

Question	Scheme		Marks	AOs
1(a)	Use of $\mathbf{v} = \mathbf{u} + \mathbf{at}$ 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)	
1(b)	Use of $\mathbf{r} = \mathbf{ut} + \frac{1}{2}\mathbf{at}^2$ 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 $\mathbf{r} = \frac{1}{2}(\mathbf{u} + \mathbf{v})t$ $(\mathbf{i} + \mathbf{j}) + \left[\frac{1}{2} [4\mathbf{i} + (10\mathbf{i} - 9\mathbf{j})] \times 3 \right]$ or $\mathbf{r} = \mathbf{vt} - \frac{1}{2}\mathbf{at}^2$ $(\mathbf{i} + \mathbf{j}) + \left[3 \times (10\mathbf{i} - 9\mathbf{j}) - \frac{1}{2} \times (2\mathbf{i} - 3\mathbf{j}) \times 3^2 \right]$ OR integration: $\mathbf{r} = (\mathbf{i} + \mathbf{j}) + \left[(2\mathbf{i} - 3\mathbf{j})\frac{1}{2}t^2 + 4\mathbf{i} \right]$, 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				
1a	M1	Complete method to find \mathbf{v} , using \mathbf{ruvat} or integration (M0 if \mathbf{i} and/or \mathbf{j} is missing)		
	A1	Apply isw if they also find the speed		
1b	M1	Complete method to find the p.v. but this mark can be scored if they omit $(\mathbf{i} + \mathbf{j})$ 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 \mathbf{i} and/or \mathbf{j} is missing)		
	A1	cao		

Question	Scheme		Marks	AOs
2(a)	16 (m s ⁻¹) seen as the answer		B1	1.1b
			(1)	
2(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:				
2a	B1	cao. Must be positive. Ignore any working.		
2b	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.		

3(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
	$\sqrt{20} = 2\sqrt{5}, 4.5 \text{ or better (m s}^{-1}\text{)}$	A1	1.1b
		(4)	
3(b)	<p><u>Using A as the initial position:</u></p> $\mathbf{r}_C = \mathbf{v}_A t + \frac{1}{2} \mathbf{a} t^2 + \mathbf{r}_A \quad \text{where } t = T$ $(4\mathbf{i} + c\mathbf{j}) = (-16\mathbf{i} - 3\mathbf{j})T + \frac{1}{2}(2.4\mathbf{i} + \mathbf{j})T^2 + (44\mathbf{i} - 10\mathbf{j})$ <p>OR</p> $\begin{pmatrix} 4 \\ c \end{pmatrix} = \begin{pmatrix} -16 \\ -3 \end{pmatrix} T + \frac{1}{2} \begin{pmatrix} 2.4 \\ 1 \end{pmatrix} T^2 + \begin{pmatrix} 44 \\ -10 \end{pmatrix}$ <p>Equating i-components, to give a quadratic equation in T only. Allow t instead of T.</p> <p>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</p>	M1	3.1a
	$4 = -16T + \frac{1}{2} \times 2.4T^2 + 44$	A1	1.1b
	$(T =) 10$	A1	1.1b
	<p>ALTERNATIVE <u>using B as the initial position:</u></p> <p>(The position vector of B, \mathbf{r}_B, should be $-6\mathbf{i} - 12.5\mathbf{j}$ but no credit for finding this)</p> $\mathbf{r}_C = \mathbf{v}_B t + \frac{1}{2} \mathbf{a} t^2 + \mathbf{r}_B \quad \text{using their } \mathbf{v}_B \text{ from (a) and their } \mathbf{r}_B$ $(4\mathbf{i} + c\mathbf{j}) = (-4\mathbf{i} + 2\mathbf{j})t + \frac{1}{2}(2.4\mathbf{i} + \mathbf{j})t^2 + (-6\mathbf{i} - 12.5\mathbf{j})$ $\begin{pmatrix} 4 \\ c \end{pmatrix} = \begin{pmatrix} -4 \\ 2 \end{pmatrix} t + \frac{1}{2} \begin{pmatrix} 2.4 \\ 1 \end{pmatrix} t^2 + \begin{pmatrix} -6 \\ -12.5 \end{pmatrix}$ <p>Equating i-components, to give a quadratic equation in t only. Allow if they have T instead of t.</p>	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)	
3(c)		Equating j-components, with <u>their value of T or t substituted</u> , 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				
3a	M1	Use of $\mathbf{v} = \mathbf{u} + \mathbf{at}$ with $t = 5$ to give an unsimplified \mathbf{v}_B M0 if $\mathbf{u} = \mathbf{0}$		

		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 \mathbf{i} 's and \mathbf{j} 's collected
	M1	Use of Pythagoras on <i>their</i> \mathbf{v}_B to give a magnitude (need the root)
	A1	Must be positive
3b	M1	Equating components of \mathbf{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 \mathbf{i} -components, and receive no credit until they do so. M0 if $\mathbf{u} = \mathbf{0}$
	A1	A correct equation in T or t only (could be in $(T - 5)$ if using B as initial position)
	A1	$T = 10$
3c	M1	Equating components of \mathbf{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 .		
4(a)	Use horizontal motion to give an equation in T and α only: $28 \cos \alpha \times T = 40$	M1	3.4
	$T = \frac{10}{7 \cos \alpha} *$	A1*	1.1b
		(2)	
4(b)	Use vertical motion to give an equation in T and α only	M1	3.3
	$20 = (28 \sin \alpha)T - \frac{1}{2}gT^2$	A1	1.1b
	Eliminate T to give an unsimplified equation in α only: $20 = (28 \sin \alpha) \times \frac{10}{7 \cos \alpha} - \frac{1}{2}g \left(\frac{10}{7 \cos \alpha} \right)^2$	M1	1.1b
	Use $\sec^2 \alpha = 1 + \tan^2 \alpha$ oe to give an unsimplified equation in tan α only : $20 = 40 \tan \alpha - \frac{1}{2}g \times \frac{100}{49}(1 + \tan^2 \alpha)$	M1	3.1b
	$\tan^2 \alpha - 4 \tan \alpha + 3 = 0 *$ (allow $0 = \tan^2 \alpha - 4 \tan \alpha + 3$)	A1*	2.2a
		(5)	
4(c)	Solve and use of $\tan \alpha = 3$ or $\sin \alpha = \frac{3}{\sqrt{10}}$ or $\alpha = 71.565..^\circ$ to find an equation in H only.	M1	3.1b
	$0 = (28 \sin \alpha)^2 - 2gH$ where $\tan \alpha = 3$ ($\alpha = 71.565..^\circ$)	M1	3.4
	$H = 36$ or 36.0 (m)	A1	1.1b
		(3)	
4(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:

4a	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
4b	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.
4c	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 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.
4d	B1	B0 if any incorrect extras

Question	Scheme	Marks	AOs
5(a)	$\frac{10}{4}$	M1	3.4
	$2.5, \frac{5}{2}, \frac{10}{4} \text{ m s}^{-2}$ units needed.	A1	1.1b
		(2)	
5(b)	Find the area, with correct structure, from $t = 0$ to 18	M1	3.1b
	$\frac{1}{2} \times 4 \times 10 + (14 \times 10)$ triangle + rectangle or $\frac{1}{2} \times 10 \times (14 + 18)$ trapezium or $(18 \times 10) - \frac{1}{2} \times 4 \times 10$ rectangle - triangle	A1	1.1b
	N.B. $\frac{1}{2} \times 4 \times 10$ may be replaced by $\frac{1}{2} \times 2.5 \times 4^2$ using $s = ut + \frac{1}{2}at^2$ or by $\frac{10^2 - 0^2}{2 \times 2.5}$ using $v^2 = u^2 + 2as$		
	160 (m)	A1	1.1b
		(3)	
5(c)	Using area, from $t = 18$ to $t = 24$, = (200 - their (b)) with correct structure OR $s = (200 - \text{their (b)})$, using <i>suvat</i> to find s N.B. If their (b) is incorrect and they don't use it, allow a correct restart.	M1	3.1b
	$6U + \frac{1}{2} \times 6 \times (10 - U) = 200 - \text{their (b)}$ rectangle + triangle or $\frac{1}{2} \times 6 \times (10 + U) = 200 - \text{their (b)}$ trapezium ($s = \left(\frac{u+v}{2}\right)t$) or $(6 \times 10) - \frac{1}{2} \times 6 \times (10 - U) = 200 - \text{their (b)}$ rectangle - triangle or $(10 \times 6) + \frac{1}{2} \left(-\frac{(10-U)}{6}\right) \times 6^2 = 200 - \text{their (b)}$ $s = ut + \frac{1}{2}at^2$ or $(U \times 6) - \frac{1}{2} \left(-\frac{(10-U)}{6}\right) \times 6^2 = 200 - \text{their (b)}$ $s = vt - \frac{1}{2}at^2$ N.B. Two stage <i>suvat</i> method: $(10 \times 6) + \frac{1}{2}a \times 6^2 = 200 - \text{their (b)} \Rightarrow$ AND $U = 10 + 6 \times \text{their } a$	A1ft	1.1b

		$\frac{10}{3} = 3\frac{1}{3}$ oe	A1	1.1b
			(3)	
(8 marks)				
Notes:				
5a	M1	Any complete <i>suvat</i> method to find <i>a</i> e.g. use $s = 20$ and $20 = \frac{1}{2}a \times 4^2$ N.B. Ignore units at this stage		
	A1	Any equivalent number with correct units. Accept m/s^2 , m/s/s , m per s per s .		
5b	M1	Complete method, they may use <i>suvat</i> on one or more sections, to find the TOTAL area. M0 if a single <i>suvat</i> equation is used for the whole motion M0 if $\frac{1}{2}$ not seen used in an area method		
	A1	Correct unsimplified expression.		
	A1	cao. Ignore units. N.B. Correct answer, with no working , can score all 3 marks.		
5c	M1	Complete method, using area or <i>suvat</i> , to give an equation in <i>U</i> only, with correct structure M0 if $\frac{1}{2}$ not seen used in an area method M0 if 10 is used instead of $(10 - U)$ or $(10 - U)$ is used instead of $(10 + U)$ in any equation		
	A1ft	Correct unsimplified equation in <i>U</i> only (allow <i>V</i> or <i>v</i> instead of <i>U</i>), ft on their 160 .		
	A1	Accept 3.3 or better. Ignore units. Allow use of <i>V</i> throughout instead of <i>U</i> , <u>including in the answer</u> . N.B. Correct answer, with no working , can score all 3 marks.		