OCR A A Level Projectile Motion solutions

Matching solutions and teaching prompts for the class review

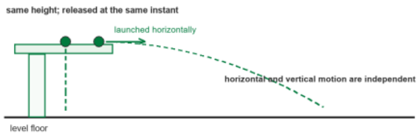
Specification points covered

• 3.1.2(a)(i) Apply equations of motion for constant acceleration in a straight line, including motion in a uniform gravitational field without air resistance.
• 3.1.3(a) Understand independence of vertical and horizontal motion of a projectile.
• 3.1.3(b) Analyse two-dimensional motion of a projectile with constant velocity in one direction and constant acceleration in a perpendicular direction.

Teaching focus

Projectile motion is analysed as two independent components: horizontal velocity stays constant and vertical velocity changes because of gravity.
Model the language expected in extended answers: a quantity can increase, decrease or stay the same; only a change in velocity is acceleration.

1. Independent horizontal and vertical motion



1. For a projectile moving through the air with air resistance ignored, state its horizontal acceleration. [1 mark]

Answer / mark points: 0 m s^{-2}.

Teacher prompt / common error: The horizontal component has no acceleration when air resistance is ignored.

2. For the same projectile, state its vertical acceleration. Include a direction. [1 mark]

Answer / mark points: 9.81 m s^{-2} vertically downward (or -9.81 m s^{-2} if upward is defined as positive).

Teacher prompt / common error: Accept an equivalent sign convention only when the direction is explicit.

3. Two identical marker balls are released from the same height at the same instant. One is dropped and the other is launched horizontally. Explain why they reach the level floor at the same time, ignoring air resistance. [2 marks]

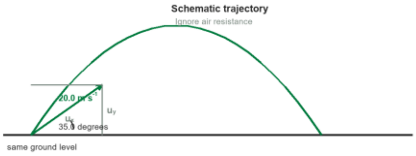
Answer / mark points: Both balls have the same initial vertical velocity (zero), the same vertical acceleration due to gravity and the same vertical displacement. Horizontal motion is independent of vertical motion, so both take the same time to fall.

Teacher prompt / common error: The required reasoning is shared vertical motion plus independence. Do not accept 'gravity pulls both down' alone for full credit.

2. Launching a survey marker at an angle

Context

The marker is launched at 20.0 m s^{-1}, 35.0 degrees above the horizontal, and returns to its launch height. Take g = 9.81 m s^{-2}.



4. Calculate the initial horizontal component u_x and initial vertical component u_y of the marker's velocity. [2 marks]

Answer / mark points: u_x = 20.0 cos 35.0 degrees = 16.4 m s^{-1}. u_y = 20.0 sin 35.0 degrees = 11.5 m s^{-1}.

Teacher prompt / common error: Award one mark for each correctly resolved component with suitable units.

5. Calculate the time taken for the marker to reach its maximum height. [1 mark]

Answer / mark points: At maximum height, v_y = 0. t = u_y / g = 11.5 / 9.81 = 1.17 s.

Teacher prompt / common error: At the top, only the vertical component of velocity is zero; horizontal velocity remains constant.

6. Calculate the maximum height of the marker above the launch point. [2 marks]

Answer / mark points: $v_y^2 = u_y^2 + 2as$. 0 = $(20.0 \sin 35.0 \text{ degrees})^2 + 2(-9.81)s$, so s = 6.71 m (6.7 m to 2 s.f.).

Teacher prompt / common error: Use vertical motion only. A positive height is expected when upward is positive.

7. Calculate the total time for which the marker is in the air. [1 mark]

Answer / mark points: The ascent and descent take equal times because the marker returns to its launch height. Total time = 2(1.17) = 2.34 s.

Teacher prompt / common error: This shortcut is valid because the marker returns to the same vertical level, with air resistance ignored.

8. Calculate the horizontal range of the marker. [2 marks]

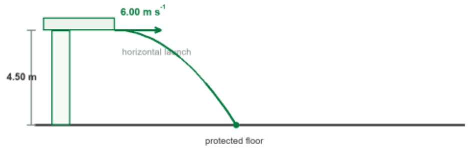
Answer / mark points: x = $u_x t$ = (20.0 cos 35.0 degrees)(2.34) = 38.3 m (38 m to 2 s.f.).

Teacher prompt / common error: Use the horizontal component and total flight time. The range is not found from a vertical SUVAT equation.

3. Horizontal launch: foam capsule

Context

The capsule leaves horizontally at 6.00 m s^{-1} from a height of 4.50 m. Take g = 9.81 m s^{-2}.



9. Calculate the time taken for the foam capsule to reach the protected floor. [2 marks]

Answer / mark points: s = 1/2 gt^2, so 4.50 = 1/2(9.81)t^2. t = 0.958 s (0.96 s to 2 s.f.).

Teacher prompt / common error: The initial vertical velocity is zero. Use vertical displacement only to find the time.

10. Calculate the horizontal displacement of the foam capsule before it reaches the protected floor. [1 mark]

Answer / mark points: x = u_xt = 6.00 x 0.958 = 5.75 m (5.8 m to 2 s.f.).

Teacher prompt / common error: The horizontal velocity is constant, so x = u_xt.

11. Calculate the vertical component of velocity of the foam capsule immediately before impact. Include a direction. [1 mark]

Answer / mark points: v_y = u_y + at = 0 + 9.81(0.958) = 9.40 m s^{-1} downward.

Teacher prompt / common error: The vertical component increases in the downward direction. Do not call the velocity 'accelerating'.

12. Calculate the resultant speed of the foam capsule immediately before impact. [2 marks]

Answer / mark points: v = sqrt(6.00^2 + 9.40^2) = 11.1 m s^{-1} (11 m s^{-1} to 2 s.f.).

Teacher prompt / common error: The components are perpendicular, so combine them using Pythagoras.

13. Calculate the direction of the foam capsule's velocity immediately before impact, measured below the horizontal. [1 mark]

Answer / mark points: theta = tan^{-1}(9.40 / 6.00) = 57.4 degrees, so about 57 degrees below the horizontal.

Teacher prompt / common error: The stated direction must be below the horizontal, not simply a positive angle.

4. Applying the model

14. A pupil says, 'the horizontal velocity gradually changes into vertical velocity'. Explain why this is not a correct description of the projectile's motion. State how each component changes. **[2 marks]**

Answer / mark points: The two components do not transform into one another; they are independent. The horizontal velocity stays constant (zero horizontal acceleration), while the downward vertical velocity increases linearly because vertical acceleration is constant.

Teacher prompt / common error: Preferred language: horizontal velocity stays constant; downward vertical velocity increases linearly. Components are independent.

15. A second identical foam capsule is launched horizontally from the same height at 12.0 m s^{-1} instead of 6.00 m s^{-1}. Compare its time in the air and horizontal displacement with those of the first capsule. Explain your answer. **[2 marks]**

Answer / mark points: The time in the air stays the same because it depends only on the vertical motion and launch height. The horizontal displacement doubles: $x = u_x t$ and u_x doubles from 6.00 to 12.0 m s^{-1}.

Teacher prompt / common error: The time is set by vertical motion. A doubled horizontal speed gives a doubled range only because the launch height is unchanged.

16. A sports-engineering team wants to test whether horizontal displacement x is proportional to launch speed u for a foam ball launched horizontally from a fixed height. Describe a safe method, including measurements, control variables, repeats and how the data should be analysed. **[4 marks]**

Answer / mark points: Use a protected horizontal launcher at one fixed, measured height, with a clear landing area and suitable eye/area safety controls. Launch the same foam ball at several measured horizontal speeds; measure horizontal displacement from the point vertically below the launch point to the first impact. Keep height, ball, launch direction and landing level the same. Repeat each speed and calculate a mean displacement. Plot mean x against u: a straight line through the origin supports x proportional to u.

Teacher prompt / common error: For all four marks expect: safe, repeatable set-up; measured u and x; controlled variables and repeats/mean; x-u graph with a straight line through the origin as the test.

Closing review

At the top of a trajectory, the vertical component of velocity is zero but the horizontal component is still present.
When air resistance is ignored, horizontal velocity stays constant while the downward vertical velocity increases linearly.