| Question | Scheme | Marks | AOs |
|---|---|---|---|
| | **Note that $g = 10$; penalise once for whole question if $g = 9.8$** | | |
| **1(a)** | Use $s = ut + \frac{1}{2}at^2$ vertically or any complete method to give an equation in $t$ only | M1 | 3.4 |
| | $-70 = 65\sin\alpha \times t - \frac{1}{2} \times g \times t^2$ | A1 | 1.1b |
| | | M (A)1 | 1.1b |
| | $t = 7$ (s) | A1 | 1.1b |
| | | **(4)** | |
| **1(b)** | Horizontal velocity component at $A = 65\cos\alpha$ (60) | B1 | 3.4 |
| | Complete method to find vertical velocity component at $A$ | M1 | 3.4 |
| | $65\sin\alpha - g \times 7$ **OR** $\sqrt{(-25)^2 + 2g \times 70}$ (45) | A1**ft** | 1.1b |
| | Sub for trig and square, add and square root : $\sqrt{60^2 + (-45)^2}$ | M1 | 3.1b |
| | 75 Accept 80 ($\text{m s}^{-1}$) | A1 | 1.1b |
| | | **(5)** | |
| **1(c)** | e.g. an approximate value of $g$ has been used, the dimensions of the stone could affect its motion, spin of the stone, $g = 10$ instead of 9.8 has been used, $g$ has been assumed to be constant, wind effect, shape of the stone | B1 | 3.5b |
| | | **(1)** | |
| | | | **(10 marks)** |

| **Notes:** | | |
|---|---|---|
| **1a** | M1 | Complete method, correct no. of terms, condone sign errors and sin/cos confusion |
| | A1 | Correct equation in $t$ only with at most one error |
| | M(A)1 | Correct equation in $t$ only |
| | | **N.B.** For 'up and down' methods etc, the two A marks are for all the equations that they use, lose a mark for each error. |
| | A1 | Cao ($g = 9.8$ , 7.1 or 7.11) ($g = 9.81$ , 7.1 or 7.12) |
| **1b** | B1 | Seen, including on a diagram. |
| | M1 | Condone sign errors and sin/cos confusion |
| | A1**ft** | Correct expression; accept negative of this, follow their $t$ |
| | M1 | Sub for trig and use Pythagoras |
| | A1 | Cao ($g = 9.8$ or 9.81 , 75 or 74.8) |

| | | |
|---|---|---|
| **1c** | B1 | B0 if incorrect extras |

| Question | Scheme | Marks | AOs |
|---|---|---|---|
| **2(a)** | Using horizontal motion | M1 | 3.3 |
| | **Whole Motion** **Half way** | | |
| | $U\cos\alpha \times t = 120$ $U\cos\alpha \times t = 60$ | A1 | 1.1b |
| | Using vertical motion **OR** | M1 | 3.4 |
| | $U\sin\alpha \times t - \frac{1}{2}gt^2 = 0$ $0 = U\sin\alpha - gt$ | A1 | 1.1b |
| | Attempt to solve problem by eliminating $t$ | DM1 | 3.1b |
| | $U^2\sin\alpha\cos\alpha = 588$ * | A1* | 2.2a |
| | | **(6)** | |
| | **N.B.** No credit given if they use the given answer from (b). | | |
| **2(b)** | Using vertical motion **OR** conservation of energy | M1 | 3.4 |
| | $0^2 = (U\sin\alpha)^2 - 2g\times 10$ $\frac{1}{2}mU^2 - \frac{1}{2}m(U\cos\alpha)^2 = mg\times 10$ | A1 | 1.1b |
| | **ALTERNATIVE 1:**<br>If $t$ is time to top: use of $10 = \frac{1}{2}gt^2$ oe ( $t = \frac{10}{7}$) to obtain<br>an equation in $U$ and $\alpha$ only M1<br>$U\sin\alpha = 14$ or $U\cos\alpha = 42$ A1<br><br>**ALTERNATIVE 2:**<br>If $t$ is time to top:<br>use of : $10 = U\sin\alpha\ t - \frac{1}{2}gt^2$ with $t = \frac{60}{U\cos\alpha}$ substituted to<br>obtain an equation in $U$ and $\alpha$ only : M1<br>$10 = U\sin\alpha \times \frac{60}{U\cos\alpha} - \frac{1}{2}g\left(\frac{60}{U\cos\alpha}\right)^2$ A1 | | |
| | Attempt to solve problem by eliminating $\alpha$ :<br>e.g. $U\sin\alpha = 14$ => $U\cos\alpha = 42$, from part (a) or from using $t = \frac{10}{7}$,<br>then square and add to give result<br><br>**OR:** $U^2\sin^2\alpha = 20g = 196$ and $U^2\sin\alpha\cos\alpha = 588$, divide to give<br>$\tan\alpha = \frac{1}{3}$ then $\sin^2\alpha = \frac{1}{10}$, hence result<br><br>**OR in ALTERNATIVE 2**: sub for $U^2$ using part (a), to give<br>$\tan\alpha = \frac{1}{3}$ then $\sin^2\alpha = \frac{1}{10}$, hence result | DM1 | 3.1b |

| | | | |
|---|---|---|---|
| | **N.B**. Just stating that $\sin^2\alpha = \frac{1}{10}$, with no working is DM0A0. | | |
| | $U^2 = 1960$ * | A1* | 2.2a |
| | **N.B.** Verification (i.e. starting with $U^2 = 1960$ and trying to work backwards) is not an acceptable method for this question. | | |
| | | **(4)** | |
| **2(c)** | $V$, since air resistance has to be overcome, or just 'because of <u>air resistance</u>' isw | B1 | 3.5a |
| | | **(1)** | |
| **2(d)** | e.g. wind effects, more accurate value of $g$, spin of ball, size of ball, shape of ball, dimensions of ball, not a particle, variable acceleration, surface area of ball, humidity. Allow wind resistance and rotational resistance<br>(Ignore any mention of air resistance or drag) | B1 | 3.5c |
| | | **(1)** | |
| | | | **(12 marks)** |

**Notes:**

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|---|---|---|
| **2a** | | **N.B**. Could score 2/6 for any one of the 4 given equations if there is no corresponding second equation or there is an attempt but it's incorrect. |
| | M1 | Complete method to give equation in $U$, $\alpha$ and $t$ only, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved |
| | A1 | Correct equation |
| | M1 | Complete method to give equation in $U$, $\alpha$ and $t$ only, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved |
| | A1 | Correct equation |
| | DM 1 | Eliminate $t$, dependent on first and second M1's |
| | A1* | Given answer correctly obtained, <u>with no wrong working seen.</u><br>Allow $588 = U^2 \sin\alpha\cos\alpha$ but nothing else |
| **2b** | M1 | Complete method to give equation in $U$ and $\alpha$ only with correct no. of terms, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved |
| | A1 | Correct equation |
| | DM 1 | Eliminate $\alpha$ and rearrange, dependent on first M1 |
| | A1* | Given answer correctly obtained with <u>no wrong working seen</u><br>(**N.B**. If they use a value for $\alpha$ (18.43.°.) they lose the final A1*) |
| **2c** | B1 | Clear statement isw |
| **2d** | B1 | B0 if there is an incorrect extra e.g. mass or weight |

| Question | Scheme | Marks | AOs |
|---|---|---|---|
| | **N.B.** In this question, allow misread of $\alpha$ for *a*. | | |
| **3(a)** | Use horizontal motion to give an equation in *T* and $\alpha$ only:<br>$28\cos\alpha \times T = 40$ | M1 | 3.4 |
| | $T = \dfrac{10}{7\cos\alpha}$ * | A1* | 1.1b |
| | | **(2)** | |
| **3(b)** | Use vertical motion to give an equation in *T* and $\alpha$ only | M1 | 3.3 |
| | $20 = (28\sin\alpha)T - \dfrac{1}{2}gT^2$ | A1 | 1.1b |
| | Eliminate *T* to give an unsimplified equation in $\alpha$ only:<br>$20 = (28\sin\alpha)\times\dfrac{10}{7\cos\alpha} - \dfrac{1}{2}g\left(\dfrac{10}{7\cos\alpha}\right)^2$ | M1 | 1.1b |
| | Use $\sec^2\alpha = 1+\tan^2\alpha$ oe to give an unsimplified equation in **tan** $\alpha$ **only**:<br>$20 = 40\tan\alpha - \dfrac{1}{2}g\times\dfrac{100}{49}(1+\tan^2\alpha)$ | M1 | 3.1b |
| | $\tan^2\alpha - 4\tan\alpha + 3 = 0$ * (allow $0 = \tan^2\alpha - 4\tan\alpha + 3$) | A1* | 2.2a |
| | | **(5)** | |
| **3(c)** | Solve and use of $\tan\alpha = 3$ or $\sin\alpha = \dfrac{3}{\sqrt{10}}$ or $\alpha = 71.565..^o$ to find an equation in *H* only. | M1 | 3.1b |
| | $0 = (28\sin\alpha)^2 - 2gH$<br>**where** $\tan\alpha = 3$ $(\alpha = 71.565..^o)$ | M1 | 3.4 |
| | *H* = 36 or 36.0 (m) | A1 | 1.1b |
| | | **(3)** | |
| **3(d)** | e.g.<br>spin of the ball, the wind, the dimensions or shape of the ball,<br>ball is modelled as a particle, uses an inaccurate value of *g*, motion takes place in 3D not in 2D, *g* could be variable.<br>B0 if mass or weight are mentioned.<br>B0 for ground may not be horizontal. | B1 | 3.5b |
| | | **(1)** | |

| | | **(11 marks)** |
|---|---|---|
| **Notes:** | | |
| **3a** | M1 | Correct no. of terms, dim correct, condone sin/cos confusion and sign errors |
| | A1* | Correct printed answer correctly obtained.<br>Allow $\frac{10}{7\cos\alpha} = T$ OR $T = \frac{40}{28\cos\alpha} = \frac{10}{7\cos\alpha}$ OR $\frac{40}{28\cos\alpha} = \frac{10}{7\cos\alpha} = T$<br>OR *t* instead of *T* |
| **3b** | M1 | Correct no. of terms, dim correct, condone sin/cos confusion and sign errors |
| | A1 | Correct equation |
| | M1 | Eliminate *T*, using either the given answer in (a) or their own *T* expression, from their equation to give an unsimplified equation in $\alpha$ only |
| | M1 | Use $\sec^2\alpha = 1 + \tan^2\alpha$ to produce an equation in $\tan\alpha$ only |
| | A1* | Given answer correctly obtained.<br>**N.B.** Must be $\alpha$ (or *a*) in the final answer but allow a different angle in the working. |
| **3c** | M1 | Solve given equation and select larger value of $\tan\alpha$ and use it to try to obtain an equation in *H* only. |
| | M1 | Complete method to give an equation in ***H* only**, using **larger** value of $\alpha$, correct no. of terms, dim correct, condone sin/cos confusion and sign errors. |
| | A1 | cao. Must be positive, (allow a negative value, changed to a positive answer).<br>**N.B.** This answer comes from use of *g* = 9.8, so must be rounded to 2 or 3 sf. |
| **3d** | B1 | B0 if any incorrect extras |