1		mark	comment	sub
(i)	$40\times0.6t-5t^2$ = $24t-5t^2$	M1 A1	Use of $s=ut+0.5at^2$ with $a=\pm9.8,\ \pm10$. Accept 40 or 40×0.8 for '*u*'. Any form	2
(ii)	**either** Need zero vertical distance so $24t-5t^2=0$ so *t* = 0 or *t* = 4.8 **or** Time to highest point, *T* 0 = 40 × 0.6 – 10*T* so *T* = 2.4 and time of flight is 4.8 range is $40\times0.8\times4.8$ = 153.6 so 154 m (3 s. f.)	**M1** A1 M1 A1 M1 A1	quate **their** *y* to zero. With fresh start must have correct *y*. Accept no reference to *t* = 0 and the other root in any form. FT **their** *y* if gives *t* > 0 Allow use of *u* = 40 and 40 × 0.8. Award even if half range found. May be awarded for doubling half range later. Horiz cpt. Accept 0.6 instead of 0.8 only if consistent with expression in (i). FT **their** *t*. cao [NB Use of half range or half time to get 76.8… (g = 10) or 78.36… (g = 9.8) scores 2] [If range formula used: M1 sensible attempt at substitution; allow $\sin2\alpha$ wrong B1 $\sin2\alpha$ correct A1 all correct A1 cao]	4
		6		

2				
(i)	$y = 25\sin\theta t + 0.5\times(-9.8)t^2$	M1	Use of $s = ut + \frac{1}{2}at^2$ .Accept sin, cos, 0.96, 0.28, ± 9.8, ± 10 , u = 25 and derivation of -4.9 not clear.	
	$= 7t - 4.9t^2$	E1	Shown including deriv of – 4.9. Accept $25\sin\theta t = 7t$ WW	
	$x = 25\cos\theta t = 25\times 0.96t = 24t$	B1	Accept $25\times 0.96t$ or $25\cos\theta t$ seen WW	3
(ii)	$0 = 7^2 - 19.6s$	M1	Accept sequence of *uvast*. Accept u=24 but not 25. Allow $u \leftrightarrow v$ and ± 9.8 and ± 10	
	s = 2.5 so 2.5 m	A1	+ve answer obtained by correct manipulation.	2
(iii)	Need $7t - 4.9t^2 = 1.25$	M1	Equate y to **their** (ii)/2 or equivalent.	
	so $4.9t^2 - 7t + 1.25 = 0$	M1	Correct sub into quad formula of their 3 term quadratic being solved (i.e. allow manipulation errors before using the formula).	
	t = 0.209209…. and 1.219361…	A1	Both. cao. [Award M1 A1 for two correct roots WW]	
	need $24\times$ (1.219… - 0.209209…) = $24\times 1.01...$ so 24.2 m (3 s.f.)	B1	FT **their** roots (only if both positive)	4
(iv) (A)	$\dot{y} = 7 - 9.8t$	M1	Attempt at $\dot{y}$. Accept sign errors and u = 24 but not 25	
	$\dot{y}(1.25) = 7 - 9.8\times 1.25 = -5.25$ m s^{-1}	A1		
(B)	Falling as velocity is negative	E1	Reason must be clear. FT **their** $\dot{y}$ even if not a velocity Could use an argument involving time.	
(C)	Speed is $\sqrt{24^2 + (-5.25)^2}$	M1	Use of Pythag and 24 or 7 with **their** $\dot{y}$	
	= 24.5675… so 24.6 m s^{-1} (3 s. f.)	A1	cao	5

(v)	$y = 7t - 4.9t^2,\ x = 24t$	M1	Elimination of t	
	so $y = \frac{7x}{24} - 4.9\left(\frac{x}{24}\right)^2$	A1	Elimination correct. Condone wrong notation with interpretation correct for the problem.	
	$y = \frac{7x}{24} - 4.9 \times \frac{x^2}{576} = \frac{0.7x}{576}(240 - 7x)$	E1	If not wrong accept as long as $24^2 = 576$ seen. Condone wrong notation with interpretation correct for the problem.	
	either Need $y = 0$	M1		
	so $x = 0$ or $\frac{240}{7}$ so $\frac{240}{7}$ m	A1	Accept $x = 0$ not mentioned. Condone $0 \le X \le \frac{240}{7}$.	
	or	B1	Time of flight $\frac{10}{7}$ s	
		B1	Range $\frac{240}{7}$ m. Condone $0 \le X \le \frac{240}{7}$.	5
				19

3		mark		Sub
	$0 = u - 9.8\times 3$ u = 29.4 so 29.4 m s^{-1}	M1 A1	*uvast* leading to u with t = 3 or t = 6 gns consistent	
	$s = 0.5\times 9.8\times 9 = 44.1$ so 44.1 m	M1 F1	*uvast* leading to s with t = 3 or t = 6 or **their** u FT **their** u if used with t = 3. Signs consistent. Award for 44.1, 132.3 or 176.4 seen. [Award maximum of 3 if one answer wrong]	
				4
				4

4		mark		Sub
(i)	$0^2 = V^2 - 2\times 9.8\times 22.5$ V = 21 so 21 m s^{-1}	M1 E1	Use of appropriate *uvast*. Give for correct expression Clearly shown. Do not allow $v^2 = 0 + 2gs$ without explanation. Accept using V = 21 to show s = 22.5.	
				2
(ii)	$28\sin\theta = 21$ so $\theta = 48.59037...$	M1 A1	Attempt to find angle of projection. Allow $\sin \leftrightarrow \cos$.	
				2
(iii)	Time to highest point is $\frac{21}{9.8} = \frac{15}{7}$	B1	Or equivalent (time of whole flight)	
	Distance is $2\times\frac{15}{7}\times 28\times\cos(\textbf{their}\,\theta)$..	M1	Valid method for horizontal distance. Accept ½ time. Do not accept 28 used for horizontal speed or vertical speed when calculating time.	
		B1	Horizontal speed correct	
	79.3725… so 79.4 m (3 s. f.)	A1	cao. Accept answers rounding to 79 or 80. [If angle with vertical found in (ii) allow up to full marks in (iii). If $\sin \leftrightarrow \cos$ allow up to B1 B1 M0 A1] [If $u^2 \sin 2\theta / g$ used then M1* Correct formula used. FT their angle. M1 Dep on *. Correct subst. FT their angle. A2 cao]	
				4
				8

5		mark		Sub
(i)	$u = \sqrt{10^2 + 12^2} = 15.62..$ $\theta = \arctan\left(\frac{12}{10}\right) = 50.1944...$ so 50.2 (3s f.)	B1 M1 A1	Accept any accuracy 2 s. f. or better Accept $\arctan\left(\frac{10}{12}\right)$ (Or **their** $15.62\cos\theta = 10$ or **their** $15.62\sin\theta = 12$) [FT **their** 15.62 if used] [If θ found first M1 A1 for θ F1 for u] [If B0 M0 SC1 for both $u\cos\theta = 10$ and $u\sin\theta = 12$ seen]	3
(ii)	vert $12t - 0.5\times10t^2 + 9$ $= 12t - 5t^2 + 9$ (AG) horiz $10t$	M1 A1 E1 B1	Use of $s = ut + 0.5at^2$, $a = \pm9.8$ or ±10 and $u = 12$ or 15.62.. Condone $-9 = 12t - 0.5\times10t^2$, condone $y = 9 + 12t - 0.5\times10t^2$. Condone g. All correct with origin of $u = 12$ clear; accept 9 omitted Reason for 9 given. Must be clear unless $y = s_0 + ...$ used.	4
(iii)	$0 = 12^2 - 20s$ $s = 7.2$ so 7.2 m	M1 A1	Use of $v^2 = u^2 + 2as$ or equiv with $u = 12$, $v = 0$. Condone $u \leftrightarrow v$ From CWO. Accept 16.2.	2
(iv)	We require $0 = 12t - 5t^2 + 9$ Solve for t the + ve root is 3 range is 30 m	M1 M1 A1 F1	Use of y equated to 0 Attempt to solve a 3 term quadratic Accept no reference to other root. cao. FT root and **their** x. [If range split up M1 all parts considered; M1 valid method for each part; A1 final phase correct; A1]	4
(v)	Horiz displacement of B: $20\cos 60t = 10t$ Comparison with Horiz displacement of A	B1 E1	Condone unsimplified expression. Award for $20\cos60 = 10$ Comparison clear, must show $10t$ for each or explain.	2
(vi)	vertical height is $20\sin 60t - 0.5\times10t^2 = 10\sqrt{3}t - 5t^2$ (AG)	A1	Clearly shown. Accept decimal equivalence for $10\sqrt{3}$ (at least 3 s. f.). Accept $-5t^2$ and $20\sin60 = 10\sqrt{3}$ not explained.	1
(vii)	Need $10\sqrt{3}t - 5t^2 = 12t - 5t^2 + 9$ $\Rightarrow t = \frac{9}{10\sqrt{3} - 12}$ $t = 1.6915\ldots$ so 1.7 s (2 s. f.) (AG)	M1 A1 E1	Equating the **given** expressions Expression for t obtained in any form Clearly shown. Accept 3 s. f. or better as evidence. Award M1 A1 E0 for 1.7 sub in each ht	3
	total	19		

6	**(i)**		Vertical motion: $s = ut + \frac{1}{2}at^2$ At water: $-1.225 = 0 \times t + \frac{1}{2} \times (-9.8) \times t^2$ $\Rightarrow t = 0.5$ s	 M1 A1 **[2]**	 Condone sign errors Signs must be consistent
	(ii)		Horizontal component of velocity = 20 m s^{-1} Vertical component = $0.5 \times 9.8 = 4.9$ m s^{-1} Speed $= \sqrt{20^2 + 4.9^2} = 20.6$ $\tan\alpha = \frac{4.9}{20}$ $\alpha = 13.8°$	B1 B1 M1 M1 A1 **[5]**	 Follow through for "their t x 9.8" Use of Pythagoras on previous two answers Use of an appropriate trig ratio with their figures for **v**. Must be explicit if final answer is incorrect. Cao

7	(i)	*A*) (*B*)	Height 5 m g has been taken to be 10 m s^{-2}	B1 B1 **[2]**	No units required; apply ISW if incorrect units given Allow +10 or –10. No units required; apply ISW if incorrect units given	
	(ii)		Displacement is $\begin{pmatrix}150\\80\end{pmatrix}-\begin{pmatrix}90\\80\end{pmatrix}$ $=\begin{pmatrix}60\\0\end{pmatrix}$	M1 A1 **[2]**	Displacement must be given as a vector. Allow a description of a vector in words. Attempts at substitution for t and subtraction of vectors must be seen Cao If the candidate then goes on to give a non-vector answer of "60 m", apply ISW.	
	(iii)		$x = 30t$ $y = 5 + 40t - 5t^2$ $y = 5 + 40\times\left(\frac{x}{30}\right) - 5\times\left(\frac{x}{30}\right)^2$ $y = 5 + \frac{4}{3}x - \frac{x^2}{180}$	B1 B1 M1 A1 **[4]**	 Attempt to eliminate t N errors	