

January 2018

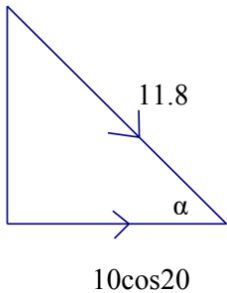
Q	Scheme	Marks	Notes
7(a)	Horizontal distance in terms of U , t and α	M1	
	$x = Ut \cos \alpha$	A1	Correct unsimplified equation
	Vertical distance in terms of U , t and α	M1	Condone sign error
	$y = Ut \sin \alpha - \frac{1}{2}gt^2$	A1	Correct unsimplified equation
	$y = U \sin \alpha \frac{x}{U \cos \alpha} - \frac{1}{2}g\left(\frac{x}{U \cos \alpha}\right)^2$	DM1	Substitute for t Dependent on the first 2 M marks
	$y = x \tan \alpha - \frac{gx^2 \sec^2 \alpha}{2U^2}$	DM1	Simplify the trig. and use Pythagoras Dependent on the first 2 M marks
	$y = x \tan \alpha - \frac{gx^2(1 + \tan^2 \alpha)}{2U^2}$ given answer	A1	Obtain given answer from correct working
		(7)	
(b)	$(\rightarrow) v_H = U$	B1	Horizontal component in U , g , T
	$(\downarrow) v_V = gT$	B1	Vertical component in U , g , T . Accept $\pm$
	Use of Pythagoras	M1	
	$v = \sqrt{U^2 + g^2 T^2}$	A1	Or equivalent. Allow t for T
		(4)	
(b) alt	$-h = d \tan \alpha - \frac{gd^2}{2U^2}(1 + \tan^2 \alpha)$	B1	$\left(h = \frac{gd^2}{2U^2}\right)$
	$d = UT \left(\Rightarrow h = \frac{gT^2}{2}\right)$	B1	
	$\frac{1}{2}mv^2 - \frac{1}{2}mU^2 = mgh$	M1	Energy equation
	$v^2 = U^2 + 2gh = U^2 + g^2 T^2$, $v = \sqrt{U^2 + g^2 T^2}$	A1	
		(4)	
(c)	$d = UT$	B1	Horizontal distance
	$-h = d \tan \alpha - \frac{gd^2(1 + \tan^2 \alpha)}{2U^2}$	M1	Substitute for x and y in given equation. Condone sign error
	$h = \frac{1}{2}gT^2$	B1	Vertical distance
	$-\frac{1}{2}gT^2 = d \tan \alpha - \frac{g(UT)^2(1 + \tan^2 \alpha)}{2U^2}$	M1	Substitute to eliminate U from the equation
	$0 = d \tan \alpha - \frac{gT^2}{2} \tan^2 \alpha$	A1	Correct equation in T and d
	$d = \frac{1}{2}gT^2 \tan \alpha$ given answer	A1	Obtain given answer from correct working
		(6)	
		[17]	

Question Number	Scheme	Marks
6a	Energy: $\frac{1}{2}m \times 144 = \frac{1}{2}m \times 64 + mgh$	M1A2
	$h = 4.1$ or 4.08 (m)	A1
	N.B. If they find an h , using a non-energy method, they score nothing in (a) BUT it can be used in (b), (c) and (d) without penalty.	(4)
6b	Vertical distance: $h = 12 \sin \alpha \times 1.5 - \frac{g}{2} \times 1.5^2$ (their h)	M1A1ft
	$(\sin \alpha = 0.839) \quad \alpha = 57.1^\circ \quad (57^\circ) \quad (0.996 \text{ rads})$	A1
		(3)
	Alt: Use $12 \cos \alpha = 8 \cos \beta$ and $-8 \sin \beta = 12 \sin \alpha - 1.5g$	
	and eliminate β to give equation in ONE trig ratio for α	M1A1ft
	$(\sin \alpha = 0.839) \quad \alpha = 57.1^\circ \quad (57^\circ) \quad (0.996 \text{ rads})$	A1
		(3)
6c	Horizontal cpts: $12 \cos \alpha = 8 \cos \beta$ (with their α for the A mark)	M1A1ft
	$\beta = 35.4^\circ \quad (35^\circ) \quad (0.617 \text{ or } 0.62 \text{ rads})$	A1
	Alt: $\tan \beta = \frac{12 \sin \alpha - 1.5g}{12 \cos \alpha} (= -0.709\dots)$ M1A1ft	
	$\beta = 35.4^\circ \quad (35^\circ) \quad (0.617 \text{ rads or } 0.62 \text{ rads})$ A1	
		(3)
	Alt: $h = \frac{(12 \sin \alpha - 8 \sin \beta)}{2} \times 1.5$ M1A1ft	
	$\beta = 35.4^\circ \quad (35^\circ) \quad (0.617 \text{ rads or } 0.62 \text{ rads})$ A1	
	Alt: $-8 \sin \beta = 12 \sin \alpha - (9.8 \times 1.5)$ M1A1ft	
	$\beta = 35.4^\circ \quad (35^\circ) \quad (0.617 \text{ rads or } 0.62 \text{ rads})$ A1	
6d	Correct strategy e.g. $2(1.5 - T)$ where T = time to max height	M1
	Correct equations e.g. Time to max height: $T = \frac{12 \sin \alpha}{g} = 1.028$	DM1A1
	$t = 2 \left(1.5 - \frac{12 \sin \alpha}{g} \right)$	
	Correct answer: $t = 0.94$ or 0.945 (s)	A1
	Alt 1: Time between the two points when $v = 8$ M1	
	$0 = 8 \sin \beta t - \frac{1}{2}gt^2 \left(= t \left(8 \sin \beta - \frac{1}{2}gt \right) \right)$ DM1A1	
	$t = 0.94, 0.945$ A1	
	Alt 2: Find the difference between the two times when $h = 4.08$ M1	
	$h = 12 \sin \alpha t - \frac{1}{2}gt^2$ for their h, α DM1A1	

Question Number	Scheme	Marks
	$t = 1.5 - 0.555 = 0.94$ or 0.945 (s) A1	
		(4)
	Alt 3: Use $v = u + at$ (vert) between the two points M1	
	$8 \sin \beta = -8 \sin \beta + gt$ DM1A1	
	$t = \frac{16 \sin \beta}{g} = 0.94, 0.945$ A1	[14]
	Notes for Qu6	
	6(a) M1 for an energy equation with correct no. of terms etc. (M0 if no energy equation used) First A1 and Second A1 for a correct equation. Third A1 for 4.1 or 4.08 (m)	
	6(b) M1 for a complete method to find an equation in $\sin \alpha$ only, using their h . (N.B. This equation could be obtained by getting two equations in α and β , which don't require h , and eliminating β , see above) First A1ft for a correct equation, ft on their h (if used) Second A1 for $57^\circ, 57.1^\circ, 1.0, 1.00$ rad	
	6(c) M1 for a complete method to find equation in α and β only Either by equating horizontal velocity components: $12 \cos \alpha = 8 \cos \beta$ Or by finding the vertical velocity component at B, v_v , and then using $\tan \beta = \frac{ v_v }{12 \cos \alpha}$ or $\sin \beta = \frac{ v_v }{8}$. First A1ft for a correct equation. N.B. v_v can be found in a number of ways: $v = u + at : v_v = 12 \sin \alpha - 1.5g$ $v^2 = u^2 + 2as : v_v = \sqrt{(12 \sin \alpha)^2 - 2g \times \text{their } h}$ $s = vt - \frac{1}{2}at^2 : h = 1.5v_v + \frac{1}{2}g \times 1.5^2 \Rightarrow v_v = \frac{h - \frac{1}{2}g \times 1.5^2}{1.5} = \frac{2h}{3} - \frac{3g}{4}$ $s = (\frac{u+v}{2})t : h = (\frac{12 \sin \alpha + v_v}{2}) \times 1.5 \Rightarrow v_v = \frac{4h}{3} - 12 \sin \alpha$ Second A1 for $\beta = 35.4^\circ$ (35°) (0.617 rads or 0.62 rads)	
	6(d) First M1 for a strategy to solve the problem Second DM1, dependent on first M, for attempt to set up an equation based on the strategy First A1 for a correct equation in t . Second A1 for 0.94 or 0.945	

Q	Scheme	Marks	Notes
4a	Velocity at T : $\rightarrow 12\cos 30^\circ = u_h (=u\cos\theta^\circ)$	M1	
	$(u\cos\theta^\circ = 6\sqrt{3} = 10.39\dots)$	A1	Correct unsimplified equation for horizontal component of u
	$\uparrow -12\sin 30^\circ = u_v - 2g (=u\sin\theta^\circ - 2\times 9.8)$	M1	
	$(u\sin\theta^\circ = 13.6)$	A1	Correct unsimplified equation for vertical component of u
	$\tan\theta^\circ = \frac{13.6}{6\sqrt{3}}$	DM1	Solve equations for u or θ Dependant on both preceding M marks
	$\theta = 52.6 \text{ (53)}$	A1	One correct (max 3 s.f.)
	$u = 17.1 \text{ (17)}$	A1	Both correct (max 3 s.f.)
		(7)	
4b	Vertical distance : $h = -12\sin 30^\circ \times 2 + \frac{1}{2} \times 9.8 \times 2^2$	M1	Complete method using <i>suvat</i> to find h .
	$\left(\text{or } h = 17.1\sin 52.6^\circ \times 2 - \frac{1}{2} \times 9.8 \times 2^2 \right)$ $\left(\text{or } 6^2 = (u\sin\theta)^\circ - 2gh \right)$	A1	Or equivalent correct unsimplified equation in h
	$h = 7.6 \text{ (7.60)}$	A1	
		(3)	
4b alt	Using energy: $\frac{1}{2}mu^2 - \frac{1}{2}m12^2 = mgh$	M1A1	
	$h = 7.6 \text{ (7.60)}$	A1	
		(3)	

Q	Scheme	Marks	Notes
4c	Double the time from max ht to T : $-12 \sin 30^\circ = -gt$	M1	
	Time above T : $2t = 2 \times \frac{12 \sin 30^\circ}{g}$	A1	
	$= 1.22 \text{ (1.2) (s)}$	A1	
		(3)	
4c alt	Vertical component of speed equal magnitude and opposite sign: $-12 \sin 30^\circ = 12 \sin 30^\circ - gT$	M1	
	$t = \frac{24 \sin 30^\circ}{g}$	A1	
	$t = 1.22$	A1	
		(3)	
4c alt	Equation for vertical distance and solve for values of t : $7.6 = u \sin \theta^\circ \times t - \frac{1}{2} g t^2$, $4.9 t^2 - 13.6 t + 7.6 = 0$	M1	
	$t_2 - t_1 = \frac{\sqrt{13.6^2 - 4 \times 4.9 \times 7.6}}{4.9}$	A1	$2 - \frac{38}{49} \text{ (2-0.7785)}$
	$t = 1.22$	A1	From correct work only
		(3)	
	For other alternatives: $\begin{cases} \text{complete strategy} & \text{M1} \\ \text{correct equation in } t & \text{A1} \\ t = 1.22 & \text{A1} \end{cases}$		
		[13]	

Q	Scheme	Marks	Notes
8a	Change in KE: $\frac{1}{2} \times 3 \times (15^2 - 10^2)$ (= 187.5) (J)	B1	One term correct unsimplified
	Gain in GPE: $3g \times 6 \sin 20$ (= 60.3....) (J)	B1	Two terms correct unsimplified
	Work done against friction: $6F$	B1	All three terms correct unsimplified
	Work energy:	M1	Dimensionally correct. All terms needed. Condone sign errors and sin/cos confusion
	$187.5 = 6F + 18g \sin 20$	A1	Correct unsimplified equation
	$F = 21.2$ (21)	A1	
		(6)	
8b	Energy:	M1	Dimensionally correct. All terms needed. Condone sign errors and sin/cos confusion
	$\frac{1}{2} \times 3 \times 100 + 3 \times 9.8 \times 6 \sin 20 = \frac{1}{2} \times 3 \times w^2$	A1	Correct unsimplified equation
	$w = 11.8$ (12) (m s^{-1})	A1	
			
	Direction : $\cos \alpha = \frac{10 \cos 20}{11.84...}$	M1	Use trig. to find a relevant angle
	37.5° (37°) below the horizontal	A1	
		(5)	
8b alt	Find components and use Pythagoras:	M1	Condone sign errors and sin/cos confusion
	$w = \sqrt{((10 \sin 20)^2 + 12g \sin 20) + (10 \cos 20)^2}$	A1	Correct unsimplified equation ($v_x = 9.396...$, $v_y = 7.205...$)
	$w = 11.8$ (12) (m s^{-1})	A1	
	Direction : $\tan \alpha = \frac{\sqrt{(10 \sin 20)^2 + 12g \sin 20}}{10 \cos 20}$	M1	Use trig. to find a relevant angle
	37.5° (37°) below the horizontal	A1	
		(5)	
			See over for (c)

Q	Scheme	Marks	Notes
8c	Use <i>suvat</i> to find height above <i>B</i> :	M1	Complete method
	$(10 \sin 20)^2 = 2g \times s \quad (s = 0.5968\dots)$	A1	Correct unsimplified equation in <i>s</i>
	Total height = $s + 6 \sin 20$	DM1	Dependent on the preceding M1
	$= 2.65 \text{ (2.6) (m)}$	A1	
		(4)	
8c alt	Vertical component of <i>w</i> (by trig or Pythagoras)	M1	
	$= 7.205\dots$	A1	
	Max ht = $\frac{v^2}{2g}$	DM1	Dependent on the preceding M1
	$= \frac{7.205^2}{19.6} = 2.65$	A1	
		(4)	
8c alt	Conservation of energy:	M1	Using speed at max ht = $10 \cos 20^\circ$ Need all terms. Condone sign error
	$\frac{1}{2} \times 3 \times (10 \cos 20^\circ)^2 + 3gh = \frac{1}{2} \times 3w^2$	A1	Correct unsimplified equation
	$h = \frac{w^2 - 100 \cos^2 20^\circ}{2g}$	DM1	Substitute for <i>w</i> and solve for <i>h</i> Dependent on the preceding M1
	$= 2.65 \text{ (2.6) (m)}$	A1	
		(4)	
		[15]	

Question Number	Scheme	Marks
7a	NB: sine/cosine confusion is not condoned in projectile questions Use of conservation of energy $\frac{1}{2}m \times 25^2 = \frac{1}{2}m \times 15^2 + mgh$ $\Rightarrow h = 20$ or 20.4 (m)	M1 A1 A1 (3)
7b	Vertical distance $20.4 = 25 \sin \alpha \times 3 - 4.5 \times 9.8$ $\alpha = 59^\circ$ or 59.3°	M1 A1ft A1 (3)
7c	Horizontal component of speed is constant $\Rightarrow 25 \cos \alpha = 15 \cos \beta$ $\beta = 32^\circ$ or 31.8°	M1 A1ft A1 (3)
7c alt	Vertical distance $20.4 = -15 \sin \beta \times 3 + 4.5 \times 9.8$ $\beta = 32^\circ$ or 31.8°	M1 A1ft A1 (3)
Notes		
7a M1 A1 A1	Need energy equation with all 3 terms. Must be dimensionally correct. Condone sign errors. Correct unsimplified equation Max 3 sf Not $\frac{1000}{49}$ nor $\frac{200}{g}$	
7b M1 A1ft A1	Use of <i>suvat</i> to find α Correct unsimplified equation in their h 0.554 rads. Max 3 sf From CWO	
7c M1 A1ft A1	Or horizontal distance travelled Correct unsimplified in α or their α 0.554 rads. Max 3 sf From CWO	
7c alt M1 A1ft A1	Use of <i>suvat</i> to find β e.g. using $s = vt - \frac{1}{2}gt^2$. Correct unsimplified equation in their h 0.554 rads. Max 3 sf From CWO	

Question Number	Scheme	Marks
7d	Min speed = horizontal component = $25 \cos \alpha (= 15 \cos \beta)$ = 13 or 12.8 (m s ⁻¹)	M1 A1 (2)
7e	By considering vertical component of speed at <i>B</i> : $15 \sin 31.8^\circ - gT = -15 \sin 31.8^\circ$ $T = 1.6$ or 1.61 (s)	M1 A1ft A1 (3)
Notes		[14]
7d M1 A1	Follow their angle. Must show working if using incorrect angle. Max 3 sf From CWO	
7e M1 A1ft A1	Complete method using <i>suvat</i> to find <i>T</i> Correct unsimplified equation in <i>T</i> - follow their angles. Max 3 sf From CWO	

Question Number	Solution	Marks	Notes
8a	Horizontal component: $p = 8$	B1	
	Vertical component: $-12 = q - 3g$	M1	Complete method to find q using <i>suvat</i> . Condone sign errors.
	$q = 17.4$	A1	17 or better
	Speed $= \sqrt{8^2 + 17.4^2}$	M1	Use of Pythagoras to find speed using their velocity. Independent M mark
	$= 19.2 \quad (19)(\text{ms}^{-1})$	A1	3 sf or 2 sf
		(5)	
8b	Use of Pythagoras to find vertical component	M1	
	vertical component $= \pm 6$	A1	Seen or implied Accept without +/-
	$-6 = 6 - 9.8T$	DM1	Complete method using <i>suvat</i> to find required time Dependent on the previous M1
	$T = 1.22 \quad (1.2)$	A1	3 sf or 2 sf. Not $\frac{60}{49}$
		(4)	
8b alt	Use <i>suvat</i> and Pythagoras to form an equation in t	M1	Or an inequality
	$8^2 + (17.4 - gt)^2 = 100$	A1	Correct unsimplified equation for t Accept inequality
	Solve for T	DM1	Complete method to obtain T Dependent on the previous M1
	$T = 1.22 \quad (1.2)$	A1	3 sf or 2 sf. Not $\frac{60}{49}$
		(4)	
8c	Velocity perpendicular $\Rightarrow$ vertical component $= \frac{2}{3} \times 8$	M1	Complete method to find vertical component of velocity at B
	$= \frac{16}{3}$	A1	
	$(-12)^2 = \left(\frac{16}{3}\right)^2 - 2g(-h)$	DM1	Complete method to find the required vertical distance using their vertical component of the velocity Dependent on the previous M1
	$h = 5.90 \quad (5.9)(\text{m})$	A1	Max 3 sf
		(4)	
8c alt	$\begin{pmatrix} 8 \\ 17.4 - gt \end{pmatrix} \cdot \begin{pmatrix} 8 \\ -12 \end{pmatrix} = 0$ and time $= 3 - t$	M1	Complete method to find the time from B to A
	Time $= 3 - 1.23\dots = 1.768\dots$	A1	
	$s = vt - \frac{1}{2}gt^2 = 12t - 4.9t^2$	DM1	Complete method to find the required vertical distance using their time Dependent on the previous M1
	$s = 5.9 \text{ (m)}$	A1	Max 3 sf

		[1]	[11]
Question Number	Scheme	Marks	Notes
7a	Equation for conservation of energy.	M1	Need all terms. Condone sign errors
	$\frac{1}{2} \times m \times 144 + m \times g \times 20 = \frac{1}{2} m v^2$	A1	Correct unsimplified equation with at most one error
		A1	Correct equation (with or without m)
	$v = 23$ or 23.2	A1	Max 3 s.f.
		[4]	
7b	$12 \cos \theta \times 5 = 40$	M1	Horizontal motion Condone sine/cosine confusion
	(minimum=) $12 \cos \theta = 8 \text{ (m s}^{-1}\text{)}$	A1	Final answer : do not ignore subsequent working
		[2]	
7c	Speed = 10 $\Rightarrow$ Vertical component = 6 (m s ⁻¹)	B1ft	Follow their horizontal component
	$(\pm)6 = 12 \sin \theta - gt$	M1	Vertical speed
	$= 12 \times \frac{\sqrt{5}}{3} - gt$ ($t = 0.30\ldots$ and $t = 1.52\ldots$)	A1	Correct equation for one value of t or for the time interval. Correct trig value seen or implied
	Time = $1.52\ldots - 0.30\ldots = 1.22\ldots$ (s)	A1	Correct interval
	Required time = $5 - 1.22$ (s)	M1	Find required time – follow their 1.22
	$= 3.78$ (s)	A1	Or 3.8. Max 3 s.f.
		[6]	
	Alternatives for M1A1A1		
	Use of $v = u + at$	(M1)	
	$-6 = 6 - gt$	(A1)	Or find time to top and double it
	$t = \frac{12}{g}$	(A1)	
	Vertical speed: $6 = 12 \sin \theta - gt_1$	(M1)	
	$-6 = 12 \sin \theta - gt_2$	(A1)	
	$12 = g(t_2 - t_1)$, $t_2 - t_1 = \frac{12}{g}$	(A1)	
	Alternatives for B1M1A1A1		
	ht above A $\frac{22}{g}$	(B1)	Using energy 2.24... seen or implied e.g. by 22.24...
	Use of $s = ut + \frac{1}{2}at^2$	(M1)	$20 + \frac{22}{g}$ used with $12 \sin \theta$ is M0
	$\frac{22}{g} = 12 \sin \theta t - \frac{1}{2}gt^2$	(A1)	
	Time = $1.52\ldots - 0.30\ldots = 1.22\ldots$ (s)	(A1)	Correct interval
	Speed 10, angle to horizontal $\alpha \Rightarrow 10 \cos \alpha = 8$	(B1)	
	Time to top: $0 = 10 \sin \alpha - gt$	(M1)	
	$10 \times 0.6 = gt$	(A1)	

	Total time = $\frac{12}{g}$	(A1)	
		[11]	

7a	$-12 = 12 - gt$	M1	Use <i>suvat</i> to find time taken
	$t = \frac{24}{g} (= 2.45)$	A1	
	$AB = 6t$	M1	Horizontal distance
	$= 14.7 (15) \text{ (m)}$	A1	3 sf or 2 sf Not $\frac{720}{49}$ (follows use of 9.8) Not $\frac{144}{g}$ (do not accept g in the denominator)
		(4)	
7b	Vertical component of velocity $= (\pm)8$	B1	
	$v^2 = u^2 + 2as$	M1	Complete method using <i>suvat</i> to find h
	$\Rightarrow 8^2 = 12^2 - 2gh$	A1	Correct unsimplified equation
	$h = 4.08 \text{ (4.1)}$	A1	3 sf or 2 sf Not $\frac{200}{49}$ (follows use of 9.8) Not $\frac{40}{g}$ (do not accept g in the denominator)
		(4)	
7b alt	$\mathbf{v} = \begin{pmatrix} 6 \\ 12 \end{pmatrix} - \begin{pmatrix} 0 \\ g \end{pmatrix} t \Rightarrow 12 - gt = (\pm)8$	B1	Correct expression for critical value(s) of t
	$h = 12t - \frac{1}{2}gt^2$	M1	Complete method using <i>suvat</i> to find h
	$= \frac{48}{g} - \frac{8}{g} \text{ or } = \frac{240}{g} - \frac{200}{g}$	A1	Correct unsimplified equation
	$h = 4.08 \text{ (4.1)}$	A1	3 sf or 2 sf
		(4)	
7c	$\begin{pmatrix} 6 \\ -12 \end{pmatrix} \cdot \begin{pmatrix} 6 \\ v \end{pmatrix} = 0$	M1	Complete method to find vertical component at C.
	$\Rightarrow v = 3$	A1	
	$\mathbf{v} = 6\mathbf{i} + 3\mathbf{j} \text{ (ms}^{-1}\text{)}$	A1	Must be a vector in terms of $\mathbf{i}$ and $\mathbf{j}$
	If see $\begin{pmatrix} 6 \\ 12 \end{pmatrix} \cdot \begin{pmatrix} 6 \\ v \end{pmatrix} = 0$ leading to $\mathbf{v} = 6\mathbf{i} - 3\mathbf{j}$ mark as a misread: M1A0A0		
		(3)	
		[11]	
	Accept working in column vectors throughout apart from the final A1		

8a	Conservation of energy	M1	Need all three terms and dimensionally correct. Condone sign errors.
	$\frac{1}{2}m \times 10^2 + mgh = \frac{1}{2}m \times 18^2$	A1	Correct unsimplified equation
	$h = 11.4 \quad (11)$	A1	3 sf or 2 sf only (not $\frac{80}{7}$)
		(3)	
8b	Vertical distance	M1	Complete method using <i>suvat</i> to find angle of projection
	$10 \sin \alpha \times 2.5 - \frac{1}{2}g \times 2.5^2 = -11.4$	A1ft	Follow their h
	$\alpha = 50.2^\circ$ or $10 \sin \alpha = v_v = 7.7678\dots$	A1	50° or better (50.1618...) Accept 50.3° from 11.4 Seen or implied Might see $\sin \alpha = \frac{43}{56}$ or $v_v = \frac{215}{28}$
	Horizontal distance = $10 \cos \alpha \times 2.5$ or $\sqrt{100 - v_v^2} \times 2.5$	M1	
	$= 16.0 \quad (16)(\text{m})$	A1	3 sf or 2 sf only
		(5)	
8c	Using energy: $\frac{1}{2}m \times 64 + mgs = \frac{1}{2}m \times 100$	M1	Complete method to find height above A
	$s = 1.8367\dots$	A1	1.8 or better
	Use of <i>suvat</i> to form equation in t	M1	
	$1.84 = 10 \sin 50.2^\circ \times t - 4.9t^2$	A1	Correct unsimplified equation
	Solve for t and find difference between roots	DM1	Complete method to find the required time Dependent on 2 previous M marks
	$T = 0.98$ or 0.978	A1	2 sf or 3 sf
		(6)	
8c alt	Use of Pythagoras	M1	Complete method to find vertical component of speed
	Vertical speed $\sqrt{64 - (10 \cos \alpha)^2} = 4.8\dots$	A1	Awrt 4.8 or better
	Use of $10 \sin \alpha - gt = \pm v$ to find t	M1	
	$\begin{cases} 10 \sin 50.2^\circ - gt_1 = 4.8 \\ 10 \sin 50.2^\circ - gt_2 = -4.8 \end{cases}$	A1	Correct unsimplified equations Could also find time to top
	$T = t_2 - t_1 = 1.27\dots - 0.29\dots$	DM1	Complete method to find the required time Dependent on 2 previous M marks
	$= 0.98$ or 0.978	A1	Final answer. 2 sf or 3 sf
		(6)	
8calt	Use of Pythagoras to form quadratic in t	M1	
	$(10 \sin \theta - gt)^2 + (10 \cos \theta)^2 = 64$	A1	

	Simplify and substitute for trig	M1	
	$36 + 9.8^2 t^2 - 150.5t = 0$	A1	
	$T = t_2 - t_1 = 1.27.. - 0.29..$	DM1	Complete method to find the required time Dependent on 2 previous M marks
	$= 0.98 \text{ or } 0.978$	A1	Final answer. 2 sf or 3 sf
		[14]	

7a	Horizontal distance	M1	Correct use of <i>suvat</i>
	$x = u \cos \alpha t$	A1	Correct equation
	Vertical distance	M1	Correct use of <i>suvat</i>
	$y = u \sin \alpha t - \frac{1}{2} g t^2$	A1	Correct equation. Correct signs. Condone if not using “y”
	$t = \frac{x}{u \cos \alpha} \Rightarrow$ $y = u \sin \alpha \cdot \frac{x}{u \cos \alpha} - \frac{g}{2} \left(\frac{x}{u \cos \alpha} \right)^2$ $\left(= x \tan \alpha - \frac{g x^2}{2 u^2} \sec^2 \alpha \right)$	DM1	Dependent on the first 2 M marks. Substitute for t to obtain y in terms of x and α
	$y = x \tan \alpha - \frac{g x^2}{2 u^2} (1 + \tan^2 \alpha) \quad *$	A1*	Obtain given answer from correct working (final step needs to be explained). Allow if $\sec^2 \alpha$ seen. Must be “y” here
		[6]	
7b	$u = 20, x = 10, y > 2 \Rightarrow$ $2 = 10 \tan \theta - \frac{100g}{800} (1 + \tan^2 \theta)$ $\left(\frac{g}{8} \tan^2 \theta - 10 \tan \theta + \left(2 + \frac{g}{8} \right) = 0 \right)$	M1	Use given values to form quadratic in $\tan \theta$ or equivalent equation in one trig function. Allow working with $=, < \text{ or } > 2$
	Critical values: $\theta^\circ = 18.6^\circ \text{ or } \theta^\circ = 82.7^\circ$	A1	One correct value to 2 sf or better
	Range: $18.6 < \theta < 82.7$	A1	Accept $< \text{ or } \leq$ $(19 \leq \theta \leq 82 \text{ or } 83)$ max 3 sf
		[3]	
7c	$y = 10 \tan 40^\circ - \frac{9.8 \times 100}{2 \times 400} (1 + \tan^2 40^\circ)$	M1	Use given formula to find vertical height
	$y = 6.3(03...) \text{ (m)}$	A1	Can be implied by correctly substituted formula
	Conservation of energy	DM1	Dependent on the first M1. Need all 3 terms. Dimensionally correct. Condone sign errors.
	$\frac{1}{2} m v^2 = \frac{1}{2} m \times 400 - mgy$	A1ft	Correct unsimplified equation in y or their y
	$v = 17 \quad (16.6) \text{ (ms}^{-1}\text{)}$	A1	2sf or 3sf only
		[5]	
7c alt	$20 \cos 40^\circ t = 10, t = \frac{1}{2 \cos 40^\circ} = 0.653....$ $\Downarrow v_v = 20 \sin 40^\circ - gt$	M1	Complete method using <i>suvat</i> to vertical component of speed e.g. by finding time taken then use of $v = u - gt$ or finding vertical distance and using <i>suvat</i>
	$= 6.5 \quad (6.459...)$	A1	6.5 or better (not final answer so allow $> 3\text{sf}$ or a correct unsimplified expression)
	$v^2 = (v_H)^2 + (v_V)^2$	DM1	Correct use of Pythagoras

			Dependent on preceding M mark
	$\leftrightarrow v_H = 20 \cos 40^\circ (= 15.3....)$	A1	Horizontal component of speed seen or implied
	$v = 17 \quad (16.6) \text{ (ms}^{-1}\text{)}$	A1	2sf or 3sf only
		[5]	
7d	$0 = x \tan 40^\circ - \frac{9.8x^2}{800} (1 + \tan^2 40^\circ)$	M1	Complete method to solve for x .
	$x = 40 \text{ (40.2) (m)}$	A1	2sf or 3sf only
		[2]	
7d Alt1	$y = 0 \Rightarrow t = \frac{40 \sin 40^\circ}{g} (= 2.623...)$ $x = 20 \cos 40^\circ \times t$	M1	Complete method to solve for x .
	$x = 40 \text{ (40.2) (m)}$	A1	2sf or 3sf only
		[2]	
7d Alt2	Range = $\frac{20^2 \sin 80^\circ}{g}$	M1	Complete method to solve for x .
	$= 40 \text{ (40.2) (m)}$	A1	2sf or 3sf only
		[2]	
		(16)	

8 (a)	Normal reaction between P and ramp $(R) = 0.3g \cos \alpha \left(= 0.3g \times \frac{24}{25} = 2.82 \dots \right)$	M1	Seen or implied. Condone sin / cos confusion (implied by use of $\frac{7}{25}$)
	Work done against friction $= \frac{1}{5} R \times 15$	M1	Use of $WD = \mu R \times \text{distance}$ with their R
	$= 8.47(8.5)(\text{J})$	A1	3 sf or 2 sf
		3	
8 (b)	Work-energy equation	M1	All terms required. Dimensionally correct. Condone sign errors.
	$\frac{1}{2} \times 0.3U^2 = \frac{1}{2} \times 0.3 \times 25^2 + (a) + 0.3 \times g \times (15 \sin \alpha)$	A1ft A1ft	Follow their answer to (a) Correct unsimplified equation with at most one error. Correct unsimplified equation
	$U = 27.6 \quad (28)$	A1	3 sf or 2 sf
		4	
8 (c)	Time to ground:	M1	Complete method using <i>suvat</i> to form an equation in t
	$-15 \sin \alpha = 7t - \frac{1}{2}gt^2$	A1	Correct unsimplified equation in t
	$t = 1.88 \quad (1.9) \quad (\text{s})$	A1	3 sf or 2 sf $\frac{5+\sqrt{67}}{7}$ is A0
		3	
8 (d)	Vertical component of speed	M1	Or use energy to find the speed
	$= \pm(7 - (\text{their } t) \times g) \quad (\pm 11.459 \dots)$	A1ft	or $0.15 \times 625 + .3 \times 9.8 \times \text{their } 4.2 = 0.15v^2 \quad (v = 26.59 \dots)$ condone $v = \frac{7\sqrt{67}}{5}$
	Correct use of trig: $\tan \theta^\circ = \frac{\text{their vertical}}{24}$	M1	or $\cos \theta^\circ = \frac{24}{\text{their speed}}$
	$\theta = 25.5(26)$	A1	3 sf or 2 sf
		4	
Reminder: The accuracy penalty for overspecified answers should be applied only once in any question (the first time seen). Similarly for the use of $g = 9.81$. If they make both of these errors they lose 2 A marks. The penalty applies to the final mark in any part.			
		(14)	

8a	Condone use of θ or a mixture of θ and α throughout but final answer should be in one variable.		
	Equation for horizontal distance	M1	Complete method using <i>suvat</i> . Condone sine / cosine confusion
	$x = u \cos \alpha t$	A1	Correct only
	Equation for vertical distance	M1	Complete method using <i>suvat</i> . Condone sine / cosine confusion and sign error
	$y = u \sin \alpha t - \frac{1}{2} g t^2$	A1	Correct only
	$t = \frac{x}{u \cos \alpha} \Rightarrow$ $y = u \sin \alpha \cdot \frac{x}{u \cos \alpha} - \frac{g}{2} \left(\frac{x}{u \cos \alpha} \right)^2$	DM1	Substitute for t to obtain y in terms of x and α Dependent on the 2 preceding M marks
	$\Rightarrow y = x \tan \alpha - \frac{g x^2}{2 u^2} (1 + \tan^2 \alpha) *$	A1*	Obtain given answer from full and correct working. Need some evidence for the final step. $\frac{1}{\cos^2 \alpha} = 1 + \tan^2 \alpha$ is not sufficient.
		6	
8b	Conservation of energy:	M1	Method specified in the question. Need all terms and dimensionally correct. Condone sign errors
	$\frac{1}{2} m \times 25^2 = \frac{1}{2} m U^2 + m g \times 20$	A1	Correct unsimplified equation
	$U = 15.3 \text{ (15)}$	A1	3 sf or 2 sf only
		3	
8c	Use part (a) or work from first principles to form an equation in $\tan \theta$	M1	$\left(-20 = 30 \tan \theta - \frac{9.8 \times 900}{2 U^2} (1 + \tan^2 \theta) \right)$
	Obtain $18.9 \tan^2 \theta - 30 \tan \theta - 1.07 = 0$ $\left(\frac{4410}{233} \tan^2 \theta - 30 \tan \theta - \frac{250}{233} = 0 \right)$	A1ft	Or 3 term equivalent Follow their U Can be implied by a correct final answer
	$\Rightarrow \theta = 58.3^\circ \text{ or } 58^\circ$	A1	3 sf or 2 sf only
		3	
		(12)	

Question	Scheme	Marks	Notes
7a	Energy equation	M1	Q requires energy. Need all terms and dimensionally correct. Condone sign error.
	$\frac{1}{2}mv^2 = \frac{1}{2}m(9+4) + mg \times 20$	A1	Correct unsimplified equation
	$v = 20(20.1)(\text{ms}^{-1})$	A1	2 sf or 3 sf only. Not $9\sqrt{5}$
		(3)	
7b	Complete method to find the direction as an angle	M1	Complete method to find trig ratio for a relevant angle
	$\cos \alpha = \frac{3}{\text{their (a)}}$	A1ft	Correct unsimplified equation for a relevant angle. Follow their part (a)
	$\alpha = 81^\circ (81.4^\circ)$ below the horizontal	A1	Or equivalent. 2 sf or 3 sf. Needs to be clear on a diagram or in words where the angle is measured. Accept “to the horizontal”
		(3)	
7b alt	Complete method to find the direction as a vector in i and j or as a column vector	M1	
	Component = $\sqrt{(a)^2 - 9}$	A1ft	Correct unsimplified equation. Follow their part (a)
	Direction $3\mathbf{i} - 19.9\mathbf{j}$	A1	2 sf or 3 sf. ISW after correct vector seen
		(3)	
7c	Form an equation in t	M1	Complete method using <i>suvat</i> Condone sign errors.
	e.g. $-20 = 2t - \frac{1}{2}gt^2$ or $(-20.1\dots)\sin \alpha = 2 - gt$	A1	Correct unsimplified equation
	$t = 2.2(2.23)(\text{s})$	A1	2 sf or 3 sf only
		(3)	
7d	Perpendicular velocity = $3\mathbf{i} - \lambda\mathbf{j}$	B1	Horizontal component unchanged and vertical not equal to ± 2 . Seen or implied
	$(3\mathbf{i} + 2\mathbf{j}) \cdot (3\mathbf{i} - \lambda\mathbf{j}) = 0$	M1	Complete method to solve for vertical component If using angles, they should be using 56.3° for the perpendicular direction.
	$\Rightarrow \mathbf{v} = \left(3\mathbf{i} - \frac{9}{2}\mathbf{j}\right)(\text{ms}^{-1})$	A1	Correct vertical component seen or implied
	Use of <i>suvat</i> or use of energy to find relevant distance	dM1	Complete method to find the vertical component of perpendicular velocity. Dependent on the previous M1 Working with $3\mathbf{i} - 2\mathbf{j}$ is not equivalent work
	$\left(\frac{9}{2}\right)^2 = 2^2 + 2gs$ or $\frac{1}{2}m(13) + mgs = \frac{1}{2}m\left(9 + \frac{81}{4}\right)$	A1	Correct unsimplified equation for their distance
	$h = 20 - s = 19(19.2)$	A1	2 sf or 3 sf
		(6)	

Question	Scheme	Mark	Notes
4a	$4 - gT_1 = 0$ or $T_1 = \frac{\sqrt{32} \sin 45^\circ}{g}$	M1	Complete method using <i>suvat</i>
	$T_1 = 0.408$ (0.41)	A1	3 sf or 2 sf only. Not $\frac{20}{49}$
		[2]	
4b	Height of Q above P :	M1	Complete method using <i>suvat</i> and 7 and 4 for the initial vertical components
	$h = (7T_1 - \frac{1}{2}gT_1^2) - (4T_1 - \frac{1}{2}gT_1^2) \quad (= 3T_1)$	A1	Correct unsimplified expression in T_1 or their T_1 . They do not need to have substituted for T_1 (2.0408... - 0.8163...)
	$h = 1.2$ (m)	A1ft	2 sf only ($3 \times \text{their } T_1$)
		[3]	
4c	Correct time for P to reach B . ($\frac{40}{49}$, 0.816, or $\frac{8}{g}$ or better)	B1	Seen or implied.
	Vertical component of speed $= 7 - g \times 2T_1 \quad (= -1)$	M1	Complete method using <i>suvat</i> with $2T_1$ or their t for the time at B M0 if not using 7
	$\tan \alpha = \pm \frac{\text{their } 1}{5}$	M1	Correct use of <i>their</i> 1 and 5 to find an equation in a relevant angle (e.g. $90 - \alpha$)
	$\alpha = 11$	A1	11 or better (e.g. 11.3)
	If they use T_1 in place of $2T_1$ can score B0M0M1A0		
		[4]	
4d	Form an equation in T_2 only	M1	Complete method using <i>suvat</i> and perpendicular gradients. e.g. $\begin{pmatrix} 5 \\ 7 \end{pmatrix} \cdot \begin{pmatrix} 5 \\ 7 - gT_2 \end{pmatrix} = 0$ Condone sign errors (Vertical component of speed $= \pm \frac{25}{7}$) (perpendicular direction is downwards at 35.5° to the horizontal)
	$-\frac{25}{7} = 7 - gT_2$	A1	Correct unsimplified equation
	$T_2 = 1.08$ or $T_2 = 1.1$	A1	3 sf or 2 sf only
		[3]	
		(12)	

8a	Use symmetry to find time taken: $-7 = 7 - gt$	M1	Or equivalent complete method using <i>suvat</i> to find the time taken e.g. find the time for vertical distance = 0
	$t = \frac{14}{g} (= 1.428...)$	A1	Correct value seen or implied
	Horizontal distance = $4t$	DM1	Complete method using <i>suvat</i> to find the distance. Dependent on the preceding M1
	$= 5.71(\text{m})$ or $5.7(\text{m})$	A1	3 sf or 2 sf only $\frac{40}{7}$ scores A0 $\frac{56}{g}$ scores A0 (incorrect units)
		[4]	
8a alt	Find speed and angle of projection	M1	Correct use of Pythagoras and trig.
	Speed = $\sqrt{16 + 49} = \sqrt{65} \text{ (ms}^{-1}\text{)}$ Direction = $\tan^{-1} \frac{7}{4} (= 60.3^\circ)$	A1	Both values seen or implied.
	Use of $R = \frac{u^2 \sin 2\alpha}{g}$	DM1	Or equivalent. Dependent on the preceding M1
	$= 5.71(\text{m})$ or $5.7(\text{m})$	A1	3 sf or 2 sf only
		[4]	
8b	$ \mathbf{v} = 5 \Rightarrow \mathbf{v} = 4\mathbf{i} + 3\mathbf{j}$ or $\mathbf{v} = 4\mathbf{i} - 3\mathbf{j}$	B1	Correct vertical component seen or implied
	$-3 = 3 - gT$	M1	Complete method to find T e.g. $T = \frac{14}{g} - 2 \times \frac{4}{g}$
	$T = 0.612$ or $T = 0.61$	A1	3 sf or 2 sf only $\frac{30}{49}$ scores A0 $\frac{6}{g}$ scores A0 (incorrect units)
		[3]	
8c	$\begin{pmatrix} 4 \\ 7 \end{pmatrix} \cdot \begin{pmatrix} 4 \\ p \end{pmatrix} = 0$	M1	Or equivalent method to find perpendicular velocity
	$\Rightarrow p = -\frac{16}{7}, \quad \mathbf{v} = 4\mathbf{i} - \frac{16}{7}\mathbf{j}$	A1	Correct vertical component Allow -2.28....
	$\left((-)\frac{16}{7} \right)^2 = 7^2 - 2gh$	DM1	Complete method using <i>suvat</i> or energy to form an equation in h only. Dependent on the preceding M1
	$h = 2.23$ or $h = 2.2$	A1	3 sf or 2 sf only cso (negative vertical component seen at some point)
		[4]	
8c alt	$\begin{pmatrix} 4 \\ 7 \end{pmatrix} \cdot \begin{pmatrix} 4 \\ 7 - gt \end{pmatrix} = 0$	M1	Or equivalent method to find time when velocity perpendicular
	$t = \frac{65}{7g} (= 0.947...)$	A1	Correct time
	$h = 7t - \frac{1}{2}gt^2$	DM1	Complete method using <i>suvat</i> to form an equation in h only.
	$h = 2.23$ or $h = 2.2$	A1	3 sf or 2 sf only cso
		[4]	
		(11)	