Mark Scheme

Q1.

Question Number	Scheme	Marks	
a	After 4 seconds from O, horizontal speed $=u\cos\theta$	B1	
	Vertical component of speed at A $= u+at$	M1	Complete method using *suvat* to find v.
	$= u\sin\theta - 4g$	A1	
	At A, components are $15\cos 20$ (horizontal) and $15\sin 20$ (vertical)	B1	
	$u\cos\theta = 15\cos 20$ $u\sin\theta = 15\sin 20 + 4g$	DM1	Form simultaneous equations in u and θ and attempt to solve for u or θ. Depends on the previous M1
	$\theta = 72.4 \quad (72)$	A1	Remember - A0 for the first overspecified answer
	$u = 46.5 \quad (47)$	A1	
		[7]	
Alt a	After 4 seconds from O, horizontal speed $=u\cos\theta$	B1	
	At $t=4$, $s = vt - \frac{1}{2}gt^2$	M1	Complete method to find the vertical height at A
	$= 98.9.....$	A1	
	At A, components are $15\cos 20$ (horizontal) and $15\sin 20$ (vertical)	B1	
	$\frac{1}{2}mv^2 = \frac{1}{2}mu^2 - 2gh$	DM1	Conservation of energy. The equation needs to include all three terms but condone sign error(s).
	$u = 46.5 \quad (47)$	A1	Remember - A0 for the first overspecified answer
	$\theta = 72.4 \quad (72)$	A1	Beware inappropriate use of *suvat*

b	$-15\sin 20 = 15\sin 20 - gt$ or $0 = 15\sin 20t - \frac{1}{2}gt^2$	M1	Complete method using *suvat* or otherwise to find the time to travel from A to B
	$t = 1.05$ (s) or 1.0 (s)	A1	
		[2]	
c	Total time $= 4 + (1.05) + 4$	B1ft	Follow their t or $\frac{2u\sin\theta}{g}$ for their u, θ
	Range $= 46.5\times\cos 72.4\times(8+1.05)$ (or $15\cos 20\times 9.05$)	M1	Correct method to find OC for their t, u and θ
	$= 128$ (m) or 127 (m) (130)	A1	
		[3]	
		(12)	

Q2.

Q.	Scheme	Marks	
(a)	$2 = -2u\sin\theta + \frac{1}{2}g\times 4$	M1	Vertical distance. Condone sign errors. Must have used $t = 2$, but could be using $u_y = u\sin\theta$
	$\left(-2 = u\sin\theta t - \frac{1}{2}gt^2\right)$	A1	All correct
	$u\sin\theta = g - 1$		
	$2u\cos\theta = 8 \quad (u\cos\theta = 4)$ $(u\cos\theta t = 8)$	B1	Horizontal distance. Accept $u_x = 4$ o.e.
	$\tan\theta = \frac{g-1}{4} = 2.2$ *	M1	Divide to obtain expression for $\tan\theta$
		A1	**Given answer** It is acceptable to quote and use the equation for the projectile path. Incorrect equation is 0/5.
(b)	$u\cos\theta = 4$	M1	Use the horizontal distance and θ to find u 9.67 or 9.7
	$u = \frac{4}{\cos\theta} = 9.66... = 9.7$	A1	NB $\theta = 65.6°$ leading to 9.68 is an accuracy penalty.
	OR use components from (a) and Pythagoras.		
(c)	$6 = (1-\rho)T + \frac{1}{2}\times 9.8T^2$	M1	Equation for vertical distance $= \pm 6$ to give a quadratic in T. Allow their u_y
	$4.9T^2 - 8.8T - 6 = 0$		
	$T = \frac{8.8 \pm \sqrt{\left[(-)8.8\right]^2 + 24\times 4.9}}{9.8}$	DM1	Solve a 3 term quadratic
	$T = 2.323... = 2.32$ or 2.3	A1	2.3 or 2.32 only
(d)	$v^2 = 8.8^2 + 2g\times 6$ or $v = -8.8 + gT$	M1	Use *suvat* to find vertical speed
		A1	Correct equation their u_y, T
	$v = 13.96...$		
	Horiz speed = 4		
	$\tan\alpha = \frac{v}{4}$	DM1	Correct trig. with their vertical speed to find the required angle.
		A1	Correct equation
	$\alpha = 74.01... = 74°$	A1	$74°$ or $74.0°$. Allow 106.
	Alternative:		
	$\frac{1}{2}m(9.6664)^2 + 6mg = \frac{1}{2}mv^2$	M1	Conservation of energy to find speed
	$v = 14.52719...$	A1	
	$\cos\alpha = \frac{4}{14.5}$	DM1	Correct method for α
		A1	
	$\alpha = 74.01... = 74°$	A1	Allow 106

Q3.

Question Number	Scheme	Marks	
(a)	$0^2 = u_v^2 - 2 \times 9.8 \times 10$	M1	Complete method using *suvat* to form an equation in u_v.
		A1	Correct equation e.g. $0 = u^2 - 20g$
	$u_v = 14$ *	A1	*Answer given* requires equation and working, including 196, seen.
		(3)	
OR	conservation of energy:	M1	Initial KE = gain in GPE + final KE
	$\frac{1}{2}m\left(u_h^2 + u_v^2\right) = mg \times 10 + \frac{1}{2}mu_h^2 \cdot \frac{1}{2}u_v^2 = 98$	A1	Correct equation
	$u_v = 14$ *	A1	*Answer given*
		(3)	
(b)		M1	Use the vertical distance travelled to find the total time taken.
	$(\uparrow)$, $-52.5 = 14t - \frac{1}{2}gt^2$	A1	At most one error
		A1	Correct equation
	$49t^2 - 140t - 525 = 0$	DM1	Solve for t. Dependent on the preceding M mark
	$(t-5)(49t+105) = 0 \quad t = 5$	A1	only
	$(\rightarrow)$, $50 = 5u_H$	M1	Use their time of flight to form an equation in u_H
	$u_H = 10$	A1	only
	$u = \sqrt{10^2 + 14^2}$	M1	Use of Pythagoras with two non-zero components, or solution of a pair of simultaneous equations in u and α.
	$= \sqrt{296}$; 17.2 m s^{-1}	A1	17.2 or 17 (method involves use of g = 9.8 so an exact surd answer is not acceptable)
		(9)	
			See next page for an alternative route to u, and (c).
OR			First 3 marks for the quadratic as above.
	$50 = u\cos\alpha t$ or $50 = u_H t$	M1	Used in their quadratic
	$49\left(\frac{50}{u_H}\right)^2 - 140\left(\frac{50}{u_H}\right) - 525 = 0$	A1	Correct quadratic in u_H
	$525(u_H)^2 + 140(u_H) - 122500 = 0$		
	Solve for u_H	DM1	Dependent on the M mark for setting up the initial quadratic equation in t.
	$u_H = 10$	A1	only
	etc.		Complete as above.
(c)	$\tan OBA = \frac{52.5}{50} = 1.05$	B1	Correct direction o.e. (accept reciprocal)
	$v_v = 1.05 \times 10 = 10.5$	M1	Use trig. with their u_H and correct interpretation of direction to find the vertical component of speed. Working with distances is M0. (condone 10 ÷ 1.05)
	$(\uparrow)$, $-10.5 = 14 - gt$	DM1	Use suvat to form an equation in t. Dependent on the preceding M.
		A1	Correct equation for their u_H
	$t = 2.5$	A1	For incorrect direction give A0 here. only
		(5)	
		17	

Q4.

Question	Scheme	Marks	AOs
	Note that $g = 10$; penalise once for whole question if $g = 9.8$		
(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)	
(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)	A1ft	1.1b
	Sub for trig and square, add and square root : $\sqrt{60^2 + (-45)^2}$	M1	3.1b
	75 Accept 80 (m s^{-1})	A1	1.1b
		(5)	
(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:		
a	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)
b	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)
c	B1	B0 if incorrect extras

Q5.

Question Number	Scheme	Marks	Notes
(a)	**Considering energy:** $\frac{1}{2}m\times14^2=\frac{1}{2}m\times10^2+mgh$ $h=\frac{48}{g}=4.90$	M1 A2 A1 (4)	All terms required. Terms need to be of the correct form but condone sign errors. -1 each error in the unsimplified equation Accept $\frac{48}{g}$. Maximum 3 s.f. if they go in to decimals.
alt(a)	Initial $v_y=14\sin\alpha$ Final $v_y=\sqrt{100-14^2\cos^2\alpha}$ $100-196\cos^2\alpha=196\sin^2\alpha-2gh$ $h=\frac{48}{g}=4.90$	 M1A2 A1 (4)	Using $v^2=u^2+2as$ on the vertical components of speed. -1 each error in the unsimplified equation Accept in exact form. Maximum 3 s.f. if they go in to decimals.
NB	Using $v^2=u^2+2as$ with 10 and 14 is M0		
NB	In part (a) they must be solving the general case, not using 0.85. However, the marks in (b) are all available if they solve the specific case in (a).		
(b)	Vertical distance: $h=14\sin\alpha t-\frac{1}{2}\times9.8t^2$ $4.9t^2-11.9t+h=0$ $t=\frac{11.9\pm\sqrt{11.9^2-4\times4.9^2}}{9.8}$ $t=1.903.....$ **Horizontal distance:** $x=14\cos\alpha\times t$ =14.0 (m)	M1 A2 DM1 A1 M1 A1 A1 (8)	A complete method to find an equation in t. Must involve trig condone sin/cos confusion Correct in h or their h. -1 each error Solve a 3 term quadratic for t. Needs their value for h now. 1.9 or better Method for the horizontal distance. Condone consistent sin/cos confusion Correct for their positive t Accept 14
Alt (b)	**Vertical speed** = $\sqrt{100-(14\cos\alpha)^2}$ (=6.75) $v=u+at=14\times0.85-9.8t$ $(-6.75=11.9-9.8t)$ $t=1.903.....$ **Horizontal distance:** $x=14\cos\alpha\times t$ =14.0 (m)	M1 A2 DM1 A1 M1 A1 A1 (8)	A complete method to find the vertical component of the speed at B. Correct insimplified. -1 each error. Use their vertical component to find t 1.9 or better Method for the horizontal distance. Correct for their positive t Accept 14
		[12]	
NB	Candidates with a false method leading to 4.9 in (a) score at most M1A1A1DM1A0M1A1A0 if they use their result in (b). This error does not affect the alt (b) approach		

Q6.

Question Number	Scheme		Marks
(a)	$(\downarrow)$ $u_y = 25\sin 30° \ (=12.5)$		B1
	$12 = 12.5t + 4.9t^2$	-1 each error	M1 A2, 1, 0
	Leading to $t = 0.743$, 0.74		A1 (5)
(b)	$(\rightarrow)$ $u_x = 25\cos 30° \left(= \frac{25\sqrt{3}}{2} \approx 21.65\right)$		B1
	$OB = 25\cos 30° \times t \ (\approx 16.094\,58)$	ft their (a)	M1 A1ft
	$TB \approx 1.1$ (m)	awrt 1.09	A1 (4)
(c)	$(\rightarrow)$ $15 = u_x \times t \Rightarrow t = \frac{15}{u_x} (= \frac{2\sqrt{3}}{5} \approx 0.693$ or $0.69)$		M1 A1
	either $(\downarrow)$ $v_y = 12.5 + 9.8t \ (\approx 19.2896)$		M1
	$V^2 = u_x^{\,2} + v_y^{\,2} \ (\approx 840.840)$		
	$V \approx 29 \ (\text{ms}^{-1})$, 29.0		M1 A1 (5)
			(14 marks)

Q7.

(a)	Using $s = ut + \frac{1}{2}at^2$ Method must be clear $\mathbf{r} = (3t)\mathbf{i} + (10 + 5t - 4.9t^2)\mathbf{j}$ Answer given	M1 A1 A1 (3)
(b)	**j** component $= 0$: $10 + 5t - 4.9t^2$ quadratic formula: $t = \frac{5 \pm \sqrt{25 + 196}}{9.8} = \frac{5 \pm \sqrt{221}}{9.8}$ $T = 2.03$(s), 2.0 (s) positive solution only.	M1 DM1 A1 (3)
(c)	Differentiating the position vector (or working from first principles) $\mathbf{v} = 3\mathbf{i} + (5 - 9.8t)\mathbf{j}$ (ms^{-1})	M1 A1 (2)
(d)	At B the **j** component of the velocity is the negative of the **i** component: $5 - 9.8t = -3$, $8 = 9.8t$, $t = 0.82$	M1 A1 (2)
(e)	$\mathbf{v} = 3\mathbf{i} - 3\mathbf{j}$, speed $= \sqrt{3^2 + 3^2} = \sqrt{18} = 4.24\,(\text{m s}^{-1})$	M1A1 (2) **[12]**

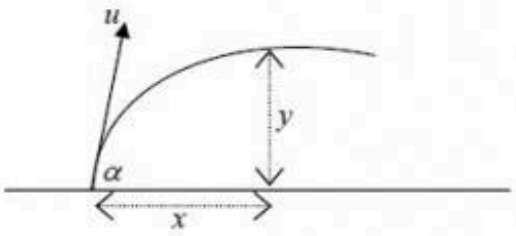
Q8.

Question Number	Scheme	Marks
	(a) $\rightarrow \quad 30 = 2ut$ $\uparrow \quad -47.5 = 5ut - 4.9t^2$ $-47.5 = 75 - 4.9t^2$ eliminating u or t $t^2 = \dfrac{75+47.5}{4.9} \left(= 25\right)$ $t = 5$ * cso	B1 M1 A1 DM1 DM1 A1 **(6)**
	(b) $30 = 2ut \Rightarrow 30 = 10u \Rightarrow u = 3$	M1 A1 **(2)**
	(c) $\uparrow \quad \dot{y} = 5u - 9.8t = -34$ M1 requires both $\rightarrow \quad \dot{x} = 2u = 6$ $\dot{x}$ and $\dot{y}$ $v^2 = 6^2 + (-34)^2$ $v \approx 34.5 \ \left(\text{ms}^{-1}\right)$ accept 35	M1 A1 A1 DM1 A1 **(5)**
		[13]
	Alternative to (c) $\frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2 = m \times g \times 47.5$ with $v_A^2 = 6^2 + 15^2 = 261$ $v_B^2 = 261 + 2 \times 9.8 \times 47.5 \ \left(= 1192\right)$ $v_B \approx 34.5 \ \left(\text{ms}^{-1}\right)$ accept 35 BEWARE : Watch out for incorrect use of $v^2 = u^2 + 2as$	M1 A(2,1,0) DM1 A1 **(5)**

Q9.

Question Number	Scheme	Marks
(a)	$\rightarrow \quad x = u\cos\alpha t = 10$	M1A1
	$\uparrow \quad y = u\sin\alpha t - \frac{1}{2}gt^2 = 2$	M1A1
	$\Rightarrow t = \frac{10}{u\cos\alpha}$	
	$2 = u\sin\alpha \times \frac{10}{u\cos\alpha} - \frac{g}{2} \times \frac{100}{u^2\cos^2\alpha}$	M1
	$= 10\tan\alpha - \frac{50g}{u^2\cos^2\alpha}$ (given answer)	A1 (6)
(b)	$2 = 10 \times 1 - \frac{100g \times 2}{2u^2 \times 1}$	M1A1
	$u^2 = \frac{100g}{8}, \; u = \sqrt{\frac{100g}{8}} = 11.1 \text{ (m s}^{-1}\text{)}$	A1
	$\frac{1}{2}mu^2 = m \times 9.8 \times 2 + \frac{1}{2}mv^2$	M1A1
	$v = 9.1ms^{-1}$	A1 (6)
		[12]

Q10.

Question Number	Scheme	Marks
(a)		
	Horiz: $x = u\cos\alpha t$	B1
	Vert: $y = u\sin\alpha t - \frac{1}{2}gt^2$	M1
	$y = u\sin\alpha \times \frac{x}{u\cos\alpha} - \frac{1}{2}g \times \frac{x^2}{u^2\cos^2\alpha}$	DM1
	$y = x\tan\alpha - \frac{gx^2}{2u^2\cos^2\alpha}$ **	A1
		(4)
(b)	$y = -7$: $-7 = \tan 45x - \frac{gx^2}{2\times 7^2\cos^2 45}$	M1 A1
	$-7 = x - \frac{9.8x^2}{7^2}$	
	$-7 = x - \frac{x^2}{5}$	M1
	$x^2 - 5x - 35 = 0$	
	$x = \frac{5 \pm \sqrt{25 + 4\times 35}}{2}$	M1
	$x = 8.92$ or 8.9	A1
		(5)
(c)	Time to travel 8.922 m horizontally $= \frac{8.922}{7\cos 45} = 1.802..$s	M1
	$v = \frac{8.922}{1.402}$	M1 A1 ft
	$= 6.36$ or 6.4 $\left(\text{m s}^{-1}\right)$	A1
		(4)
		13

Q11.

Question Number	Scheme	Marks
(a)	$\mathbf{i} \rightarrow$ distance $= 6t$	B1
	$\mathbf{j} \uparrow$ distance $= 12t - \frac{1}{2}gt^2$	M1 A1
	At B, $2\left(12t - \frac{1}{2}gt^2\right) = 6t$	M1 A1
	$(24-6)t = gt^2$	DM1
	$18 = gt$, $t = \frac{18}{g} (= 1.84\text{s})$	A1
		(7)
(b)	$\mathbf{i} \rightarrow$ speed $= 6$	B1
	$\mathbf{j} \uparrow$ velocity $= 12 - gt = -6$	M1 A1
	$\therefore$ speed at A $= \sqrt{6^2 + 6^2} = \sqrt{72} = 6\sqrt{2} (= 8.49) (\text{ms}^{-1})$	M1 A1
		(5)
(c)	$\uparrow$ speed $= 12 - gt = +6$	M1 A1 ft
	$t = \frac{6}{g} (= 0.61\text{s})$	A1
		(3)
		15

Q12.

Q.	Scheme	Marks	Notes
a			
	$30\cos 60\times 2+q\cos\theta\times 2=40$	M1	Equation for horizontal distance Need to be using the 40 m
		A1	Correct unsimplified
	$30\sin 60\times 2-4.9\times 4=q\sin\theta\times 2-4.9\times 4$ $30\sin 60=q\sin\theta$	M1	Equal vertical distance or initial vertical components of velocity
		A1	Correct unsimplified (no error seen)
	$q\cos\theta=\pm 5$ $q\sin\theta=15\sqrt{3}$		
	$\tan\theta=3\sqrt{3}$ $(\tan\theta=6\sin 60)$	DM1	Solve for q or θ Dependent on both preceding M marks
	$\theta=79.1\ \ (79)$		(1.38 radians) or better
	$q=26.45...=26.5$	A1	(26 or better) $(10\sqrt{7})$ Both correct and no error seen
		(6)	
b	Vertical component of speed =	M1	Must be working towards speed of P (or v^2) (condone if working on Q - they equal vertical components of velocity)
	$30\sin 60-2g\ (=6.38...)$	A1	Correct unsimplified. Accept ±
	speed $=\sqrt{(30\cos 60)^2+6.38^2}$	DM1	Use Pythagoras. Dependent on previous M Follow their vertical component.
		A1ft	Correct unsimplified equation in v or v^2.
	$=\sqrt{15^2+6.38^2}=16.3\,(\text{m s}^{-1})$	A1	or 16 2 or 3 sf only
		(5)	
b alt	Vertical distance =	M1	Must be working towards speed of P
	$30\sin 60\times 2-4.9\times 4=32.36$	A1	Correct unsimplified
	Conservation of energy:	DM1	Dependent on previous M. Follow their vertical distance.
	$\frac{1}{2}mv^2+mg\times 32.36=\frac{1}{2}m\times 900$	A1ft	Correct unsimplified equation in v or v^2.
	$v=16.3\ (\text{m s}^{-1})\ \ (16)$	A1	
		(5)	
		[11]	

Q13.

Question	Scheme	Marks	AOs
(a)	Using horizontal motion	M1	3.3
	$U\cos 45° t = 100$	A1	1.1b
	Using vertical motion	M1	3.4
	$U\sin 45° t - \frac{1}{2}gt^2 = -25$	A1	1.1b
	Solve problem by eliminating t and solving for U	M1	3.1b
	$U = 28$*	A1*	1.1b
		(6)	
(b)	Using vertical motion	M1	3.4
	$0^2 = (28\sin 45°)^2 - 2gh$	A1	1.1b
	Greatest height = 45 m	A1	1.1b
		(3)	
(c)	New value > 28	B1	3.5a
		(1)	
(d)	e.g. wind effects, more accurate value of g, spin of ball, include size of the ball, not model as a particle, shape of ball	B1	3.5c
		(1)	
			(11 marks)

Notes:		
a	M1	Complete method to give equation in U and t only, condone sin/cos confusion and sign errors
	A1	Correct equation
	M1	Complete method to give equation in U and t only, condone sin/cos confusion and sign errors
	A1	Correct equation (g does not need to be substituted)
	M1	Must have earned the previous two M marks. Eliminate t and solve for U. **N.B.** They may solve for t first $(100-\frac{1}{2}gt^2=-25)$ and then use it to find U.
	A1*	Exact given answer correctly obtained with no wrong working (e.g. $g = 9.81$ used) or approximation seen.
b	M1	Complete method to give equation in h only (allow if U not substituted), condone sin/cos confusion and sign errors
	A1	Correct equation (g does not need to be substituted) (A0 if U is used instead of 28)
	A1	cao
c	B1	Clear statement
d	B1	Penalise incorrect extras i.e. B0 if there are incorrect extras. The ground being horizontal, the cliff being vertical, .. are not part of the model so B0 Include weight/mass of the ball B0