Question	Scheme	Marks	AOs
1.(a)	$14.7 = -14.7 + 9.8T$ or $0 = 14.7T - \frac{1}{2} \times 9.8T^2$ or $0 = 14.7 - 9.8 \times \left(\frac{1}{2}T\right)$ oe	M1	3.4
	$T = 3$	A1	1.1b
		(2)	
(b)	$s_1 = \frac{(14.7 + 0)}{2} \times 1.5$ (11.025 or $\frac{441}{40}$)	M1	1.1b
	$s_2 = \frac{1}{2} \times 9.8 \times 2.5^2$ (30.625 or $\frac{245}{8}$) **OR** $s_3 = 14.7 \times 1 + \frac{1}{2} \times 9.8 \times 1^2$ (19.6 or $\frac{98}{5}$) **OR** $-s_3 = 14.7 \times 4 - \frac{1}{2} \times 9.8 \times 4^2$ (- 19.6) (allow omission of – on LHS)	M1	1.1b
	Total distance = $s_1 + s_2$ **OR** $2s_1 + s_3$	M1	2.1
	= 41.7 m or 42 m	A1	1.1b
		(4)	
(c)	e.g. Take account of the dimensions of the stone (e.g. allow for spin), do not model the stone as a particle, use a more accurate value for g	B1	3.5c
		(1)	
			(7 marks)

Notes: If they use g = 9.81 or 10, penalise once for whole question.		
1a	M1	Complete method to find T, condone sign errors (M0 if they only find time to top)
	A1	$T = 3$ correctly obtained.
1b	M1	Complete method to find one key distance
	M1	Correct method to find another key distance
	M1	Complete method to find the total distance
	A1	41.7 or 42 (after use of $g = 9.8$)
1c	B1	B0 if there are incorrect extra refinements but ignore extra incorrect statements.

Question	Scheme	Marks	AOs
2(a)	Complete method to produce an equation in U only	M1	3.4
	e.g. $10^2 = U^2 + 2\times g\times 1.8$ oe	A1	1.1b
	OR a **complete** method where they find T first and use it to find an equation in U only M1		
	A correct equation in U only. A1		
	$U = 8$ (only this answer)	A1	1.1b
		(3)	
(b)	Complete method to find an equation in T only: $10 = -8 + gT$ or $1.8 = 10T - \frac{1}{2}gT^2$ or $1.8 = \frac{(-8+10)}{2}T$ or $1.8 = -8T + \frac{1}{2}gT^2$ **OR** a **complete** method if they split the time. In both cases, the M1 is only earned on the final line when they try to add the two times to give an equation in T. **ALT 1**: time up + time down e.g. $0 = 8 - gt_{UP}$ $(\Rightarrow t_{UP} = 0.8)$ $h_{UP} = \frac{(8+0)}{2}\times 0.8$ $(= 3.2)$ $(h_{UP} + 1.8) = \frac{(0+10)}{2}\times t_{DOWN}$ $(\Rightarrow t_{DOWN} = 1)$ $T = t_{UP} + t_{DOWN}$ **ALT 2:** time to A + time from A to ground e.g. $8 = -8 + gt_A$ $(\Rightarrow t_A = 1.6)$ $1.8 = \frac{(8+10)}{2}\times t_{AG}$ $(\Rightarrow t_{AG} = 0.2)$ $T = t_A + t_{AG}$	M1	3.4
	$T = 1.8$ oe e.g. 9/5	A1	1.1b
		(2)	
(c)	e.g. Use a more accurate (less rounded) value for g (or gravity), use $g = 9.8$ or $g = 9.81$, allow for wind effects, allow for the spin of the stone, include dimensions of stone (not a particle), shape and/or size of stone, allow for variable acceleration. If air resistance is mentioned as an extra, ignore it.	B1	3.5c

			(1)	
(d)		*U* would be greater. Allow without *U*, e.g it would be greater, or just 'greater' oe ISW	B1	3.5a
			(1)	
				(7 marks)
Notes:				
2a	M1	Use the model to obtain an equation in *U* only, condone sign errors, but M0 if using an incorrect formula.		
	A1	A correct equation in *U* only, *g* does not need to be substituted (so allow $g = 9.8$ or 9.81)		
	A1	cao (A0 if $g = 10$ has not been used)		
2b	M1	Use the model to obtain an equation in *T* only , *g* does not need to be substituted (so allow $g = 9.8$ or 9.81) condone sign errors, but M0 if using an incorrect formula. Follow through on their *U* where necessary		
	A1	cao (A0 if $g = 10$ has not been used) A0 if they give two answers.		
2c	B1	Any appropriate refinement. B0 if an incorrect extra is given e.g. the mass or weight is mentioned		
2d	B1	cao		

If they use *g* = 9.81 or 10 in this question, penalise once for whole question.

Question	Scheme	Marks	AOs
3(a)	Attempt to find the displacement after 10 s	M1	3.1b
	$39.2\times10-\frac{1}{2}g\times10^2$ **OR** $-39.2\times10+\frac{1}{2}g\times10^2$	A1	1.1b
	98 (m) (must be positive)	A1	1.1b
		(3)	
3(b)	Complete method to find either half the time or the full time	M1	3.1b
	Correct equation e.g. $0=24.5-gt$ **OR** $-24.5=24.5-gt$	A1	1.1b
	5 (s)	A1	1.1b
		(3)	
3(c)	e.g. (include) air resistance	B1	3.5c
		(1)	
			(7 marks)

Notes:		**Penalise explicit use of *g* = 9.81 or 10 once for the whole question the first time it occurs.**
3a	M1	Complete method, using $s=ut+\frac{1}{2}at^2$ or possibly $s=vt-\frac{1}{2}at^2$ with the motion reversed, or an 'up and down' method i.e an appropriate equation for the motion from *O* to the top **AND** an appropriate equation from the top down to the ground **AND** combining to give the total distance
	A1	Correct expression (s) **N.B.** If using an 'up and down method', this mark is for **all** the intermediate values: Distance up = 78.4, Time up = 4, time down = 6, distance down = 176.4 **AND** combining correctly i.e. (176.4 – 78.4) or (78.4 –176.4) These are the values for *g* = 9.8
	A1	cao
3b	M1	Complete method to find half the time or the full time. Allow inequalities. e.g. for half the time, they may find *t* = 4 and *t* = 1.5 and subtract e.g. for the full time, they may find *t* = 6.5 and *t* = 1.5 and subtract
	A1	Correct equation or equations if they are using more than one.
	A1	cao
3c	B1	e.g. (use) a more accurate value of *g*, (include) spin of the stone, (include)shape of the stone, (include) size of the stone, (include) wind effects , rotation B0 if any incorrect extras are included e.g. the mass or weight of the stone DO NOT ALLOW NEGATIVES OF THESE e.g there is no air resistance

Question	Scheme	Marks	AOs
4(a)	Use of $\mathbf{v} = \mathbf{u} + \mathbf{a}t$ with $t = 2$: $\mathbf{v} = 4\mathbf{i} + 2(2\mathbf{i} - 3\mathbf{j})$ **OR integration**: $\mathbf{v} = (2\mathbf{i} - 3\mathbf{j})t + 4\mathbf{i}$, with $t = 2$	M1	3.1a
	$\mathbf{v} = 8\mathbf{i} - 6\mathbf{j}$	A1	1.1b
		(2)	
4(b)	Use of $\mathbf{r} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$ at $t = 3$: $(\mathbf{i} + \mathbf{j}) + \left[3 \times 4\mathbf{i} + \frac{1}{2} \times (2\mathbf{i} - 3\mathbf{j}) \times 3^2\right]$ **OR**: find $\mathbf{v}$ at $t = 3$: $4\mathbf{i} + 3(2\mathbf{i} - 3\mathbf{j}) = (10\mathbf{i} - 9\mathbf{j})$ then use $\mathbf{r} = \frac{1}{2}(\mathbf{u} + \mathbf{v})t$ $(\mathbf{i} + \mathbf{j}) + \left[\frac{1}{2}\left[4\mathbf{i} + (10\mathbf{i} - 9\mathbf{j})\right] \times 3\right]$ or $\mathbf{r} = \mathbf{v}t - \frac{1}{2}\mathbf{a}t^2$ $(\mathbf{i} + \mathbf{j}) + \left[3 \times (10\mathbf{i} - 9\mathbf{j}) - \frac{1}{2} \times (2\mathbf{i} - 3\mathbf{j}) \times 3^2\right]$ **OR integration:** $\mathbf{r} = (\mathbf{i} + \mathbf{j}) + \left[(2\mathbf{i} - 3\mathbf{j})\frac{1}{2}t^2 + 4t\mathbf{i}\right]$, with $t = 3$	M1	3.1a
	$\mathbf{r} = 22\mathbf{i} - 12.5\mathbf{j}$	A1	2.2a
		(2)	
			(4 marks)

Notes: Accept column vectors throughout		
4a	M1	Complete method to find **v**, using **ruva***t* or integration (M0 if **i** and/or **j** is missing)
	A1	Apply isw if they also find the speed
4b	M1	Complete method to find the p.v. but this mark can be scored if they omit **(i + j)** i.e. the M1 is for the expression in the square bracket If they integrate, the M1 is earned once the expression in the square bracket is seen with $t = 3$ (M0 if **i** and/or **j** is missing)
	A1	cao

Question	Scheme	Marks	AOs
5(a)	16 ($\mathrm{m\,s^{-1}}$) seen as the answer	B1	1.1b
		(1)	
5(b)	$s=\frac{1}{2}\times 3.2\times 5^2$ **OR** $s=\frac{(0+16)}{2}\times 5$ **OR** $s=(16\times 5)-\frac{1}{2}\times 3.2\times 5^2$ **OR** $16^2=2\times 3.2\times s$ **OR** from a *v*-*t* graph, $s=\frac{1}{2}\times 5\times 16$	M1	3.1b
	s = 40 (m)	A1	1.1b
		(2)	
			(3 marks)

Notes:

5a	B1	cao. Must be positive. Ignore any working.		
5b	M1	Complete method to find an equation in s only, possibly using their '16' Allow 'reversed motion': use of $s=vt-\frac{1}{2}at^2$ with v = 0 i.e. $s=-\frac{1}{2}\times 3.2\times 5^2$ can score M1 and s = -40 so distance is 40 (m) can score the A1		
	A1	cao. Must be positive.		
		N.B. correct answer only, in (b), can score both marks.		

6(a)	$\mathbf{v}_B = (-16\mathbf{i} - 3\mathbf{j}) + 5(2.4\mathbf{i} + \mathbf{j})$	M1	3.4
	$\mathbf{v}_B = (-4\mathbf{i} + 2\mathbf{j})$	A1	1.1b
	$\sqrt{(-4)^2 + 2^2}$	M1	3.1a
	$\sqrt{20}$ = $2\sqrt{5}$, 4.5 or better ($\mathrm{m\,s^{-1}}$)	A1	1.1b
		(4)	
6(b)	Using *A* as the initial position: $\mathbf{r}_C = \mathbf{v}_A t + \frac{1}{2}\mathbf{a}t^2 + \mathbf{r}_A$ where $t = T$ $(4\mathbf{i} + c\mathbf{j}) = (-16\mathbf{i} - 3\mathbf{j})T + \frac{1}{2}(2.4\mathbf{i} + \mathbf{j})T^2 + (44\mathbf{i} - 10\mathbf{j})$ **OR** $\begin{pmatrix}4\\c\end{pmatrix} = \begin{pmatrix}-16\\-3\end{pmatrix}T + \frac{1}{2}\begin{pmatrix}2.4\\1\end{pmatrix}T^2 + \begin{pmatrix}44\\-10\end{pmatrix}$ Equating **i**-components, to give a **quadratic** equation in *T* only. Allow *t* instead of *T*. **N.B.** Allow omission of 44 for this M mark. Also allow ± 4 but M0 if 4 is not used at all i.e. $4 = -16T + \frac{1}{2} \times 2.4T^2$ scores M1A0A0	M1	3.1a
	$4 = -16T + \frac{1}{2} \times 2.4T^2 + 44$	A1	1.1b
	(T =) 10	A1	1.1b
	ALTERNATIVE using *B* as the initial position: (The position vector of *B*, $\mathbf{r}_B$, should be $-6\mathbf{i} - 12.5\mathbf{j}$ but no credit for finding this) $\mathbf{r}_C = \mathbf{v}_B t + \frac{1}{2}\mathbf{a}t^2 + \mathbf{r}_B$ using **their** $\mathbf{v}_B$ from (a) and **their** $\mathbf{r}_B$ $(4\mathbf{i} + c\mathbf{j}) = (-4\mathbf{i} + 2\mathbf{j})t + \frac{1}{2}(2.4\mathbf{i} + \mathbf{j})t^2 + (-6\mathbf{i} - 12.5\mathbf{j})$ $\begin{pmatrix}4\\c\end{pmatrix} = \begin{pmatrix}-4\\2\end{pmatrix}t + \frac{1}{2}\begin{pmatrix}2.4\\1\end{pmatrix}t^2 + \begin{pmatrix}-6\\-12.5\end{pmatrix}$ Equating **i**-components, to give a **quadratic** equation in *t* only. Allow if they have *T* instead of *t*.	M1	3.1a

	N.B. Allow omission of their -6 or if they use 44 for this M mark. Also allow ± 4 but M0 if 4 is not used at all. e.g. $4 = -4t + \frac{1}{2} \times 2.4t^2$ scores M1A0A0		
	$4 = -4t + \frac{1}{2} \times 2.4t^2 - 6$	A1	1.1b
	t = 5 so (T =) 10	A1	1.1b
		(3)	
6(c)	Equating **j**-components, with their value of T or t substituted, to give an equation, which must have a square term, in c only. **N.B.** Allow $\pm c$ in their equation. **(N.B.** Allow omission of -10 or their -12.5 for this M mark i.e. if using A as initial position $c = (-3 \times 10) + \frac{1}{2} \times 1 \times 10^2$ scores M1M0A0 **OR** if using B as initial position $c = (2 \times 5) + \frac{1}{2} \times 1 \times 5^2$ scores M1M0A0)	M1	2.1
	if using A as initial position $c = (-3 \times 10) + \frac{1}{2} \times 1 \times 10^2 + (-10)$ **N.B.** Allow $\pm c$ and/or $\pm(-10)$ in their equation **OR** if using B as initial position $c = (2 \times 5) + \frac{1}{2} \times 1 \times 5^2 + (-12.5)$ **N.B.** Allow $\pm c$ and/or $\pm(-12.5)$ in their equation	M1	1.1b
	c = 10	A1	1.1b
		(3)	
			(10 marks)

Notes: Accept column vectors throughout

6a	M1	Use of **v** = **u** + **a***t* with t = 5 to give an unsimplified $\mathbf{v}_B$ M0 if **u** = **0**

		N.B. If using integration, they must get to the same stage i.e. have found the constant and put $t = 5$ M0 if they omit the constant altogether
	A1	Correct $\mathbf{v}_B$ with **i**'s and **j**'s collected
	M1	Use of Pythagoras on *their* $\mathbf{v}_B$ to give a magnitude (need the root)
	A1	Must be positive
6b	M1	Equating components of **i** to give an equation in T or t only. **N.B.** (they could use integration to get to the same stage) for this M mark, they **only** need to be equating the **i**-components, and receive no credit until they do so. M0 if **u** = **0**
	A1	A correct equation in T or t only (could be in $(T - 5)$ if using B as initial position)
	A1	$T = 10$
6c	M1	Equating components of **j** to give an equation in c only but allow omission of their initial position
	M1	With their value of T or t and **must include t = 0 position** (should be -10 if using A **OR** their -12.5 if using B)
	A1	cao

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

		(11 marks)
Notes:		
7a	M1	Correct no. of terms, dim correct, condone sin/cos confusion and sign errors
	A1*	Correct printed answer correctly obtained. Allow $\frac{10}{7\cos\alpha} = T$ OR $T = \frac{40}{28\cos\alpha} = \frac{10}{7\cos\alpha}$ OR $\frac{40}{28\cos\alpha} = \frac{10}{7\cos\alpha} = T$ OR *t* instead of *T*
7b	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 α only
	M1	Use $\sec^2\alpha = 1 + \tan^2\alpha$ to produce an equation in $\tan\alpha$ only
	A1*	Given answer correctly obtained. **N.B.** Must be α (or *a*) in the final answer but allow a different angle in the working.
7c	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 **<u>larger</u>** value of α , 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). **N.B.** This answer comes from use of *g* = 9.8, so must be rounded to 2 or 3 sf.
7d	B1	B0 if any incorrect extras