal velocity if air resistance is negligible. This means it has 0 horizontal acceleration (but it has a vertical acceleration of g or $-g$).

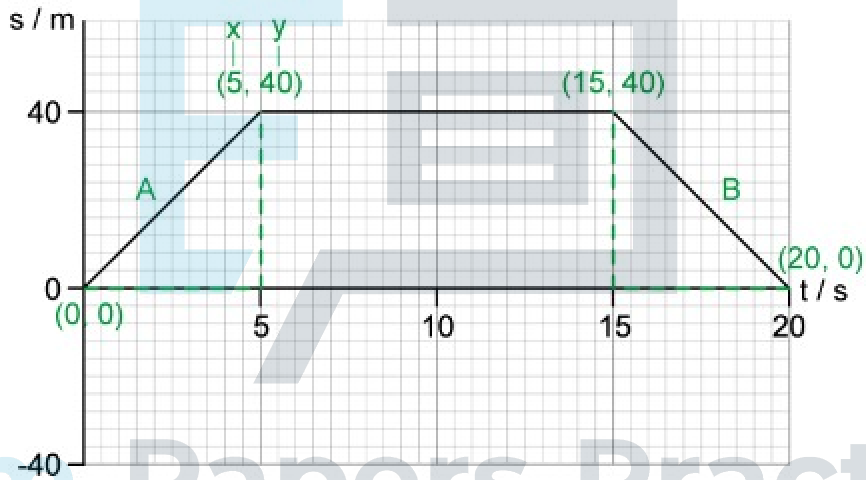
The key distractor here would be option **C**, 60°, which is equal to $cos^{-1}\left(\frac{1}{2}\right)$. Make sure you have resolved the velocity vector correctly since the angle is from the **vertical**.



8

The correct answer is **C** because:

- The average speed is defined as:
  - Average speed = $\frac{total\ distance}{total\ time}$
- From the graph:
  - The total distance = 40 × 2 = 80 m
  - Total time = 20 s
- Therefore, the average speed is:
  - Average speed = $\frac{80}{20}$ = 4 m s^{-1}
- The average velocity is the **gradient** of the displacement-time graph



- The gradient of part A gives a velocity of:
  - $\frac{\Delta y}{\Delta x} = \frac{40}{5-0}$ = 8 m s^{-2}
- The gradient of part B gives a velocity of:
  - $\frac{\Delta y}{\Delta x} = \frac{40}{15-20}$ = –8 m s^{-2}
- Therefore, the average velocity is:
  - 8 – 8 = 0 m s^{-2}

Since velocity is a vector which means it has both magnitude **and** direction, we have to consider whether it is positive or negative. This is important when considering the average velocity, since if the displacement-time graph has a negative gradient (sloping downwards), this indicates a **negative** velocity.

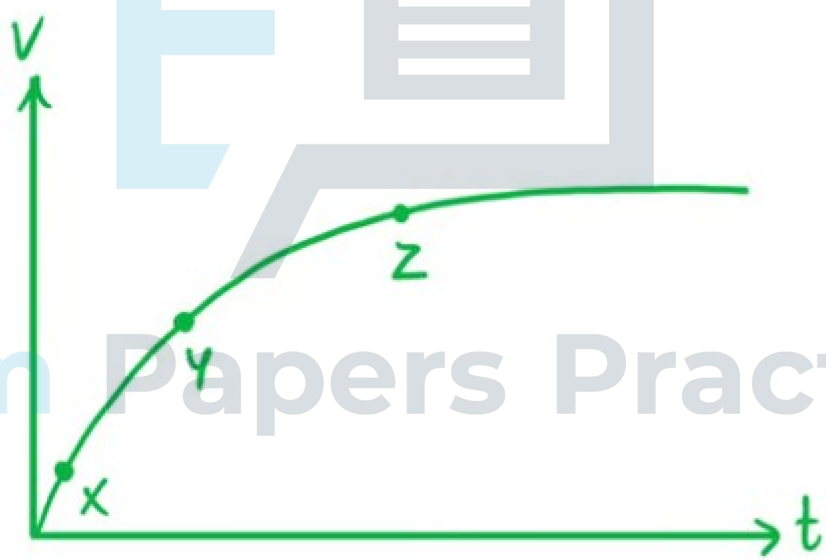
The gradient of the middle part of the graph (horizontal line) hasn't been considered because it is 0. This implies the particle is stationary and therefore has no velocity.

The distance is different to the displacement. Since the particle moves to a displacement of 20 m, then back to 0 m, this means its distance **there and back** is 40 m.

9

The correct answer is **D** because:

- A sketch of the graph for an object attaining terminal velocity is shown:



- At point X:
  - The object's velocity is small
  - The gradient is steep, hence the acceleration is large
- At point Y:
  - The object's velocity has increased from point X
  - The gradient is less steep, hence the acceleration has decreased
- At point Z:
  - The object's velocity has increased from point Y
  - The gradient is less steep (almost zero!) hence the acceleration has decreased
- Therefore, the velocity increases but the acceleration decreases
  - This means the correct option is **D**

10

The correct answer is **D** because:

- Considering the motion of the ball:
  - $s = 0.060$ m
  - $u = 0$
  - v = not given
  - $a = a$
  - $t = 4 \times 0.50 = 2.0$ ms $= 2.0 \times 10^{-3}$ s
- Therefore, we need the SUVAT equation linking s, u, a and t
  - $s = ut + \frac{1}{2}at^2$
- Substituting in the values gives:
  - $0.060 = \frac{1}{2}a(2.0 \times 10^{-3})^2$
- Rearranging for a gives:
  - $a = \frac{2 \times 0.060}{(2 \times 10^{-3})^2} = \frac{0.12}{4 \times 10^{-6}}$
  - $a = 30\,000$ m s^{-2}

A is incorrect as	the time has been calculated as 5 × 0.5 ms instead of 4 × 0.5 ms
B is incorrect as	the time has been calculated as 5 × 0.5 ms instead of 4 × 0.5 ms and the 2 ms hasn't been squared
C is incorrect as	the 2 ms hasn't been squared

Since this is a non-calculator paper, make sure you're confident with division with decimals. When there are decimals with a lot of zeros, the easiest way to divide is:

- Multiply the numerator and denominator by a factor of 10 that makes either the number no longer a decimal. In this case it would be 100 so the 0.12 becomes 12
- Divide the non-zero numbers, in this case, $\frac{12}{4} = 3$
- Add on the all the zeros that are left from either number in the fraction. In this case, 4 (remember the 0 before the decimal point as well!)