1		mark		Sub
(i)	$x = 14\cos 60t$ so $x = 7t$ $y = 14\sin 60t - 4.9t^2 + 1$ $y = 7\sqrt{3}t - 4.9t^2 + 1$ ($y = 12.124...t - 4.9t^2 + 1$)	M1 A1 M1 A1 A1	Consider motion in *x* direction. Need not resolve. Allow $\sin \leftrightarrow \cos$. Condone +1 seen. Need not be simplified. Suitable *uvast* used for *y* with *g* $= \pm 9.8, \pm 10, \pm 9.81$ soi Need not resolve. Allow $\sin \leftrightarrow \cos$. Allow + 1omitted. Any form and 2 s. f. Need not be simplified All correct. +1 need not be justified. Accept any form and 2 s. f. Need not be simplified.	5
(ii) (A)	time taken to reach highest point $0 = 7\sqrt{3} - 9.8T$ so $\frac{5\sqrt{3}}{7}$ s (1.23717…. = 1.24 s (3 s. f.))	 M1 A1	 Appropriate *uvast* . Accept u = 14 and $\sin \leftrightarrow \cos$ and $u \leftrightarrow v$. Require v = 0 or equivalent. $g = \pm 9.8, \pm 10, \pm 9.81$ soi. ca [If time of flight attempted, do not award M1 if twice interval obtained]	2
(B)	distance from base is $7 \times \frac{5\sqrt{3}}{7} = 5\sqrt{3}$ m (= 8.66025… so 8.66 m (3 s. f.))	M1 B1	Use of **their** $x = 7t$ with **their** T FT **their** T only in $x = 7t$. Accept values rounding to 8.6 and 8.7.	2
(C)	**either** Height at this time is $H = 7\sqrt{3} \times \frac{5\sqrt{3}}{7} - 4.9 \times \left(\frac{5\sqrt{3}}{7}\right)^2 + 1$ = 8.5	 M1 A1 A1	 Subst in **their quadratic** *y* with **their** *T*. Correct subst of **their** *T* in **their** *y* which has attempts at all 3 terms. Do not accept u = 14.	

	clearance is $8.5-6=2.5$ m **or** for height above pt of projection $0=\left(7\sqrt{3}\right)^2+2\times-9.8\times s$ s = 7.5 so clearance is $7.5-5=2.5$ m	E1 M1 A1 A1 E1	Clearly shown. Appropriate *uvast* . Accept u = 14. g $=\pm9.8,\pm10,\pm9.81$ soi Attempt at vert cpt accept $\sin\leftrightarrow\cos$ .Accept sign errors but not u = 14. Clearly shown.	4
(iii)	See over			

(iii)	Elim t between $y=7\sqrt{3}$ ^{2} $t-4.9t$ $+1$ and x = $7t$ so $y=7\sqrt{3}\frac{x}{7}-4.9\left(\frac{x}{7}\right)^2+1$ so $y=\sqrt{3}x$ ^{2} $-0.1x$ $+1$	M1 F1	**their** quadratic y (accept bracket errors) Must see **their** $t = x/7$ fully substituted in Accept any form correctly written. FT **their** x and 3 term quadratic y (neither using u = 14)	2
(iv)	**either** need $6=7\sqrt{3}t-4.9t^2+1$ so $4.9t^2-7\sqrt{3}t+5=0$ $t=\frac{5\left(\sqrt{3}\pm1\right)}{7}$ (0.52289…. or 1.95146…) moves by $\left(\frac{5(\sqrt{3}+1)}{7}-\frac{5\sqrt{3}}{7}\right)\times7$ [(1.95146.. – 1.23717…)×7] = 5 m **or** using equation of trajectory with y = 6	M1 M1 A1 M1 A1	**their** quadratic y from (i) = 6, or equivalent. Dep. Attempt to solve this 3 term quadratic. (Allow u = 14). for either root Moves by |**their** root - **their** (ii)(A)|×7 or equivalent. Award this for recognition of correct dist (no calc) cao [If new distance to wall found must have larger of 2 +ve roots for 3rd M and award max 4/5 for 13.66]	

	$6 = \sqrt{3}x - 0.1x^2 + 1$	M1	Equating **their** quadratic trajectory equn to 6	
	Solving $x^2 - 10\sqrt{3}x + 50 = 0$	M1	Dep. Attempt to solve this 3 term quadratic. (Allow $u = 14$).	
	$x = 5\left(\sqrt{3} \pm 1\right)$ (13.660… or 3.6602….)	A1	for either root	
	distance is $5\left(\sqrt{3}+1\right) - 5\sqrt{3}$	M1	distance is $\lvert$**their** root $-$ **their**(ii)(B)$\rvert$	
			Award this for recognition of correct dist (no calc)	
	= 5 m	A1	Cao [If new distance to wall found must have larger of 2 + ve roots for 3rd M and award max 4/5 for 13.66]	
				5
				20

2		mark		
(i)	Height reached by first particle is given by $0 = 21^2 - 2\times 9.8\times s$ so s = 22.5 so 22.5 m	 M1 A1	 Other methods must be complete. Allow $g = \pm 9.8, \pm 10$ Accept with consistent signs	2
(ii)	**Sol (1)** t seconds after second particle projected its height is $15t - 4.9t^2$ and the first particle has height $22.5 - 4.9t^2$ (or $21t - 4.9t^2$) **either** Sub t = 1.5 to show both have same value State height as 11.475 m **or** $15t - 4.9t^2 = 22.5 - 4.9t^2$ giving t = 1.5 and height as 11.475 m	M1 A1 M1 A1 E1 A1 M1 A1	Allow $g = \pm 9.8, \pm 10$ Allow $g = \pm 9.8, \pm 10$ Award only if used correctly (or sub t = 3.64 into $21t - 4.9t^2$ for 1st & t = 1.5 for 2nd) cao. Accept any reasonable accuracy. Don't award if only one correctly used equation obtained. Both. t shown. Ht cao (to any reasonable accuracy)	
	Sol (2) t seconds after second particle projected its height is $15t - 4.9t^2$ and the first particle has fallen $4.9t^2$ Collide when $15T - 4.9T^2 + 4.9T^2 = 22.5$ so $T = 1.5$ H = $22.5 - 4.9\times 1.5^2 = 11.475$ m	M1 A1 B1 M1 E1 A1	Allow $g = \pm 9.8, \pm 10$ Or other correct method cao. Accept any reasonable accuracy. Don't award if only one correctly used equation obtained.	6
	total	8		

3		mark		
(i)	Horiz $(40\cos 50)t$	B1		
	Vert $(40\sin 50)t - 4.9t^2$	M1	Use of $s = ut + 0.5at^2$ with $a = \pm 9.8$ or ± 10. Allow u = 40. Condone s ↔ c.	
		A1	Any form	3
(ii)	Need $(40\sin 50)t - 4.9t^2 = 0$	M1	Equating **their** y to zero. Allow quadratic y only	
	so $t = \dfrac{40\sin 50}{4.9}$	M1	Dep on 1st M1. Attempt to solve.	
	= 6.2534… so 6.253 s (3 d. p.)	E1	Clearly shown [**or** M1 (allow u = 40 and s ↔ c) A1 time to greatest height; E1]	
	Range is $(40\cos 50)\times 6.2534...$	M1	Use of **their** horiz expression	
	= 160.78… so 161 m (3 s. f.)	A1	Any reasonable accuracy	5
(iii)	Time AB is given by $(40\cos 50)T = 30$ so T = 1.16679… so 1.17 s	M1 A1	Equating **their** linear x to 30.	
	then **either** By symmetry, time AC is time AD – time AB	M1	Symmetry need not be explicit. Method may be implied. Any valid method using symmetry.	
	so time AC is 6.2534… $-\dfrac{30}{40\cos 50}$ = 5.086…. so 5.09 s (3 s. f.)	A1	cao	
	or height is $(40\sin 50)T - 4.9T^2$ and we need $(40\sin 50)t - 4.9t^2 = (40\sin 50)T - 4.9T^2$ solved for larger root	M1	Complete method to find time to second occasion at that height	
	i.e. solve $4.9t^2 - (40\sin 50)t + 29.08712... = 0$ for larger root giving 5.086…	A1	cao	4
(iv)	$\dot{x} = 40\cos 50$	B1	Must be part of a method using velocities.	
	$\dot{y} = 40\sin 50 - 9.8\times 5.086...$	M1	Use of vert cpt of vel Allow only sign error.	
		A1	FT use of **their** 5.086..	
	Need $\arctan\dfrac{\dot{y}}{\dot{x}}$	M1	May be implied. Accept $\arctan\dfrac{\dot{x}}{\dot{y}}$ but not use of $\dot{y}_0$.	
	So –36.761…° so 36.8° below horizontal (3 s f.)	A1	Accept ±36.8 or equivalent. Condone direction not clear.	5
	total	17		