Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

1.5 s is only the time to reach the top. The ball takes as long again to fall back (the motion is symmetric), so it is in the air for **3.0 s**.
(Or with s = 0 when it lands: $0 = 14.7t - 4.9t^2$, so $t = 14.7 \div 4.9 = 3.0$ s.)

MARKING SCHEME

- ✓ The mistake: 1.5 s is the time to the top only.
- ✓ The fall back down takes the same time (or s = 0 at landing).
- ✓ 3.0 s in the air.

2 Read the graph

ANSWER A · 4

i. A rise from (0, 0) to (4, 12), a flat line to (10, 12), a fall to (14, 0). Accelerations: $12 \div 4 = \mathbf{3\ m/s^2}$, then **0**, then $-12 \div 4 = \mathbf{-3\ m/s^2}$ (a retardation of 3 m/s^2).

ii. Area $= \frac{1}{2} \times 4 \times 12 + 6 \times 12 + \frac{1}{2} \times 4 \times 12 = 24 + 72 + 24 = \mathbf{120\ m}$.

iii. Average speed = total distance ÷ total time $= 120 \div 14 = \mathbf{8.6\ m/s}$, less than the top speed, because it was slower while speeding up and slowing down.

MARKING SCHEME

- ✓ The three accelerations 3, 0 and −3 m/s^2.
- ✓ Distance as the area under the graph.
- ✓ 120 m.
- ✓ Average speed 120 ÷ 14 = 8.6 m/s, not 12 m/s.

3 How deep is the well?

ANSWER HA · 5

i. Let t_1 be the stone's fall time: $h = 4.9t_1^2$, and the sound takes h ÷ 340. So $t_1 + 4.9t_1^2 \div 340 = 2.5$, that is $4.9t_1^2 + 340t_1 - 850 = 0$.

$t_1 = \dfrac{-340 + \sqrt{340^2 + 4 \times 4.9 \times 850}}{2 \times 4.9} = 2.42$ s, and the sound takes 0.08 s.

$h = 4.9 \times 2.416^2 = \mathbf{28.6\ m}$.

ii. $\frac{1}{2} \times 9.8 \times 2.5^2 = 30.6$ m, about **2 m (7%) too deep**: the last 0.08 s was sound, not falling, and those are the fastest-falling moments.

MARKING SCHEME

- ✓ Two times: the fall ($h = \frac{1}{2}gt_1^2$) and the sound (h ÷ 340), adding to 2.5 s.
- ✓ The quadratic $4.9t_1^2 + 340t_1 - 850 = 0$.
- ✓ $t_1 = 2.42$ s.
- ✓ h = 28.6 m.
- ✓ 30.6 m is about 2 m too deep.

4 Work backwards

ANSWER A · 3

i. $\tan\theta = v_p/v_r$, so $v_r = 3 \div \tan 30° = \mathbf{5.2\ m/s}$.

ii. $\tan\theta = 6 \div 5.2 = 1.155$, $\theta = \mathbf{49}°$ from the vertical.

MARKING SCHEME

- ✓ $\tan\theta = v_p/v_r$ used.
- ✓ Rain at 5.2 m/s.
- ✓ 49° when running.

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5 Predict, then explain

ANSWER U · 3

They land **at the same time**. Both start with zero vertical velocity and fall with the same g; the horizontal motion doesn't change the vertical one, so both take $\sqrt{2h/g}$.
The **thrown** stone lands faster: it has the same vertical velocity as the dropped one plus its 10 m/s horizontally, $v = \sqrt{10^2 + v_y^2}$.

MARKING SCHEME

- ✓ Same time.
- ✓ The vertical motions are the same (same $u_y = 0$ and g); the horizontal motion is independent.
- ✓ The thrown stone is faster on landing (its horizontal 10 m/s adds).

6 Two ways to the same spot

ANSWER A · 4

i. Greatest range $u^2/g = 100 \div 9.8 =$ **10.2 m**, at 45°.
ii. $\sin 2\theta = Rg/u^2 = 8.0 \times 9.8 \div 100 = 0.784$, so $2\theta = 51.6°$ or 128.4°: $\theta =$ **25.8° or 64.2°**.
iii. $T = 2u \sin\theta/g$: **0.89 s** at 25.8° and **1.84 s** at 64.2°. The lower jet arrives first, in about half the time.

MARKING SCHEME

- ✓ Greatest range 10.2 m.
- ✓ $\sin 2\theta = 0.784$.
- ✓ $\theta = 25.8°$ and 64.2°.
- ✓ Times 0.89 s and 1.84 s: the lower jet is sooner.

7 Distance or displacement?

ANSWER A · 4

i. $v = dx/dt = 6t^2 - 12t$; $a = dv/dt = 12t - 12$.
ii. $v = 6t(t - 2) = 0$ at **t = 0 and t = 2 s**. At t = 0, $a = -12$ m/s^2; at t = 2 s, a = **12 m/s^2**: at rest, but not without acceleration.
iii. x(0) = 5 m, x(2) = 16 − 24 + 5 = −3 m, x(3) = 54 − 54 + 5 = 5 m. Displacement = 5 − 5 = **0**. It went back 8 m (5 to −3), then forward 8 m: distance = **16 m**.

MARKING SCHEME

- ✓ $v = 6t^2 - 12t$ and $a = 12t - 12$.
- ✓ At rest at t = 0 and 2 s, with $a = -12$ and 12 m/s^2.
- ✓ Displacement 0.
- ✓ Distance 16 m (it turns round at t = 2 s).

8 Correct the misconceptions

ANSWER U · 3

1. A negative acceleration only points in the negative direction: a body moving in the negative direction speeds up with it (a ball falling, with up taken as positive).
2. At the top the velocity is zero, but the acceleration is still g, downward; that is why it starts to fall.
3. In a vacuum all bodies fall with the same acceleration g, whatever their mass.

MARKING SCHEME

- ✓ Negative acceleration can speed a body up (when it moves in the negative direction).
- ✓ At the top a = g, not zero (only v = 0).
- ✓ In a vacuum heavy and light bodies fall together.

9 Think

ANSWER

With u = 0, $s_{nth} = \frac{a}{2}(2n - 1)$: for n = 1, 2, 3 this is $\frac{a}{2} \times 1$, $\frac{a}{2} \times 3$, $\frac{a}{2} \times 5$, so 1 : 3 : 5.
(Or: in 1, 2, 3 s it falls 4.9, 19.6, 44.1 m, so in each second 4.9, 14.7, 24.5 m = 1 : 3 : 5.)

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The ratio is **the same, 1 : 3 : 5**, for any uniform acceleration from rest: a cancels out. That is how Galileo could study falling by rolling balls down a slope. HA · 3

MARKING SCHEME

- ✓ The distance in the nth second from rest, ½a(2n − 1), or the differences of ½at^2.
- ✓ Ratio 1 : 3 : 5 shown.
- ✓ The same ratio on the slope: it doesn't depend on a.

10 Make your own

ANSWER HA · 2

For example: a kick at 30° needs u^2 sin 60° = 40 × 9.8 = 392, so u^2 = 392 ÷ 0.866 = 452.6 and **u = 21.3 m/s**. Check: R = 21.3^2 × sin 60° ÷ 9.8 = 453.7 × 0.866 ÷ 9.8 = 40.1 m ≈ 40 m. Any u and θ with u^2 sin 2θ = 392 m^2/s^2 works (u at least 19.8 m/s, at 45°).

MARKING SCHEME

- ✓ A speed and angle with u^2 sin 2θ = 40g (= 392 m^2/s^2).
- ✓ Checked with R = u^2 sin 2θ/g = 40 m.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Magnetic Braking** (exhibit): Drop the magnet through each tube: in plastic its velocity–time graph is a rising straight line; in copper it soon levels off: steady speed, zero acceleration.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	9	15	10	**34**

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