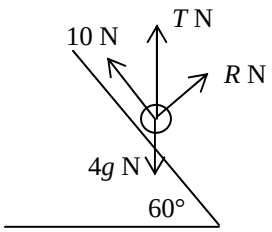
Q 1		**mark**		**Sub**
(i)	Acceleration is 8 m s^{-2} speed is $0+0.5\times4\times8=16$ m s^{-1}	B1 B1		2
(ii)	$a = 2t$	B1		1
(iii)	$t = 7$ $a > 0$ for $t < 7$ and $a < 0$ for $t > 7$	B1 E1	Full reason required	2
(iv)	Area under graph $0.5\times2\times8-0.5\times1\times4=6$ so 6 m s^{-1} Increase	M1 B1 E1	Both areas under graph attempted. Accept both positive areas. If 2×3 seen accept ONLY IF reference to average accn has been made. Award for $v=-2t^2+28t+c$ seen or 24 and 30 seen Award if 6 seen. Accept '24 to 30'. This must be clear. Mark dept. on award of M1	3
	total	8		

Q 2		**mark**		**Sub**
(i)	$a = 24-12t$	M1 A1	Differentiate cao	2
(ii)	Need $24t-6t^2=0$ $t = 0, 4$	M1 A1	Equate $v = 0$ and attempt to factorise (or solve). Award for one root found. Both. cao.	2
(iii)	$s=\int_0^4\left(24t-6t^2\right)\,\mathrm{d}t$ $=\left[12t^2-2t^3\right]_0^4$ $(12\times16-2\times64)-0$ = 64 m	M1 A1 M1 A1	Attempt to integrate. No limits required. Either term correct. No limits required Sub $t = 4$ in integral. Accept no bottom limit substituted or arb const assumed 0. Accept reversed limits. FT **their** limits. cao. Award if seen. [If trapezium rule used. M1 At least 4 strips: M1 enough strips for 3 s. f. A1 (dep on 2nd M1) One strip area correct: A1 cao]	4
	total	8		

Q 3		**mark**		**Sub**
(i)	$\mathbf{R} + \begin{pmatrix}-3\\4\end{pmatrix} + \begin{pmatrix}21\\-7\end{pmatrix} = \begin{pmatrix}0\\0\end{pmatrix}$	M1	Sum to zero	
	$\mathbf{R} = \begin{pmatrix}-18\\3\end{pmatrix}$	A1	Award if seen here or in (ii) or used in (ii). [SC1for $\begin{pmatrix}18\\-3\end{pmatrix}$]	2
(ii)	$\lvert\ \mathbf{R}\ \rvert = \sqrt{18^2+3^2}$	M1	Use of Pythagoras	
	= 18.248… so 18.2 N (3 s. f.)	A1	Any reasonable accuracy. FT **R** (with 2 non-zero cpts)	
	angle is $180 - \arctan\left(\frac{3}{18}\right) = 170.53…°$	M1	Allow $\arctan\left(\frac{\pm 3}{\pm 18}\right)$ or $\arctan\left(\frac{\pm 18}{\pm 3}\right)$	
	so 171° (3 s. f.)	A1	Any reasonable accuracy. FT **R** provided their angle is obtuse but not 180°	4
	total	6		

Q 4		**mark**		**Sub**
(i)		B1	All forces present. No extras. Accept *mg*, *w* etc. All labelled with arrows. Accept resolved parts only if clearly additional. Accept no angles	1
(ii)	Resolve parallel to the plane $10 + T\cos 30 = 4g\cos 30$	M1	All terms present. Must be resolution in at least 1 term. Accept $\sin \leftrightarrow \cos$. If resolution in another direction there must be an equation only in *T* with no forces omitted. No extra forces.	
		A1	All correct	
	T = 27.65299… so 27.7 N (3 s. f.)	A1	Any reasonable accuracy	3
(iii)	Resolve perpendicular to the plane $R + 0.5\,T = 2g$	M1	At least one resolution correct . Accept resolution horiz or vert if at least 1 resolution correct. All forces present. No extra forces.	
		A1	Correct. FT *T* if evaluated.	
	R = 5.7735… so 5.77 N (3 s. f.)	A1	Any reasonable accuracy. cao.	3
	total	7		

Q 5		mark		Sub
(i)	$x = 2 \Rightarrow t = 4$ $t = 4 \Rightarrow y = 16 - 1 = 15$	B1 F1	cao FT **their** t and y. Accept 15 **j**	2
(ii)	$x = \frac{1}{2}t$ and $y = t^2 - 1$ Eliminating t gives $y = \left((2x)^2 - 1\right) = 4x^2 - 1$	M1 E1	Attempt at elimination of expressions for x and y in terms of t Accept seeing $(2x)^2 - 1 = 4x^2 - 1$	2
(iii)	**either** We require $\frac{dy}{dx} = 1$ so $8x = 1$ $x = \frac{1}{8}$ and the point is $\left(\frac{1}{8}, -\frac{15}{16}\right)$ **or** Differentiate to find **v** equate **i** and **j** cpts so $t = \frac{1}{4}$ and the point is $\left(\frac{1}{8}, -\frac{15}{16}\right)$	 M1 B1 A1 M1 M1 A1	 This may be implied Differentiating correctly to obtain $8x$ Equating the **i** and **j** cpts of **their v**	3
	total	7		

Q 6		mark		Sub
(i)	$2000 = 1000a$ so $a = 2$ so 2 m s^{-2}	B1		
		M1	Use of appropriate *uvast* for t	
	$12.5 = 5 + 2t$ so $t = 3.75$ so 3.75 s	A1	cao	3
(ii)	$2000 - R = 1000 \times 1.4$	M1	N2L. Accept $F = mga$. Accept sign errors. Both forces present. Must use $a = 1.4$	
	$R = 600$ so 600 N (AG)	E1		2
(iii)	$2000 - 600 - S = 1800 \times 0.7$	M1	N2L overall or 2 paired equations. $F = ma$ and use 0.7. Mass must be correct. Allow sign errors and 600 omitted.	
		A1	All correct	
	$S = 140$ so 140 N (AG)	E1	Clearly shown	3
(iv)	$T - 140 = 800 \times 0.7$	M1	N2L on trailer (or car). $F = 800a$ (or $1000a$). Condone missing resistance otherwise all forces present. Condone sign errors.	
		B1	Use of 140 (or 2000 – 600) and 0.7	
	$T = 700$ so 700 N	A1		3
(v)	N2L in direction of motion car and trailer			
	$-600 - 140 - 610 = 1800a$	M1	Use of $F = 1800a$ to find new accn. Condone 2000 included but not T. Allow missing forces.	
		A1	All forces present; no extra ones Allow sign errors.	
	$a = -0.75$	A1	Accept $\pm$. cao.	
	For trailer $T - 140 = -0.75 \times 800$	M1	N2Lwith their a ($\neq 0.7$) on trailer or car. Must have correct mass and forces. Accept sign errors	
	so $T = -460$ so 460	A1	cao. Accept ± 460	
	thrust	F1	Dep on M1. Take tension as +ve unless clear other convention	6
	total	17		

Q 7		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		

Section A

Q 1		mark		**Sub**
(i)	$\frac{-15}{6} = -2.5$ so -2.5 m s^{-2}	M1 A1	Use of $\Delta v / \Delta t$. Condone use of v/t. Must have - ve sign. Accept no units.	2
(ii)	$\frac{1}{2} \times 10 \times 4 = 20$ m	M1 A1	Attempt at area or equivalent	2
(iii)	Area under graph is $\frac{1}{2} \times 5 \times 5 = 12.5$ (and -ve) closest is $20 - 12.5 = 7.5$ m	M1 A1	May be implied. Area from 4 to 9 attempted. Condone missing –ve sign. Do not award if area beyond 9 is used (as well). cao	2
				6

Q 2		mark		**Sub**
(i)	Pulley is smooth (and the string is light)	E1	Only require pulley is smooth. Do not accept only 'string is light'.	1
(ii)	$4g$ = 39.2 N	B1	Accept either	1
(iii)	Let tension in each string be T $39.2 = 2T \cos 20$ T = 20.85788… so 20.9 N (3 s.f.)	M1 B1 F1	Equating 39.2 to attempt at tensions in **both** BC and BD. Tensions need not be equal. No extra forces. Must attempt resolution. Condone $\sin \leftrightarrow \cos$. For one occurrence of $T \cos 20$ in any equation. Accept reference to only one string. FT **their** $4g$ If Lami's Theorem used: M1 correct format B1 equation correct. FT **their** $4g$ F1 FT **their** $4g$ If Triangle of Forces used: M1 triangle with **their** $4g$ labelled **and** an	

			attempt to use this triangle. Ignore arrows. B1 for correct equation. FT **their** 4*g*. F1 FT **their** 4*g*.	3
				5

Q 3		**mark**		**Sub**
(i)	$\lvert\mathbf{F}\rvert = 12.5$ so 12.5 N bearing is $90 - \arctan\frac{12}{3.5}$ = (0)16.260… so (0)16.3° (3 s. f.)	B1 M1 A1	 Use of arctan with 3.5 and 12 or equiv May be obtained directly as $\arctan\frac{3.5}{12}$	3
(ii)	24/7 = 12/3.5 or …. **G** = 2**F** so $\lvert\mathbf{G}\rvert = 2\lvert\mathbf{F}\rvert$	E1 B1	Accept **statement** following **G** = 2**F** shown. Accept equivalent in words.	2
(iii)	$\frac{9+12}{3.5} = \frac{-18+q}{12}$ so $q = 6\times12+18 = 90$	M1 A1	Or equivalent or in scalar equations. Accept $\frac{21}{q-18}$ or $\frac{q-18}{21}$ = tan (i) or tan(90 - (i)) Accept 90**j**	2
				7

Q 4		**mark**		**Sub**
(i)	N2L in direction of motion $D - (100+300) = (900+700)\times1.5$ D = 2800 so 2800 N	M1 A1 A1	Apply N2L. Allow 1 resistance omitted and sign error but total mass must be used. Condone use of $F = mga$. No extra forces. All correct cao	3
(ii)	N2L on trailer $T - 300 = 700\times1.5$ T =1350 so 1350 N	M1 A1	Use either car or trailer. All forces present. No extras. Correct mass and a Allow sign error. Must use $F = ma$. cao	2
				5

Q 5		mark		Sub
(i)	$9\mathbf{i}$ m s^{-2}; $(9\mathbf{i} - 12\mathbf{j})$ m s^{-2}	B1	Award for either. Accept no units. (isw e.g. finding magnitudes)	1
(ii)	N2L $\mathbf{F} = 4(9\mathbf{i} - 12\mathbf{j}) = (36\mathbf{i} - 48\mathbf{j})$ N	B1	Accept factored form. isw. FT **a**(3). Accept 60 N or **their** $4\lvert\mathbf{a}\rvert$	1
(iii)	$\mathbf{v} = \int \begin{pmatrix} 9 \\ -4t \end{pmatrix} dt = \begin{pmatrix} 9t + C \\ -2t^2 + D \end{pmatrix}$ Using $\mathbf{v} = 4\mathbf{i} + 2\mathbf{j}$ when $t = 1$ $\begin{pmatrix} 4 \\ 2 \end{pmatrix} = \begin{pmatrix} 9 + C \\ -2 + D \end{pmatrix}$ $\Rightarrow C = -5, D = 4$ so $\mathbf{v} = (9t - 5)\mathbf{i} + (4 - 2t^2)\mathbf{j}$	M1 A1 M1 A1	Integration. At least one term correct. Neglect arbitrary constant(s) Sub at $t = 1$ to find arb const(s) Any form	4
				6

Q 6		mark		Sub
(i)	$14 = 2u + 0.5a \times 4$ $19 = u + 5a$ Solving gives $u = 4$ and $a = 3$	M1 A1 A1 M1 F1	Use of appropriate *uvast* for either equn Any form Any form Attempt at solution of 2 equns in 2 unknowns. At least one value found . Must have complete correct solution to **their** equns. .	5
(ii)	$19^2 = 4^2 + 2 \times 3 \times s$ or $s = 4 \times 5 + 0.5 \times 3 \times 25$ $s =$ 57.5 so 57.5 m	M1 A1	Use of appropriate *uvast* and **their** u, a & t = 5. cao [Accept 50 if $t = 7$ instead of $t = 5$ in (i) for 2/2]	2
				7

Section B

Q 7		mark		Sub
(i)	60 N	B1		1
(ii)	$60 + 70\cos 30 = 120.62...$ so 121 N (3 s. f.)	M1 A1	70 cos30 or 70 sin 30 used only with 60N. Accept sign errors. cao. Any reasonable accuracy	2
(iii)	resolve ↑ $R + 70\sin 30 - 50g = 0$ R = 455 so 455 N	M1 A1 A1	Resolve ↑ All forces present. No extras. Allow sign errors and $\sin \leftrightarrow \cos$. All correct. cao	3
(iv)	N2L → $160 - 125 = 50a$ a = 0.7 so 0.7 m s^{-2}	M1 A1	N2l. No extra forces. Accept 125 N omitted but not use of $F = mga$	2
(v)	N2L → $-125 = 50a$ $a = -2.5$ $0 = 1.5^2 + 2\times -2.5\times s$ s = 0.45 so 0.45 m	M1 A1 M1 A1	N2L to find new accn. Accept +125 but not $F = mga$. May be implied. Accept +2.5 Appropriate (sequence of) *uvast* using a new value for acceln. Allow use of ± **their new** a cao. Signs must be justified.	4
(vi)	N2L → $160 + Q\cos 30 - 115 = 50\times 3$ Q = 121.24… so 121 (3 s. f.)	M1 B1 A1 A1	Use of N2L with cpt of Q attempted. Accept 115 omitted or taken to be 125 and a wrong. Do not allow $F = mga$. Qcos30 seen in any equn. All correct cao	4
				16

Q 8		mark		Sub
(i)	$x = 14\cos 60t$	M1	Consider motion in x direction. Need not resolve. Allow $\sin \leftrightarrow \cos$. Condone +1 seen.	
	so $x = 7t$	A1	Need not be simplified.	
	$y = 14\sin 60t - 4.9t^2 + 1$	M1	Suitable *uvast* used for y with g $= \pm 9.8, \pm 10, \pm 9.81$ soi Need not resolve. Allow $\sin \leftrightarrow \cos$.	
	$y = 7\sqrt{3}t - 4.9t^2 + 1$ $(y = 12.124...t - 4.9t^2 + 1)$	A1 A1	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 $0 = 7\sqrt{3} - 9.8T$	M1	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.	
	so $\frac{5\sqrt{3}}{7}$ s (1.23717…. = 1.24 s (3 s. f.))	A1	cao [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 $H = 7\sqrt{3} \times \frac{5\sqrt{3}}{7} - 4.9 \times \left(\frac{5\sqrt{3}}{7}\right)^2 + 1$	M1	Subst in **their quadratic** y with **their** T.	
	= 8.5	A1 A1	Correct subst of **their** T in **their** y which has attempts at all 3 terms. Do not accept u = 14.	

	clearance is $8.5-6=2.5\,\text{m}$ **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 E1	Clearly shown. Appropriate *uvast* . Accept u = 14. $g = \pm 9.8, \pm 10, \pm 9.81$ soi Attempt at vert cpt accept $\sin \leftrightarrow \cos$ .Accept sign errors but not u = 14. Clearly shown.	4
(iii)	See over			

Q 8	**continued**	**mark**		**sub**
(iii)	Elim t between $y=7\sqrt{3}t-4.9t^2+1$ and $x = 7t$ so $y=7\sqrt{3}\frac{x}{7}-4.9\left(\frac{x}{7}\right)^2+1$ so $y=\sqrt{3}x-0.1x^2+1$	M1 F1	Must see **their** $t = x/7$ fully substituted in **their** quadratic y (accept bracket errors) 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 $\left(\frac{5(\sqrt{3}+1)}{7}-\frac{5\sqrt{3}}{7}\right)\times7$ $[(1.95146..-1.23717\ldots)\times7]$ = 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 $\lvert$**their** root - **their** (ii)(A)$\rvert\times7$ 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

Q 1

	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 Signs 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

Q 2

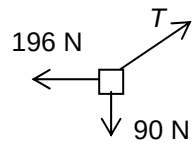
		mark		Sub
(i)	$\sqrt{(-6)^2+13^2} = 14.31782...$ so 14.3 N (3 s. f.)	M1 A1	Accept $\sqrt{-6^2+13^2}$	2
(ii)	Resultant is $\begin{pmatrix}-6\\13\end{pmatrix}-\begin{pmatrix}-3\\5\end{pmatrix}=\begin{pmatrix}-3\\8\end{pmatrix}$	B1	May not be explicit. If diagram used it must have correct orientation. Give if final angle correct.	
	Require 270 + arctan$\frac{8}{3}$	M1	Use of arctan$\left(\pm\frac{8}{3}\right)$ or arctan$\left(\pm\frac{3}{8}\right)$ (±20.6° or ±69.4°) or equivalent on **their** resultant	
	so 339.4439…° so 339°	A1	cao. Do not accept -21°.	3
(iii)	$\begin{pmatrix}-3\\5\end{pmatrix} = 5\mathbf{a}$	M1	Use of N2L with accn *used* in vector form	
	so (–0.6 **i** + **j**) m s^{-2}	A1	Any form. Units not required. isw.	
	change in velocity is (–6 **i** + 10 **j**) m s^{-1}	F1	10**a** seen. Units not required. Must be a vector. [SC1 for $a = \sqrt{3^2+5^2}/5 = 1.17$]	3
				8

Q 3		mark		Sub
(i)	$F = 14000 \times 0.25$	M1	Use of N2L . Allow $F = mga$ and wrong mass. No extra forces.	
	so 3500 N	A1		2
(ii)	$4000 - R = 3500$ so 500 N	B1	FT F from (i). Condone negative answer.	1
(iii)	$1150 - R_T = 4000 \times 0.25$	M1	N2L applied to truck (or engine) using all forces required. No extras. Correct mass. Do not allow use of $F = mga$. Allow sign errors.	
	so 150 N	A1	cao	2
(iv)	**either**			
	Component of weight down slope is	M1	Attempt to find cpt of *weight* (allow wrong mass). Accept $\sin \leftrightarrow \cos$. Accept use of $m \sin\theta$.	
	Extra driving force is cpt of mg down slope	M1	May be implied. Correct mass. No extra forces. Must have resolved weight component. Allow $\sin \leftrightarrow \cos$	
	$14000g \sin 3°$ $= 14000 \times 9.8 \times 0.0523359... = 7180.49...$ so 7180 N (3 s. f.)	A1		
	or			
		M1	Attempt to find cpt of *weight* (allow wrong mass). Accept $\sin \leftrightarrow \cos$. Accept use of $m \sin\theta$.	
	$D - 500 - 14000g \sin 3 = 14000 \times 0.25$	M1	N2L with all terms present with correct signs and mass. No extras. FT 500 N. Accept **their** 500 + 150 for resistance. Must have resolved weight component. Allow $\sin \leftrightarrow \cos$.	
	D = 11180.49… so extra is 7180 N (3 s. f.)	A1	Must be the extra force.	3
				8

Q 4		mark		Sub
(i)	**either**			
	Need **j** cpt 0 so $18t^2 - 1 = 0$	M1	Need not solve	
	$\Rightarrow t^2 = \frac{1}{18}$. Only one root as $t > 0$	E1	Must establish only one of the two roots is valid	
	or			
	Establish sign change in **j** cpt	B1		
	Establish only one root	B1		
				2
(ii)	$\mathbf{v} = 3\,\mathbf{i} + 36t\,\mathbf{j}$	M1	Differentiate. Allow **i** or **j** omitted	
		A1		
	Need **i** cpt 0 and this never happens	E1	Clear explanation. Accept '**i** cpt always there' or equiv	
				3
(iii)	$x = 3t$ and $y = 18t^2 - 1$	B1	Award for these two expressions seen.	
	Eliminate t to give			
	$y = 18\left(\frac{x}{3}\right)^2 - 1$	M1	t properly eliminated. Accept any form and brackets missing	
	so $y = 2x^2 - 1$	A1	cao	
				3
				8

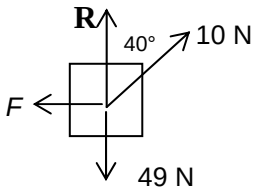
Q 5		mark		Sub
(i)	$0^2 = V^2 - 2 \times 9.8 \times 22.5$	M1	Use of appropriate *uvast*. Give for correct expression	
	$V = 21$ so 21 m s^{-1}	E1	Clearly shown. Do not allow $v^2 = 0 + 2gs$ without explanation. Accept using $V = 21$ to show $s = 22.5$.	
				2
(ii)	$28\sin\theta = 21$	M1	Attempt to find angle of projection. Allow $\sin \leftrightarrow \cos$.	
	so $\theta = 48.59037...$	A1		
				2
(iii)	Time to highest point is $\frac{21}{9.8} = \frac{15}{7}$	B1	Or equivalent (time of whole flight)	
	Distance is $2 \times \frac{15}{7} \times 28 \times \cos(\mathbf{their}\,\theta)$..	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

Q 6		mark		Sub
(i)	$0.5\times2\times12+0.5\times4\times12$ so 36 m	M1 A1	Attempt at sum of areas or equivalent. No extra areas.	2
(ii)	$8-\frac{36}{12}=5$ seconds	B1	cao	1
(iii)	-6 m s^{-2}	M1 B1	Attempt at accn for $0\le t\le2$ must be - ve or equivalent	2
(iv)	$58.5=12\times6+0.5\times a\times36$ so $a=-0.75$	M1 A1	Use of *uvast* with 12 and 58.5	2
(v)	$a=-10+\frac{9}{2}t-\frac{3}{8}t^2$ $a(1)=-10+\frac{9}{2}-\frac{3}{8}=-5.875$	M1 A1 A1	Differentiation cao	3
(vi)	$s=\int\left(12-10t+\frac{9}{4}t^2-\frac{1}{8}t^3\right)\mathrm{d}t$ $=12t-5t^2+\frac{3}{4}t^3-\frac{1}{32}t^4+C$ $s=0$ when $t=0$ so $C=0$ $s(8)=32$	M1 A1 A1 A1*	Attempt to integrate At least one term correct All correct. Accept + *C* omitted Clearly shown cao (award even if A1* is not given)	5
(vii)	**either** $s(2)=9.5$ and $s(4)=8$ Displacement is negative Car going backwards **or** Evaluate $v(t)$ where $2<t<4$ or appeal to shape of the graph Velocity is negative Car going backwards	B1 E1 E1 B1 E1 E1	Both calculated correctly from **their** *s*. No further marks if **their** $s(2)\le s(4)$ Do *not* need car going backwards *throughout* the interval. e.g. $v(3)=-1.125$ No further marks if **their** $v\ge0$ Do *not* need car going backwards *throughout* the interval [Award WW2 for 'car going backwards'; WW1 for velocity or displacement negative]	3 18

Q 7		mark		Sub
(i)	$T_{AB}\sin\alpha = 147$	M1	Attempt at resolving. Accept $\sin \leftrightarrow \cos$. Must have *T* resolved and equated to 147.	
	so $T_{AB} = \dfrac{147}{0.6}$	B1	Use of 0.6. Accept correct subst for angle in wrong expression.	
	= 245 so 245 N	A1	Only accept answers agreeing to 3 s. f. [Lami: M1 pair of ratios attempted; B1 correct sub;A1]	3
(ii)	$T_{BC} = 245\cos\alpha$	M1	Attempt to resolve 245 and equate to *T*, or equiv Accept $\sin \leftrightarrow \cos$	
	$= 245\times 0.8 = 196$	E1	Substitution of 0.8 clearly shown [SC1 $245\times 0.8 = 196$] [Lami: M1 pair of ratios attempted; E1]	2
(iii)	Geometry of A, B and C and weight of B the same and these determine the tension	E1 E1	Mention of two of: same weight: same direction AB: same direction BC Specific mention of same geometry & weight or recognition of same force diagram	2
(iv)			No extra forces.	
		B1	Correct orientation and arrows	
		B1	'*T*' 196 and 90 labelled. Accept 'tension' written out.	
	either			
	Realise that 196 N and 90 N are horiz and vert forces where resultant has magnitude and line of action of the tension	M1	Allow for only β or *T* attempted	
	$\tan\beta = 90/196$	B1	Use of arctan (196/90) or arctan (90/196) or equiv	
	$\beta = 24.6638...$ so 24.7 (3 s. f.)	A1		
	$T = \sqrt{196^2 + 90^2}$	M1	Use of Pythagoras	
	T = 215.675… so 216 N (3 s. f.)	E1		
	or			
	$\uparrow \quad T\sin\beta - 90 = 0$	B1	Allow if *T* = 216 assumed	
	$\rightarrow\ T\cos\beta - 196 = 0$	B1	Allow if *T* = 216 assumed	
	Solving $\tan\beta = \dfrac{90}{196} = 0.45918...$	M1	Eliminating *T*, or…	
	$\beta = 24.6638...$ so 24.7 (3 s. f.)	A1	[If *T* = 216 assumed, B1 for β ; B1 for check in 2nd	
	T = 215.675… so 216 N (3 s. f.)	E1	equation; E0]	7
(v)	Tension on block is 215.675.. N (pulley is smooth and string is light)	B1	May be implied. Reasons not required.	
	$M\times 9.8\times\sin 40 = 215.675... + 20$	M1	*Equating* their tension on the block unresolved $\pm$ 20 to weight component. If equation in any other direction, normal reaction must be present.	
		A1	Correct	
	M = 37.4128… so 37.4 (3 s. f.)	A1	Accept answers rounding to 37 and 38	4
				18

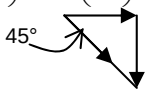
Q 1		mark		sub
	either			
		M1	Attempt at area. If not trapezium method at least one part area correct. Accept equivalent.	
	$70V$ obtained	A1	Or equivalent – need not be evaluated.	
	So $70V = 1400$	M1	Equate **their** $70V$ to 1400. Must have attempt at complete areas or equations.	
	and $V = 20$	A1	cao	
	or	M1	Attempt to find areas in terms of ratios (at least one correct)	
		A1	Correct total ratio – need not be evaluated. (Evidence may be 800 or 400 or 200 seen).	
		M1	Complete method. (Evidence may be 800/40 or 400/20 or 200/10 seen).	
	$V = 20$	A1	cao [Award 3/4 for 20 seen WWW]	
				4

Q 2		mark		sub
	$(v =)12 - 3t^2$	M1	Differentiating	
		A1	Allow confusion of notation, including $x =$	
	$v = 0 \Rightarrow 12 - 3t^2 = 0$	M1	Dep on 1st M1. Equating to zero.	
	so $t^2 = 4$ and $t = \pm 2$	A1	Accept one answer only but no extra answers. FT only if quadratic or higher degree.	
	$x = \pm 16$	A1	cao. Must have both and no extra answers.	
				5

Q 3		mark		sub
(i)	$R = mg$ so 49 N	B1	Equating to weight. Accept $5g$ (but not mg)	1
(ii)		B1	All except F correct (arrows and labels) (Accept mg, W etc and no angle). Accept cpts instead of 10N. No extra forces.	
		B1	F clearly marked and labelled	2
(iii)	$\uparrow \quad R + 10\cos 40 - 49 = 0$	M1	Resolve vertically. All forces present and 10N resolved	
		B1	Resolution correct and seen in an equation. (Accept $R = \pm 10\cos 40$ as an equation)	
	$R = 41.339\ldots$ so 41.3 N (3 s. f.)	A1		
	$F = 10\sin 40 = 6.4278\ldots$ so 6.43 N (3 s. f.)	B1	Allow –ve if consistent with the diagram.	4
				7

Q 4		mark		sub
(i)	$\downarrow \quad 20+16\cos 60=28$	B1		1
(ii)	**either** $\rightarrow 16\sin 60$ Mag $\sqrt{28^2+192}=31.2409...$ so 31.2 N (3 s.f.) **or** Cos rule $\text{mag}^2=16^2+20^2-2\times16\times20\times\cos120$ 31.2 N (3 s. f.)	B1 M1 F1 M1 A1 A1	Any form. May be seen in (i). Accept any appropriate equivalent resolution. Use of Pythag with 2 distinct cpts (but not 16 and $\pm$ 20) Allow 34.788… only as FT Must be used with 20 N, 16 N and 60° or 120° Correct substitution	3
(iii)	Magnitude of accn is 15.620… m s^{-2} so 15.6 m s^{-2} (3 s. f.) angle with 20 N force is $\arctan\left(\frac{16\sin 60}{28}\right)$ so 26.3295… so 26.3° (3 s. f.)	B1 M1 A1	Award only for **their** $F\div2$ Or equiv. May use force or acceleration. Allow use of sine or cosine rules. FT only $\text{s}\leftrightarrow\text{c}$ and sign errors. Accept reciprocal of the fraction. cao	3
				7

Q 5		mark		sub
(i)	 sphere $19.6-T=2a$ block $T-14.8=4a$	M1 A1 A1	N2L. All forces attempted in one equation. Allow sign errors. No extra forces. Don't condone $F=mga$. Accept 2g for 19.6	3
(ii)	Solving T = 18 a = 0.8	M1 A1 F1	Attempt to solve. Award only if two equations present both containing a and T. Either variable eliminated. Either found cao Other value. Allow wrong equation(s) and wrong working for 1st value [If combined equation used award: M1 as in (i) for the equation with mass of 6 kg; A1 for a = 0.8; M1 as in (i) for equation in T and a for either sphere or block; A1 equation correct; F1 for T, FT **their** a; B1 Second equation in T and a.]	3
				6

Q 6		mark		sub
(i)	$t = 2.5 \Rightarrow \mathbf{v} = \begin{pmatrix} -5 \\ 10 \end{pmatrix} + 2.5\begin{pmatrix} 6 \\ -8 \end{pmatrix} = \begin{pmatrix} 10 \\ -10 \end{pmatrix}$	B1	Need not be in vector form	
		E1	Accept diag and/or correct derivation of just $\pm 45°$	
	speed is $\sqrt{10^2 + 10^2} = 14.14...$ so 14.1 m s^{-1} (3 s. f.)	F1	FT **their v**	3
(ii)	$\mathbf{s} = 2.5\begin{pmatrix} -5 \\ 10 \end{pmatrix} + \frac{1}{2} \times 2.5^2 \times \begin{pmatrix} 6 \\ -8 \end{pmatrix}$	M1	Consideration of **s** (const accn or integration)	
		A1	Correct sub into *uvast* with **u** and **a.** (If integration used it must be correct but allow no arb constant)	
	$= \begin{pmatrix} 6.25 \\ 0 \end{pmatrix}$	A1		
	so 090°	A1	cao. CWO.	4
				7

Q 7		mark		sub
(i)	acceleration is $\frac{24}{12}$ so 2 m s^{-2}	B1		1
(ii)	$24-15=12a$ a = 0.75 m s^{-2} 1st distance is $0.5\times2\times16=16$ 2nd distance is $0.5\times0.75\times16=6$ Difference is 10 m	M1 A1 M1 A1 A1	Use of N2L. Both forces present. Must be $F = ma$. No extra forces. Appropriate *uvast* applied at least once. Need not evaluate. Both found. May be implied. FT (i) cao	5
(iii)	$12g\sin5-15=12a$ $a=-0.39587...$ so – 0.396 m s^{-2} (3 s. f.)	M1 M1 A1 A1	Use of $F = ma$, allow 15 N missing *or* weight not resolved. No extra forces. Allow use of $12\sin5$. Attempt at weight cpt. Allow sin $\leftrightarrow$ cos. Accept seen on diagram. Accept the use of 12 instead of 12g. Weight cpt correct. Accept seen on diagram. Allow not used. Correct direction must be made clear	4
(iv)	time $0=1.5+at\Rightarrow t=3.789...$ so 3.79 s (3 s. f.) distance $s=0.5\times(1.5+0)\times3.789...$ (or…) giving s = 2.8418… so 2.84 m (3 s. f.)	M1 A1 M1 A1	Correct *uvast* . Use of 0, 1.5 and **their** a from (iii) or **their** s from (iv). Allow sign errors. Condone $u\leftrightarrow v$. Correct *uvast* . Use of 0, 1.5 and **their** a from (iii) or **their** t from (iv). Allow sign errors. Condone $u\leftrightarrow v$. [The first A1 awarded for t or s has FT **their** a if signs correct; the second awarded is cao]	4
(v)	accn is given by $0=1.5+3.5a\Rightarrow a=-\frac{3}{7}=-0.42857...$ $12g\sin5-R=12\times-0.42857...$ so R = 15.39… so 15.4 N (3 s. f.)	M1 A1 M1 A1	Use of 0, 1.5 and 3.5 in correct *uvast.* Condone $u\leftrightarrow v$. Allow $\pm$ N2L. Must use **their** *new* accn. Allow only sign errors. cao	4
				18

Q 8		mark		sub
(i)	Using $s = ut + 0.5at^2$ with u = 10 and a = -10	E1	Must be clear evidence of derivation of – 5. Accept one calculation and no statement about the other.	1
(ii)	**either** s = 0 gives $10t - 5t^2 = 0$ so $5t(2-t) = 0$ so t = 0 or 2. Clearly need t = 2 **or** Time to highest point is given by 0 = 10 – 10t Time of flight is 2×1 = 2 s horizontal range is 40 m as 40 < 70, hits the ground	 B1 M1 A1 M1 M1 A1 B1 E1	 Factorising Award 3 marks for t = 2 seen WWW Dep on 1st M1. Doubling **their** t. Properly obtained FT $20 \times$ **their** t Must be clear. FT **their** range.	5
(iii)	need $10t - 5t^2 = -15$ Solving $t^2 - 2t - 3 = 0$ so $(t-3)(t+1) = 0$ and t = 3 range is 60 m	 M1 M1 A1 M1 A1	[May divide flight into two parts] Equate s = -15 or equivalent. Allow use of ± 15. Method leading to solution of a quadratic. Equivalent form will do. Obtaining t = 3. Allow no reference to the other root. [Award SC3 if t = 3 seen WWW] Range is $20 \times$ **their** t (provided t > 0) cao. CWO.	5
(iv)	Using (ii) & (iii), since 40 + 60 > 70, paths cross (For $0 < t \leq 2$) both have same vertical motion so B is always 15 m above A	E1 E1	Must be convincing. Accept sketches. Do not accept evaluation at one or more points alone. That B is *always* above A must be clear.	2
(v)	Need x components summing to 70 $20 \times 0.75 + 20 \times 2.75 = 15 + 55 = 70$ so true Need y components the same $10 \times 2.75 - 5 \times 2.75^2 + 15 = 4.6875$ $10 \times 0.75 - 5 \times 0.75^2 = 4.6875$	M1 E1 M1 B1 E1	May be implied. Or correct derivation of 0.75 s or 2.75 s Attempt to use 0.75 and 2.75 in two vertical height equations (accept same one or wrong one) 0.75 and 2.75 each substituted in the appropriate equn Both values correct. [Using cartesian equation: B1, B1 each equation: M1 solving: A1 correct point of intersection: E1 Verify times]	5
				18

Q1				
(i)	$\rightarrow \quad 40 - P\cos 60 = 0$ $P = 80$	M1 A1 A1	For any resolution in an equation involving P. Allow for $P = 40\cos 60$ or $P = 40\cos 30$ or $P = 40\sin 60$ or $P = 40\sin 30$ Correct equation cao	3
(ii)	$\downarrow \quad Q + P\cos 30 = 120$ $Q = 40\left(3 - \sqrt{3}\right) = 50.7179\ldots$ so 50.7 (3 s. f.)	M1 A1	Resolve vert. All forces present. Allow $\sin \leftrightarrow \cos$ No extra forces. Allow wrong signs. cao	2
				5

Q2				
(i)	Straight lines connecting (0, 10), (10, 30), (25, 40) and (45, 40)	B1 B1 B1	Axes with labels (words or letter). Scales indicated. Accept no arrows. Use of straight line segments and horiz section All correct with salient points clearly indicated	3
(ii)	$0.5(10+30)\times 10 + 0.5(30+40)\times 15 + 40\times 20$ = 200 + 525 + 800 = 1525	M1 M1 A1	Attempt at area(s) or use of appropriate *uvast* Evidence of attempt to find whole area cao	3
(iii)	$0.5\times 40\times T = 1700 - 1525$ so $20T = 175$ and $T = 8.75$	M1 F1	Equating triangle area to 1700 – **their** (ii) (1700 – **their** (ii))/20. Do not award for – ve answer.	2
				8

Q3				
(i)	String light and pulley smooth	E1	Accept pulley smooth alone	1
(ii)	$5g$ (49) N thrust	M1 B1 A1	Three forces in equilibrium. Allow sign errors. for $15g$ (147) N used as a tension $5g$ (49) N thrust. Accept $\pm 5g$ (49). Ignore diagram. [Award SC2 for $\pm 5g$ (49) N without 'thrust' and SC3 if it is]	3
				4

Q4				
(i)	$P - 800 = 20000 \times 0.2$ $P = 4800$	M1 A1 A1	N2L. Allow $F = mga$. Allow wrong or zero resistance. No extra forces. Allow sign errors. If done as 1 equn need m = 20 000. If A and B analysed separately, must have 2 equns with 'T'. N2L correct.	3
(ii)	New accn $4800 - 2800 = 20000a$ $a = 0.1$	M1 A1	$F = ma$. Finding new accn. No extra forces. Allow 500 N but not 300 N omitted. Allow sign errors. FT **their** P	2
(iii)	$T - 2500 = 10000 \times 0.1$ T = 3500 so 3500 N	M1 A1	N2L with new a. Mass 10000. All forces present for A or B except allow 500 N omitted on A. No extra forces cao	2
				7

Q5				
	Take F +ve up the plane $F + 40\cos 35 = 100\sin 35$ F = 24.5915… so 24.6 N (3 s. f.) up the plane	M1 B1 A1 A1	Resolve // plane (or horiz or vert). All forces present. At least one resolved. Allow sin ↔ cos and sign errors. Allow 100g used. Either $\pm 40\cos 35$ or $\pm 100\sin 35$ or equivalent seen Accept $\pm$ 24.5915… or $\pm$90.1237... even if inconsistent or wrong signs used. 24.6 N up the plane (specified or from diagram) or equiv all obtained from consistent and correct working.	4
				4

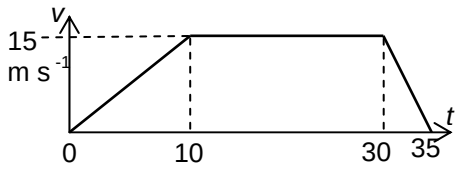
Q6				
(i)	$(-\mathbf{i}+16\mathbf{j}+72\mathbf{k})+(-80\mathbf{k})=8\mathbf{a}$ $\mathbf{a}=\left(-\frac{1}{8}\mathbf{i}+2\mathbf{j}-\mathbf{k}\right)\text{m s}^{-2}$	M1 E1	Use of N2L. All forces present. Need at least the **k** term clearly derived	2
(ii)	$\mathbf{r}=4(\mathbf{i}-4\mathbf{j}+3\mathbf{k})+0.5\times16\left(-\frac{1}{8}\mathbf{i}+2\mathbf{j}-\mathbf{k}\right)$ $= 3\mathbf{i} + 4\mathbf{k}$	M1 A1 A1	Use of appropriate **uvas***t* or integration (twice) Correct substitution (or limits if integrated)	3
(iii)	$\sqrt{3^2+4^2}=5$ so 5 m	B1	FT **their** (ii) even if it not a displacement. Allow surd form	1
(iv)	$\arctan\frac{4}{3}$ $= 53.130\ldots$ so 53.1° (3 s. f.)	M1 A1	Accept $\arctan\frac{3}{4}$. FT **their** (ii) even if not a displacement. Condone sign errors. (May use arcsin4/5 or equivalent. FT **their** (ii) and (iii) even if not displacement. Condone sign errors) cao	2
				8

Q7				
(i)	8 m s^{-1} (in the negative direction)	B1	Allow $\pm$ and no direction indicated	1
(ii)	$(t+2)(t-4)=0$ so $t = -2$ or 4	M1 A1	Equating v to zero and solving or subst If subst used then both must be clearly shown	2
(iii)	$a = 2t-2$ $a = 0$ when $t = 1$ $v(1) = 1-2-8 = -9$ so 9 m s^{-1} in the negative direction $(1,-9)$	M1 A1 F1 A1 B1	Differentiating Correct Accept -9 but not 9 without comment FT	5
(iv)	$\int_1^4 \left(t^2-2t-8\right)\,\mathrm{d}x$ $=\left[\frac{t^3}{3}-t^2-8t\right]_1^4$ $=\left(\frac{64}{3}-16-32\right)-\left(\frac{1}{3}-1-8\right)$ $= -18$ distance is 18 m	M1 A1 M1 A1 A1	Attempt at integration. Ignore limits. Correct integration. Ignore limits. Attempt to sub correct limits and subtract Limits correctly evaluated. Award if -18 seen but no need to evaluate Award even if -18 not seen. Do not award for -18. cao	5
(v)	$2\times 18 = 36$ m	F1	Award for $2\times$ **their** (iv).	1
(vi)	$\int_4^5 \left(t^2-2t-8\right)\,\mathrm{d}x = \left[\frac{t^3}{3}-t^2-8t\right]_4^5$ $=\left(\frac{125}{3}-25-40\right)-\left(-\frac{80}{3}\right)=3\frac{1}{3}$ so $3\frac{1}{3}+18=21\frac{1}{3}$ m	M1 A1 A1	$\int_4^5$ attempted or, otherwise, complete method seen. Correct substitution Award for $3\frac{1}{3}$ + **their** (positive) (iv)	3
				17

Q8				
(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 $7t - 4.9t^2 = 1.25$ so $4.9t^2 - 7t + 1.25 = 0$	M1	Equate y to **their** (ii)/2 or equivalent.	
		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× (1.219… - 0.209209…) = 24×1.01... 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

4761 Mechanics 1

Q 1		Mark	Comment	Sub
(i)		B1 B1 B1	Acc and dec shown as straight lines Horizontal straight section All correct with *v* and times marked and at least one axis labelled. Accept (*t*, *v*) or (*v*, *t*) used.	3
(ii)	Distance is found from the area area is $\frac{1}{2}\times10\times15+20\times15+\frac{1}{2}\times5\times15$ (or $\frac{1}{2}\times(20+35)\times15$) = 412.5 so distance is 412.5 m	M1 A1 A1	At least one area attempted or equivalent *uvast* attempted over one appropriate interval. Award for at least two areas (or equivalent) correct Allow if a trapezium used and only 1 substitution error. FT **their** diagram. cao (Accept 410 or better accuracy)	3
		6		
2 (i)	$\begin{pmatrix}6\\9\end{pmatrix}=1.5\mathbf{a}$ giving $\mathbf{a}=\begin{pmatrix}4\\6\end{pmatrix}$ so $\begin{pmatrix}4\\6\end{pmatrix}$ m s^{-2}	M1 A1	Use of N2L with an attempt to find **a**. Condone spurious notation. Must be a vector in proper form. Penalise only once in paper.	2
(ii)	Angle is $\arctan\left(\frac{6}{4}\right)$ = 56.309… so 56.3° (3 s. f.)	M1 F1	Use of arctan with **their** $\frac{6}{4}$ or $\frac{4}{6}$ or equiv. May use **F**. FT **their a** provided both cpts are +ve and non-zero.	2
(iii)	Using $\mathbf{s}=t\mathbf{u}+0.5t^2\mathbf{a}$ we have $\mathbf{s}=2\begin{pmatrix}-2\\3\end{pmatrix}+0.5\times4\begin{pmatrix}4\\6\end{pmatrix}$ so $\begin{pmatrix}4\\18\end{pmatrix}$ m	M1 A1 A1 7	Appropriate single ***uvast*** (or equivalent sequence of ***uvast***). If integration used twice condone omission of **r**(0) but not **v**(0). FT **their a** only cao. isw for magnitude subsequently found. Vector must be in proper form (penalise only once in paper).	3

Q 3		Mark	Comment	Sub
(i)	$m \times 9.8 = 58.8$ so m = 6	M1 A1	$T = mg$. Condone sign error. cao. CWO.	2
(ii)	Resolve $\rightarrow$ $58.8\cos 40 - F = 0$ F = 45.043… so 45.0 N (3 s. f.)	M1 B1 A1	Resolving **their** tension. Accept $s \leftrightarrow c$. Condone sign errors but not extra forces. (**their** T) × $\cos 40$ (or equivalent) seen Accept $\pm$ 45 only.	3
(iii)	Resolve $\uparrow$ $R + 58.8\sin 40 - 15 \times 9.8 = 0$ R = 109.204… so 109 N (3 s. f.)	M1 A1 A1	Resolving **their** tension. All forces present. No extra forces. Accept $s \leftrightarrow c$. Condone errors in sign. All correct cao	3
		8		
Q 4		**Mark**	**Comment**	**Sub**
(i)	Resultant is $\begin{pmatrix}4\\1\\2\end{pmatrix}+\begin{pmatrix}-6\\2\\4\end{pmatrix}=\begin{pmatrix}-2\\3\\6\end{pmatrix}$ Magnitude is $\sqrt{(-2)^2+3^2+6^2} = \sqrt{49} = 7$ N	M1 A1 M1 F1	Adding the vectors. Condone spurious notation. Vector must be in proper form (penalise only once in the paper). Accept clear components. Pythagoras on **their** 3 component vector. Allow e.g. -2^2 for $(-2)^2$ even if evaluated as – 4. FT **their** resultant.	4
(ii)	**F** + 2**G** + **H** = **0** So **H** = - 2**G** - **F** = $-\begin{pmatrix}-12\\4\\8\end{pmatrix}-\begin{pmatrix}4\\1\\2\end{pmatrix}$ = $\begin{pmatrix}8\\-5\\-10\end{pmatrix}$	M1 A1 A1	Either **F** + 2**G** + **H** = **0** or **F** + 2**G** = **H** Must see attempt at **H** = – 2 **G** – **F** cao. Vector must be in proper form (penalise only once in the paper).	3
		7		

Q 5		Mark	Comment	Sub
	$a = 12 - 6t$	M1 A1	Differentiation, at least one term correct.	
	a = 0 gives t = 2	F1	Follow **their** a	
	$x = \int (2 + 12t - 3t^2)\mathrm{d}x$	M1	Integration indefinite or definite, at least one term correct.	
	$2t + 6t^2 - t^3 + C$	A1	Correct. Need not be simplified. Allow as definite integral. Ignore C or limits	
	x = 3 when t = 0	M1	Allow x = ± 3 or argue it is $\int_0^2$ from A then ± 3	
	so $3 = C$ and $x = 2t + 6t^2 - t^3 + 3$	A1	Award if seen WWW or $x = 2t + 6t^2 - t^3$ seen with +3 added later.	
	$x(2) = 4 + 24 - 8 + 3 = 23$ m	B1	FT **their** t and **their** x if obtained by integration but not if -3 obtained instead of +3. [If 20 m seen WWW for displacement award SC6] [Award SC1 for position if constant acceleration used for displacement and then +3 applied]	8
		8		

Q 6		Mark	Comment	Sub
(i)	$3.5 = 0.5 + 1.5T$ so T = 2 so 2 s $s = \frac{3.5+0.5}{2} \times 2$ so s = 4 so 4 m	M1 A1 M1 F1	Suitable *uvast*, condone sign errors. cao Suitable *uvast*, condone sign errors. FT **their** T. [If s found first then it is cao. In this case when finding T, FT **their** s, if used.]	4
(ii) **(A)**	N2L ↓: $80 \times 9.8 - T = 80 \times 1.5$ T = 664 so 664 N	M1 B1 A1	Use of N2L. Allow weight omitted and use of $F = mga$ Condone errors in sign but do not allow extra forces. weight correct (seen in (A) or (B)) cao	
(B)	N2L ↓: $80 \times 9.8 - T = 80 \times (-1.5)$ T = 904 so 904 N	M1 A1	N2L with all forces and using $F = ma$. Condone errors in sign but do not allow extra forces. cao [Accept 904 N seen for M1 A1]	5
(iii)	N2L ↑: $2500 - 80 \times 9.8 - 116 = 80a$ a = 20 so 20 m s^{-2} upwards.	M1 A1 A1 A1	Use of N2L with $F = ma$. Allow 1 force missing. No extra forces. Condone errors in sign. ± 20, accept direction wrong or omitted upwards made clear (accept diagram)	4
(iv)	N2L ↑ on equipment: $80 - 10 \times 9.8 = 10a$ $a = -1.8$ N2L ↑ **either** all: $T - (80+10) \times 9.8 - 116 = 90 \times (-1.8)$ **or** on man: T – (80×9.8) – 116 – 80 = 80×(– 1.8) T = 836 so 836 N	M1 A1 M1 A1	Use of N2L on equipment. All forces. $F = ma$. No extra forces. Allow sign errors. Allow ± 1.8 N2L for system or for man alone. Forces correct (with no extras); accept sign errors; **their** ± 1.8 used cao [NB The answer 836 N is independent of the value taken for g and hence may be obtained if all weights are omitted.]	4
		17		

Q 7		Mark	Comment	Sub
(i)	Horiz $21t = 60$ so $\frac{20}{7}$ s (2.8571…) **either** $0 = u - 9.8 \times \frac{20}{7}$ **or** $-u = u - 9.8 \times \left(\frac{40}{7}\right)$ **or** $40 = u \times \frac{20}{7} - 4.9\left(\frac{20}{7}\right)^2$ so u = 28 so 28 m s^{-1}	M1 A1 M1 E1	Use of horizontal components and a = 0 or $s = vt - 0.5at^2$ with v = 0. Any form acceptable. Allow M1 A1 for answer seen WW. [If $s = ut + 0.5at^2$ and u = 0 used without justification award M1 A0] [If u = 28 *assumed* to find time then award SC1] Use of $v = u + at$ (or $v^2 = u^2 + 2as$) with v = 0. **or** Use of $v = u + at$ with $v = -u$ and appropriate t. **or** Use of $s = ut + 0.5at^2$ with s = 40 and appropriate t Condone sign errors and, where appropriate, $u \leftrightarrow v$. Accept signs not clear but not errors. Enough working must be given for 28 to be properly shown. [NB u = 28 may be found first and used to find time]	4
(ii)	$y = 28t - 0.5 \times 9.8t^2$	E1	*Clear & convincing* use of g = – 9.8 in $s = ut + 0.5at^2$ or $s = vt - 0.5at^2$ **NB: AG**	1
(iii)	Start from same height with same (zero) vertical speed at same time, same acceleration Distance apart is $0.75 \times 21t = 15.75t$	E1 M1 A1	For two of these reasons 0.75×21t seen **or** 21t and 5.25t both seen with intention to subtract. Need simplification - LHS alone insufficient. CWO.	3
(iv) (A)	**either** Time is $\frac{20}{7}$ s by symmetry so $15.75 \times \frac{20}{7} = 45$ so 45 m **or** Hit ground at same time. By symmetry one travels 60 m so the other travels 15 m in this time ($\frac{1}{4}$ speed) so 45 m.	B1 B1 B1 B1	Symmetry or *uvast* FT their (iii) with $t = \frac{20}{7}$ [SC1 if 90 m seen]	2
(B)	see next page			

Q7	continued			
(B)	**either** Time to fall is $40-10=0.5\times9.8\times t^2$ t = 2.47435… need $15.75\times2.47435..=38.971..$ so 39.0 (3sf) **or** Need time so $10=28t-4.9t^2$ $4.9t^2-28t+10=0$ so $t=\frac{28\pm\sqrt{28^2-4\times4.9\times10}}{9.8}$ so 0.382784… or 5.33150… Time required is 5.33150… $-\frac{20}{7}$ = 2.47435.. need $15.75\times2.47435..=38.971..$ so 39.0 (3sf)	 M1 A1 A1 A1 F1 M1 M1* A1 M1 F1	[SC1 if **either** and **or** methods mixed to give $\pm30=28t-4.9t^2$ or $\pm10=4.9t^2$] Considering time from explosion with u = 0. Condone sign errors. LHS. Allow ±30 All correct cao FT **their** (iii) only. Equating $28t-4.9t^2=\pm10$ Dep. Attempt to solve quadratic by a method that could give two roots. Larger root correct to at least 2 s. f. Both method marks may be implied from two correct roots alone (to at least 1 s. f.). [SC1 for either root seen WW] FT **their** (iii) only.	5
(v)	Horiz $(x=)\ 21t$ Elim t between $x=21t$ and $y=28t-4.9t^2$ so $y=28\left(\frac{x}{21}\right)-4.9\left(\frac{x}{21}\right)^2$ so $y=\frac{4x}{3}-\frac{0.1x^2}{9}=\frac{1}{90}\left(120x-x^2\right)$	B1 M1 A1 E1	Intention must be clear, with some attempt made. t completely and correctly eliminated from their expression for x and correct y. Only accept wrong notation if subsequently explicitly given correct value e.g. $\frac{x^2}{21}$ *seen* as $\frac{x^2}{441}$. Some simplification must be shown. [SC2 for 3 points shown to be on the curve. Award more only if it is made clear that (a) trajectory is a parabola (b) 3 points define a parabola]	4
		19		

4761 Mechanics 1

Q 1		mark	comment	sub
(i)	N2L ↑ $1000-100\times9.8=100a$ a = 0.2 so 0.2 m s^{-2} upwards	M1 B1 A1	N2L. Accept $F = mga$ and no weight Weight correct (including sign). Allow if seen. Accept ±0.2 . Ignore units and direction	3
(ii)	$T_{BA}-980=100\times0.8$ so tension is 1060 N	M1 A1	N2L. $F = ma$. Weight present, no extras. Accept sign errors.	2
(iii)	$T_{BA}\cos30=1060$ $T_{BA}=1223.98...$ so 1220 N (3 s. f.)	M1 A1 A1	Attempt to resolve their (ii). Do not award for **their** 1060 resolved unless all forces present and all resolutions needed are attempted. If start again allow no weight. Allow $\sin\leftrightarrow\cos$. No extra forces. Condone sign errors FT **their** 1060 only cao	3
		8		

Q 2		mark	comment	sub
(i)		B1	Sketch. O, **i**, **j** and **r** (only require correct quadrant.) Vectors must have arrows. Need not label **r**.	1
(ii)	$\sqrt{4^2+(-5)^2}$ = $\sqrt{41}$ or 6.4031… so 6.40 (3 s. f.) Need $180-\arctan\left(\frac{4}{5}\right)$ 141.340 so 141°	M1 A1 M1 A1	Accept $\sqrt{4^2-5^2}$ Or equivalent. Award for $\arctan\left(\pm\frac{4}{5}\right)$ or $\arctan\left(\pm\frac{5}{4}\right)$ or equivalent seen without 180 or 90. cao	4
(iii)	12**i** – 15**j** or $\begin{pmatrix}12\\-15\end{pmatrix}$	B1	Do not award for magnitude given as the answer. Penalise spurious notation by 1 mark at most once in paper	1
		6		

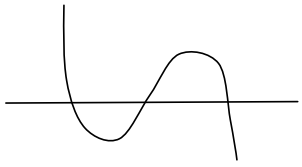
Q 3		mark	comment	sub
(i)	**F** = $5\begin{pmatrix}-1\\2\end{pmatrix}=\begin{pmatrix}-5\\10\end{pmatrix}$ so $\begin{pmatrix}-5\\10\end{pmatrix}$ N	 M1 A1	Penalise spurious notation by 1 mark at most once in paper Use of N2L in vector form Ignore units. [Award 2 for answer seen] [SC1 for $\sqrt{125}$ or equiv seen]	 2
(ii)	**s** = $\begin{pmatrix}-2\\3\end{pmatrix}+4\begin{pmatrix}4\\5\end{pmatrix}+\frac{1}{2}\times4^2\times\begin{pmatrix}-1\\2\end{pmatrix}$ $\mathbf{s}=\begin{pmatrix}6\\39\end{pmatrix}$ so $\begin{pmatrix}6\\39\end{pmatrix}$ m	M1 A1 B1	Use of $\mathbf{s}=t\mathbf{u}+0.5t^2\mathbf{a}$ or integration of **a**. Allow $\mathbf{s}_0$ omitted. If integrated need to consider **v** when t = 0 Correctly evaluated; accept $\mathbf{s}_0$ omitted. Correctly adding $\mathbf{s}_0$ to a vector (FT). Ignore units. [NB $\begin{pmatrix}8\\36\end{pmatrix}$ seen scores M1 A1]	 3
		5		

Q 4		mark	comment	sub
(i)	The distance travelled by P is $0.5\times0.5\times t^2$ The distance travelled by Q is 10t	B1 B1	 Accept 10t + 125 if used correctly below.	 2
(ii)	Meet when $0.25t^2=125+10t$ so $t^2-40t-500=0$ Solving t = 50 (or -10) Distance is $0.25\times50^2=625$ m	M1 F1 M1 A1 A1	Allow **their** wrong expressions for P and Q distances Allow ± 125 or 125 omitted Award for **their** expressions as long as one is quadratic and one linear. Must have 125 with correct sign. Accept any method that yields (smaller) + ve root of their 3 term quadratic cao Allow –ve root not mentioned cao [SC2 400 m seen]	 5
		7		

Q 5		mark	comment	sub
	either Overall, N2L → 135 – 9 = (5 +4)*a* *a* = 14 so 14 m s $^{-2}$ For A, N2L → *T* – 9 = 4×14 so 65 N **or** 135 – *T* = 5*a* *T* – 9 = 4*a* Solving *T* = 65 so 65 N	 M1 A1 M1 A1 M1 A1 M1 A1	 Use of N2L. Allow *F* = *mga* but no extra forces. Allow 9 omitted. N2L on A or B with correct mass. *F* = *ma*. All relevant forces and no extras. cao * 1 equation in *T* and *a*. Allow sign errors. Allow *F* = *mga* Both equations correct and consistent Dependent on M* solving for *T*. cao.	 4
		4		

Q 6		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	 Equate **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		

Q 7		mark	comment	sub
(i)	Continuous string: smooth ring: light string	E1 E1	One reason Another reason	2
(ii)	Resolve $\leftarrow$: $60\cos\alpha - 60\cos\beta = 0$ (so $\cos\alpha = \cos\beta$) and so $\alpha = \beta$	M1 E1	[(ii) and (iii) may be argued using Lami or triangle of forces] Resolution and an equation or equivalent. Accept $s \leftrightarrow c$. Accept a *correct* equation seen without method stated. Accept the use of '*T*' instead of '60'. Shown. Must have stated method (allow $\rightarrow$ seen).	2
(iii)	Resolve $\uparrow$ $2\times 60\times\sin\alpha - 8g = 0$ so α = 40.7933… so 40.8° (3 s. f.)	M1 B1 B1 A1 A1	Resolution and an equation. Accept $s \leftrightarrow c$. Do not award for resolution that cannot give solution (e.g. horizontal) Both strings used (accept use of half weight), seen in an equation $\sin\alpha$ or equivalent seen in an equation All correct	5
(iv)	Resolve $\rightarrow$ $10 + T_{QC}\cos 25 - T_{PC}\cos 45 = 0$ Resolve $\uparrow\ T_{PC}\sin 45 + T_{QC}\sin 25 - 8g = 0$ Solving $T_{CQ} = 51.4701...$ so 51.5 N (3 s. f.) $T_{CP} = 80.1120...$ so 80.1 N (3 s. f.)	M1 M1 A1 M1 A1 M1 A1 F1	Recognise strings have different tensions. Resolution and an equation. Accept $s \leftrightarrow c$. No extra forces. All forces present. Allow sign errors. Correct. Any form. Resolution and an equation. Accept $s \leftrightarrow c$. No extra forces. All forces present. Allow sign errors. Correct. Any form. * A method that leads to at least one solution of a pair of simultaneous equations. cao either tension other tension. Allow FT only if M1* awarded [Scale drawing: 1st M1 then A1, A1 for answers correct to 2 s.f.]	8
		17		

Q 8		mark	comment	sub
(i)	10	B1		1
(ii)	$v = 36 + 6t - 6t^2$	M1 A1	Attempt at differentiation	2
(iii)	$a = 6 - 12t$	M1 F1	Attempt at differentiation	2
(iv)	Take a = 0 so $t = 0.5$ and v = 37.5 so 37.5 m s^{-1}	M1 A1 A1	Allow table if maximum indicated or implied FT **their** a cao Accept no justification given that this is maximum	3
(v)	**either** Solving $36 + 6t - 6t^2 = 0$ so t = -2 or t = 3 **or** Sub the values in the expression for v Both shown to be zero A quadratic so the only roots **then** x(-2) = -34 x(3) = 91	 M1 B1 E1 M1 E1 B1 B1 B1	 A method for two roots using **their** v Factorization or formula or … of **their** expression Shown Allow just 1 substitution shown Both shown Must be a clear argument cao cao	5
(vi)	$\lvert x(3) - x(0)\rvert + \lvert x(4) - x(3)\rvert$ = $\lvert 91 - 10\rvert + \lvert 74 - 91\rvert$ = 98 so 98 m	M1 A1 A1	Considering two parts Either correct cao [SC 1 for s(4) – s(0) = 64]	3
(vii)	At the SP of v x(-2) = -34 i.e. < 0 and x(3) = 91 i.e. > 0 Also x(-4) = 42 > 0 and x(6) = -98 < 0  so three times	M1 B1 B1	Or any other valid argument e.g find all the zeros, sketch, consider sign changes. Must have some working. If only a sketch, must have correct shape. Doing appropriate calculations e.g. find all 3 zeros; sketch cubic reasonably (showing 3 roots); sign changes in range 3 times seen	3
		19		

4761 Mechanics 1

Q 1		Mark	Comment	Sub
(i)	6 m s^{-1} 4 m s^{-2}	B1 B1	Neglect units. Neglect units.	2
(ii)	$v(5) = 6 + 4 \times 5 = 26$ $s(5) = 6 \times 5 + 0.5 \times 4 \times 25 = 80$ so 80 m	B1 M1 A1	Or equiv. FT (i) and **their** $v(5)$ where necessary. cao	3
(iii)	distance is 80 + $26 \times (15-5) + 0.5 \times 3 \times (15-5)^2$ = 490 m	M1 M1 A1	Their 80 + attempt at distance with $a = 3$ Appropriate *uvast* . Allow $t = 15$. FT **their** v(5). cao	3
		8		

Q 2		Mark	Comment	Sub
(i)	When $t = 2$, velocity is $6 + 4 \times 2 = 14$	M1 A1	Recognising that areas under graph represent changes in velocity in (i) or (ii) or equivalent *uvast.*	2
(ii)	Require velocity of – 6 so must inc by – 20 $-8 \times (t-2) = -20$ so $t = 4.5$	M1 F1	FT ±(6 + **their** 14) used in any attempt at area/ *uvast* FT **their** 14 [Award SC2 for 4.5 WW and SC1 for 2.5 WW]	2
		4		

Q 3		Mark	Comment	Sub
(i)	$\mathbf{F} + \begin{pmatrix} -4 \\ 8 \end{pmatrix} = 6\begin{pmatrix} 2 \\ 3 \end{pmatrix}$ $\mathbf{F} = \begin{pmatrix} 16 \\ 10 \end{pmatrix}$	M1 B1 B1 A1	N2L. $F = ma$. All forces present Addition to get resultant. May be implied. For $\mathbf{F} \pm \begin{pmatrix} -4 \\ 8 \end{pmatrix} = 6\begin{pmatrix} 2 \\ 3 \end{pmatrix}$. SC4 for $\mathbf{F} = \begin{pmatrix} 16 \\ 10 \end{pmatrix}$ WW. If magnitude is given, final mark is lost unless vector answer is clearly intended.	4
(ii)	$\arctan\left(\frac{16}{10}\right)$ 57.994… so 58.0° (3 s. f.)	M1 A1	Accept equivalent and FT **their F** only. Do not accept wrong angle. Accept 360 - $\arctan\left(\frac{16}{10}\right)$ cao. Accept 302º (3 s.f.)	2
		6		

Q4		Mark	Comment	Sub
	either We need $3.675 = 9.8t - 4.9t^2$ Solving $4t^2 - 8t + 3 = 0$ gives $t = 0.5$ or $t = 1.5$ **or** Time to greatest height $0 = 35 \times 0.28 - 9.8t$ so $t = 1$ Time to drop is 0.5 total is 1.5 s **then** Horiz distance is $35 \times 0.96t$ So distance is $35 \times 0.96 \times 1.5 = 50.4$ m	*M1 M1* A1 F1 M1 A1 A1 A1 B1 F1	Equating given expression or **their** attempt at y to ± 3.675 . If **they** attempt y, allow sign errors, $g = 9.81$ etc. and $u = 35$. Dependent. Any method of solution of a 3 term quadratic. cao. Accept only the larger root given Both roots shown and larger chosen provided both +ve. Dependent on 1st M1. [Award M1 M1 A1 for 1.5 seen WW] Complete method for total time from motion in separate parts. Allow sign errors, $g = 9.81$ etc. Allow $u = 35$ initially only. Time for 1st part Time for 2nd part cao Use of $x = u\cos\alpha t$. May be implied. FT **their** quoted t provided it is positive.	6
		6		

Q5		Mark	Comment	Sub
(i)	For the parcel $\uparrow$ N2L $55 - 5g = 5a$ $a = 1.2$ so 1.2 m s^{-2}	M1 A1 A1	Applying N2L to the parcel. Correct mass. Allow $F = mga$. Condone missing force but do not allow spurious forces. Allow only sign error(s). Allow –1.2 only if sign convention is clear.	3
(ii)	$R - 80g = 80 \times 1.2$ or $R - 75g - 55 = 75 \times 1.2$ $R = 880$ so 880 N	M1 A1	N2L. Must have correct mass. Allow only sign errors. FT **their** a cao [NB beware spurious methods giving 880 N]	2
		5		

Q6		Mark	Comment	Sub
	Method 1			
	$\uparrow\ v_A = 29.4 - 9.8T \qquad \downarrow\ v_B = 9.8T$	M1	Either attempted. Allow sign errors and g = 9.81 etc	
		A1	Both correct	
	For same speed $29.4 - 9.8T = 9.8T$	M1	Attempt to equate. Accept sign errors and T = 1.5 substituted in both.	
	so T = 1.5	E1	If 2 subs there must be a statement about equality	
	and V = 14.7	F1	FT T or V, whichever is found second	
	$H = 29.4\times1.5 - 0.5\times9.8\times1.5^2$ $+ 0.5\times9.8\times1.5^2$	M1	Sum of the distance travelled by each attempted	
	$= 44.1$	A1	cao	
	Method 2			
	$V^2 = 29.4^2 - 2\times9.8\times x = 2\times9.8\times(H - x)$	M1	Attempts at V^2 for each particle equated. Allow sign errors, 9.81 etc Allow h_1, h_2 without $h_1 = H - h_2$	
		B1	Both correct. Require $h_1 = H - h_2$ but not an equation.	
	$29.4^2 = 19.6H$ so H = 44.1	A1	cao	
	Relative velocity is 29.4 so	M1	Any method that leads to T or V	
	$T = \frac{44.1}{29.4}$	E1		
	Using $v = u + at$	M1	Any method leading to the other variable	
	$V = 0 + 9.8\times1.5 = 14.7$	F1		
			Other approaches possible. If 'clever' ways seen, reward according to weighting above.	
				7
		7		

Q7		Mark	Comment	Sub
(i)	Diagram	B1 B1	Weight, friction and 121 N present with arrows. All forces present with suitable labels. Accept *W*, *mg*, 100*g* and 980. No extra forces.	
	Resolve $\rightarrow$ $121\cos 34 - F = 0$ F = 100.313… so 100 N (3 s. f.)	M1 E1	Resolving horiz. Accept $s \leftrightarrow c$. Some evidence required for the *show*, e.g. at least 4 figures. Accept $\pm$.	
	Resolve $\uparrow$ $R + 121\sin 34 - 980 = 0$ R = 912.337… so 912 N (3 s. f.)	M1 B1 A1	Resolve vert. Accept $s \leftrightarrow c$ and sign errors. All correct	7
(ii)	It will continue to move at a constant speed of 0.5 m s^{-1}.	E1 E1	Accept no reference to direction Accept no reference to direction [Do not isw: conflicting statements get zero]	2
(iii)	Using N2L horizontally $155\cos 34 - 95 = 100a$ a = 0.335008… so 0.335 m s^{-2} (3 s. f.)	M1 A1 A1	Use of N2L. Allow $F = mga$, F omitted and 155 not resolved. Use of $F = ma$ with resistance and T resolved. Allow $s \leftrightarrow c$ and signs as the **only** errors.	3
(iv)	$a = 5 \div 2 = 2.5$ N2L down the slope $100g\sin 26 - F = 100 \times 2.5$ F = 179.603… so 180 N (3 s. f.)	M1 A1 M1 B1 A1	Attempt to find a from information $F = ma$ using **their** "new" a. All forces present. No extras. Require attempt at wt cpt. Allow $s \leftrightarrow c$ and sign errors. Weight term resolved correctly, seen in an equn or on a diagram. cao. Accept – 180 N if consistent with direction of F on their diagram	5
		17		

Q8		Mark	Comment	Sub
(i)	$v_x = 8 - 4t$ $v_x = 0 \Leftrightarrow t = 2$ so at $t = 2$	M1 A1 F1	**either** Differentiating **or** Finding 'u' and 'a' from x and use of $v = u + at$ FT **their** $v_x = 0$	3
(ii)	$y = \int (3t^2 - 8t + 4)\,\mathrm{d}t$ $= t^3 - 4t^2 + 4t + c$ $y = 3$ when $t = 1$ so $3 = 1 - 4 + 4 + c$ so $c = 3 - 1 = 2$ and $y = t^3 - 4t^2 + 4t + 2$	M1 A1 M1 E1	Integrating v_y with at least one correct integrated term. All correct. Accept no arbitrary constant. Clear evidence Clearly shown and stated	4
(iii)	We need $x = 0$ so $8t - 2t^2 = 0$ so $t = 0$ or $t = 4$ $t = 0$ gives $y = 2$ so 2 m $t = 4$ gives $y = 4^3 - 4^3 + 16 + 2 = 18$ so 18 m	M1 A1 A1 A1	May be implied. Must have both Condone 2**j** Condone 18**j**	4
(iv)	We need $v_x = v_y = 0$ From above, $v_x = 0$ only when $t = 2$ so evaluate $v_y(2)$ $v_y(2) = 0$ [$(t - 2)$ is a factor] so yes only at $t = 2$ At $t = 2$, the position is (8, 2) Distance is $\sqrt{8^2 + 2^2} = \sqrt{68}$ m (8.25 3 s.f.)	M1 M1 A1 B1 B1	**either** Recognises $v_x = 0$ when $t = 2$ **or** Finds time(s) when $v_y = 0$ **or** States or implies $v_x = v_y = 0$ Considers $v_x = 0$ **and** $v_y = 0$ with **their** time(s) $t = 2$ recognised as only value (accept as evidence only $t = 2$ used below). For the last 2 marks, no credit lost for reference to $t = \frac{2}{3}$. May be implied FT from **their** position. Accept one position followed through correctly.	5
(v)	$t = 0, 1$ give (0, 2) and (6, 3)	B1 B1 B1	At least one value $0 \le t < 2$ correctly calc. This need not be plotted Must be x-y curve. Accept sketch. Ignore curve outside interval for t. Accept unlabelled axes. Condone use of line segments. At least three correct points **used** in x-y graph or sketch. General shape correct. Do not condone use of line segments.	3
		19		

4761 Mechanics 1

Q 1		mark	comment	sub
(i)	$0.5\times8\times10=40$ m	M1	Attempt to find whole area or … If *suvat* used in 2 parts, accept any *t* value $0\le t\le 8$ for max.	2
(ii)		A1	cao	
	$0.5\times5(T-8)=10$	M1	$0.5\times5\times k=10$ seen. Accept ±5 and ±10 only. If *suvat* used need whole area; if in 2 parts, accept any *t* value $8\le t\le T$ for min.	
		B1	Attempt to use $k = T - 8$.	
	$T = 12$	A1	cao. [Award 3 if $T = 12$ seen]	3
(iii)				
	40 – 10 = 30 m	B1	FT **their** 40.	1
		6		

Q 2		mark	comment	sub
(i)				
	$\sqrt{10^2+24^2}=26$ so 26 N	B1		
	arctan ($^{10}/_{24}$)	M1	Using arctan or equiv. Accept arctan ($^{24}/_{10}$) or equiv.	
	= 22.619… so 22.6° (3 s. f.)	A1	Accept 157.4°.	3
(ii)				
	W = $-w$ **j**	B1	Accept $\begin{pmatrix}0\\-w\end{pmatrix}$ and $\begin{pmatrix}0\\-w\mathrm{j}\end{pmatrix}$	1
(iii)				
	$\mathbf{T}_1 + \mathbf{T}_2 + \mathbf{W} = \mathbf{0}$	M1	Accept in any form and recovery from **W** = w **j**. Award if not explicit and part (ii) and **both** k and w correct.	
	$k = -10$	B1	Accept from wrong working.	
	$w = 34$	B1	Accept from wrong working but not – 34. [Accept – 10 **i** *or* 34 **j** but not both]	3
		7		

Q 3		mark	comment	sub
(i)				
	The line is not straight	B1	Any valid comment	1
(ii)				
	$a = 3 - 6t/8$	M1	Attempt to differentiate. Accept 1 term correct but not $3 - \frac{3t}{8}$.	
	$a(4) = 0$	F1		
	The sprinter has reached a steady speed	E1	Accept 'stopped accelerating' but not just $a = 0$. Do not FT $a(4) \neq 0$.	3
(iii)				
	We require $\int_1^4 \left(3t - \frac{3t^2}{8}\right) \mathrm{d}t$	M1	Integrating. Neglect limits.	
	$= \left[\frac{3t^2}{2} - \frac{t^3}{8}\right]_1^4$	A1	One term correct. Neglect limits.	
	$= (24 - 8) - \left(\frac{3}{2} - \frac{1}{8}\right)$	M1	Correct limits subst in integral. Subtraction seen. If arb constant used, evaluated to give $s = 0$ when $t = 1$ and then sub $t = 4$.	
	$= 14\frac{5}{8}$ m (14.625 m)	A1	cao. Any form. [If trapezium rule used M1 use of rule (must be clear method and at least two regions) A1 correctly applied M1 At least 6 regions used A1 Answer correct to at least 2 s.f.)]	4
		8		

Q 4		mark	comment	sub
(i)	$32\cos\alpha t$	B1		1
(ii)	$32\cos\alpha\times 5 = 44.8$	M1	FT **their** x.	
	so $160\cos\alpha = 44.8$ and $\cos\alpha = 0.28$	E1	Shown. Must see some working e.g $\cos\alpha$ = 44.8/160 or 160 $\cos\alpha$ = 44.8. If 32 × 0.28 × 5 = 44.8 seen then this needs a statement that 'hence $\cos\alpha$ = 0.28'.	2
(iii)	$\sin\alpha = 0.96$	B1	Need not be explicit e.g. accept sin(73.73…) seen.	
	either			
	$0 = (32\times 0.96)^2 - 2\times 9.8\times s$	M1	Allow use of 'u' = 32, g = ± (10, 9.8, 9.81).	
		A1	Correct substitution.	
	s = 48.1488… so 48.1 m (3 s. f.)	A1	cao	
	or			
	Time to max height is given by 32 × 0.96 -9.8 T = 0 so T = 3.1349….	B1	Could use ½ total time of flight to the horizontal.	
	y = 32 × 0.96 t – 4.9 t^2	M1	Allow use of 'u' = 32, g = ± (10, 9.8, 9.81) May use $s = \frac{(u+v)}{2}t$.	
	putting t = T, y = 48.1488 so 48.1 m (3 s. f.)	A1	cao	4
		7		

Q 5		mark	comment	sub
(i)				
	$\mathbf{v} = \mathbf{i} + (3-2t)\mathbf{j}$	M1	Differentiating **r.** Allow 1 error. Could use const accn.	
		A1		
	v(4) = **i** – 5**j**	F1	Do not award if $\sqrt{26}$ is given as vel (accept if **v** given and *v* given as well called speed or magnitude).	
				3
(ii)				
	a = – 2**j**	B1	Diff **v.** FT **their v.** Award if – 2**j** seen & isw.	
	Using N2L **F** = $1.5\times$ (– 2**j**)	M1	Award for $1.5\times(\pm$ **their a** or $a)$ seen.	
	so – 3**j** N	A1	cao Do not award if final answer is not correct. [Award M1 A1 for – 3**j** WW]	
				3
(iii)				
	$x = 2 + t$ and $y = 3t - t^2$	B1	Must have both but may be implied.	
	Substitute $t = x - 2$			
	so $y = 3(x-2) - (x-2)^2$	B1	cao. isw. Must see the form *y* = ….	
	$[= (x-2)(5-x)]$			
				2
		8		

Q 6		mark	comment	sub
(i)				
	Up the plane $T - 4g\sin 25 = 0$	M1	Resolving parallel to the plane. If any other direction used, all forces must be present. Accept $s \leftrightarrow c$. Allow use of *m*. No extra forces.	
	T = 16.5666… so 16.6 N (3 s. f.)	A1		
				2
(ii)				
	Down the plane, $(4+m)g\sin 25 - 50 = 0$	M1	No extra forces. Must attempt resolution in at least 1 term. Accept $s \leftrightarrow c$. Accept *Mg*sin25. Accept use of mass.	
		A1	Accept *Mg*sin25	
	m = 8.0724… so 8.07 (3 s. f.)	A1		
				3
(iii)				
	Diagram	B1	Any 3 of weight, friction normal reaction and *P* present	

		B1	in approx correct directions with arrows. All forces present with suitable directions, labels and arrows. Accept *W*, *mg*, 4*g* and 39.2.	2
(iv)				
	Resolving up the plane	M1	Resolving parallel to the plane or All forces must be present . Accept $s \leftrightarrow c$. Allow use of *m*. At least one resolution attempted and accept wrong angles. Allow sign errors.	
		B1	$P\cos 15$ term correct. Allow sign error.	
	$P\cos 15 - 20 - 4g\sin 25 = 0$	B1	Both resolutions correct. Weight used. Allow sign errors. FT use of *P*sin 15.	
		A1	All correct but FT use of *P*sin 15.	
	P = 37.8565…. so 37.9 N (3 s. f.)	A1		5
(v)				
	Resolving perpendicular to the plane	M1	May use other directions. All forces present. No extras. Allow $s \leftrightarrow c$. Weight not mass used. Both resolutions attempted. Allow sign errors.	
	$R + P\sin 15 - 4g\cos 25 = 0$	B1	Both resolutions correct. Allow sign errors. Allow use of *P*cos15 if *P*sin15 used in (iv).	
		F1	All correct. Only FT **their** *P* and their use of *P*cos15.	
	R = 25.729… so 25.7 N	A1	cao	4
		16		

If there is a consistent $s \leftrightarrow c$ error in the weight term throughout the question, penalise only two marks for this error. In the absence of other errors this gives
(i) 35.52… (ii) 1.6294… (iv) 57.486… (v) 1.688…

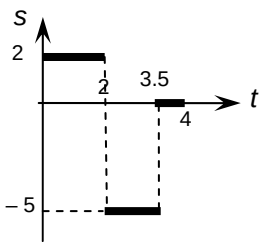
For use of mass instead of weight lose maximum of 2.

Q 7		mark	comment	sub
	With the 11.2 N resistance acting to the left			
(i)				
	N2L $F - 11.2 = 8 \times 2$	M1	Use of N2L (allow $F = mga$). Allow 11.2 omitted; no extra forces.	
		A1	All correct	
	F = 27.2 so 27.2 N	A1	cao	
				3
(ii)	The string is inextensible	E1	Allow 'light inextensible' but not other irrelevant reasons given as well (e.g. smooth pulley).	
				1
(iii)		B1	One diagram with all forces present; no extras; correct arrows and labels accept use of words.	
		B1	Both diagrams correct with a common label.	
				2
(iv)	**method (1)**	M1	For either box or sphere, $F = ma$. Allow omitted force and sign errors but not extra forces. Need correct mass. Allow use of mass not weight.	
	box N2L $\rightarrow 105 - T - 11.2 = 8a$	A1	Correct and in any form.	
	sphere N2L $\uparrow$ $T - 58.8 = 6a$	A1	Correct and in any form. [box and sphere equns with consistent signs]	
	Adding 35 = 14a	M1	Eliminating 1 variable from 2 equns in 2 variables.	
	a = 2.5 so 2.5 m s^{-2}	E1		
	Substitute a = 2.5 giving T = 58.8 + 15	M1	Attempt to substitute in either box or sphere equn.	
	T = 73.8 so 73.8 N	A1		
	method (2)			
	105 – 11.2 – 58.8 = 14a	M1	For box and sphere, $F = ma$. Must be correct mass. Allow use of mass not weight.	
	a = 2.5	A1		
		E1	Method made clear.	
		M1	For **either** box **or** sphere, $F = ma$. Allow omitted force and sign errors but not extra forces. Need correct mass. Allow use of mass not weight.	
	either: box N2L $\rightarrow 105 - T - 11.2 = 8a$			
	or: sphere N2L $\uparrow$	A1	Correct and in any form.	

	$T - 58.8 = 6a$ Substitute a = 2.5 in either equn T = 73.8 so 73.8 N	M1 A1	Attempt to substitute in either box or sphere equn. [If AG used in either equn award M1 A1 for that equn as above and M1 A1 for finding T. For full marks, both values must be shown to satisfy the second equation.]	7
(v) **(A)**	g downwards	B1	Accept $\pm g,\ \pm 9.8,\ \pm 10,\ \pm 9.81$	1
(B)	Taking ↑ + ve, $s = -1.8$, u = 3 and $a = -9.8$ so $-1.8 = 3T - 4.9T^2$ and so $4.9T^2 - 3T - 1.8 = 0$	M1 E1	Some attempt to use $s = ut + 0.5at^2$ with $a = \pm 9.8$ etc $s = \pm 1.8$ and $u = \pm 3$. Award for a = g even if answer to (A) wrong. Clearly shown. No need to show +ve required.	2
(C)	See over			
(C)	Time to reach 3 m s^{-1} is given by $3 = 0 + 2.5t$ so t = 1.2 remaining time is root of quad time is 0.98513… s Total 2.1851…so 2.19 s (3 s. f.) With the 11.2 N resistance acting to the right	B1 M1 B1 A1	Quadratic solved and + ve root added to time to break. Allow 0.98. [Award for answer seen WW] cao	
(i)	F + 11.2 = 8 × 2 so F = 4.8		The same scheme as above	
(iii)			The 11.2 N force may be in either direction, otherwise the same scheme	
(iv)	The same scheme with + 11.2 N instead of – 11.2 N acting on the box method (1) box N2L $\rightarrow 105 - T + 11.2 = 8a$ sphere as before			

	method (2) 105 + 11.2 – 58.8 = 14*a* These give *a* = 4.1 and *T* = 83.4	Allow 2.5 substituted in box equation to give *T* = 96.2 If the sign convention gives as positive the direction of the sphere descending, *a* = – 4.1. Allow substituting *a* = 2.5 in the equations to give *T* = 43.8 (sphere) or 136.2 (box).	
(v)		In (C) allow use of a = 4.1 to give time to break as 0.73117..s. and total time as 1.716…s	4
	20		

4761 Mechanics 1

1 (i)	$0 < t < 2$, $v = 2$ $2 < t < 3.5$ $v = -5$	B1 B1	Condone '5 downwards' and ' – 5 downwards'	2
(ii)		 B1 B1	Condone intent – e.g. straight lines free-hand and scales not labelled; accept non-vertical sections at $t = 2$ & 3.5. Only horizontal lines used and 1st two parts present. BOD t-axis section. One of 1st 2 sections correct. FT (i) and allow if answer correct with (i) wrong All correct. Accept correct answer with (i) wrong. FT (i) only if 2nd section –ve in (i)	2
(iii)	(A) upwards; (B) and (C) downwards	E1	All correct. Accept +/- ve but not towards/away from O Accept forwards/backwards. Condone additional wrong statements about position.	1
				5
2 (i)	$\begin{pmatrix}12\\9\end{pmatrix} = \begin{pmatrix}2\\-3\end{pmatrix} + 4\mathbf{a}$ so $\mathbf{a} = \begin{pmatrix}2.5\\3\end{pmatrix}$	M1 A1	Use of $\mathbf{v} = \mathbf{u} + \mathbf{a}t$ If vector **a** seen, isw.	2
(ii)	**either** $\mathbf{r} = \begin{pmatrix}-1\\2\end{pmatrix} + \begin{pmatrix}2\\-3\end{pmatrix} \times 4 + \frac{1}{2}\mathbf{a} \times 4^2$ $\mathbf{r} = \begin{pmatrix}27\\14\end{pmatrix}$ so $\begin{pmatrix}27\\14\end{pmatrix}$ m **or**	M1 A1 A1 M1 A1 A1	For use of $\mathbf{s} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$ with **their a.** Initial position may be omitted. FT **their a.** Initial position may be omitted. cao. Do not condone magnitude as final answer. Use of $\mathbf{s} = 0.5t(\mathbf{u} + \mathbf{v})$ Initial position may be omitted. Correct substitution. Initial position may be omitted. cao Do not condone mag as final answer. SC2 for $\begin{pmatrix}28\\12\end{pmatrix}$	3

(iii)	Using N2L $\mathbf{F} = 5\mathbf{a} = \begin{pmatrix}12.5\\15\end{pmatrix}$ so $\begin{pmatrix}12.5\\15\end{pmatrix}$ N	M1 F1	Use of $\mathbf{F} = m\mathbf{a}$ or $\mathbf{F} = mg\mathbf{a}$. FT **their a** only. Do not accept magnitude as final ans.	2
				7
3 (i)	$\lvert\mathbf{F}\rvert = \sqrt{(-1)^2 + 5^2}$ $= \sqrt{26} = 5.0990...$ = 5.10 (3 s. f.) Angle with **j** is arctan(0.2) so 11.309… so 11.3° (3 s. f.)	M1 A1 M1 A1	Accept $\sqrt{-1^2 + 5^2}$ even if taken to be $\sqrt{24}$ accept arctan(p) where $p = \pm 0.2$ or ± 5 o.e. cao	4
(ii)	$\begin{pmatrix}-2\\3b\end{pmatrix} = 4\begin{pmatrix}-1\\5\end{pmatrix} + \begin{pmatrix}2a\\a\end{pmatrix}$ $a = 1$, $b = 7$ so $\mathbf{G} = \begin{pmatrix}2\\1\end{pmatrix}$ and $\mathbf{H} = \begin{pmatrix}-2\\21\end{pmatrix}$ or $\mathbf{G} = 2\mathbf{i} + \mathbf{j}$ and $\mathbf{H} = -2\mathbf{i} + 21\mathbf{j}$	M1 M1 A1 A1	$\mathbf{H} = 4\mathbf{F} + \mathbf{G}$ soi Formulating at least 1 scalar equation from **their** vector equation soi a correct **or G** follows from their wrong a **H** cao	4
				8
4(i)	20cos 15 = 19.3185…. so 19.3 N (3 s. f.) in direction BC	B1	Accept no direction. Must be evaluated	1
(ii)	Let the tension be T T sin 50 = 19.3185…. so T = 25.2185… so 25.2 N (3 s. f.)	M1 F1	Accept $\sin \leftrightarrow \cos$ but not (i) × sin 50 FT **their** 19.3… only. cwo	2
(iii)	R + 20 sin 15 – 2.5g – 25.2185…× cos 50 = 0 R = 35.5337… so 35.5 N (3 s. f.)	M1 B1 A1 A1	Allow 1 force missing or 1 tension not resolved. FT T. No extra forces. Accept mass used. Accept $\sin \leftrightarrow \cos$. Weight correct All correct except sign errors. FT **their** T cao. Accept 35 or 36 for 2. s.f.	4
(iv)	The horizontal resolved part of the 20 N force is not changed.	E1	Accept no reference to vertical component but do not accept 'no change' to both components. No need to be explicit that value of tension in AB depends only on horizontal component of force at C	
				1
				8

5(i)	$a = 6t - 12$	M1 A1	Differentiating cao	2
(ii)	We need $\int_1^3 (3t^2 - 12t + 14)\mathrm{d}t$ $= \left[t^3 - 6t^2 + 14t\right]_1^3$ **either** $= (27 - 54 + 42) - (1 - 6 + 14)$ $= 15 - 9 = 6$ so 6 m **or** $s = t^3 - 6t^2 + 14t + C$ $s = 0$ when $t = 1$ gives $0 = 1 - 6 + 14 + C$ so $C = -9$ Put $t = 3$ to give $s = 27 - 54 + 42 - 9 = 6$ so 6 m.	M1 A1 M1 A1 M1 A1	Integrating. Neglect limits. At least two terms correct. Neglect limits. Dep on 1st M1. Use of limits with attempt at subtraction seen. cao Dep on 1st M1. An attempt to find C using $s(1) = 0$ and then evaluating $s(3)$. cao	4
(iii)	$v > 0$ so the particle always travels in the same (+ve) direction As the particle never changes direction, the final distance from the starting point is the displacement.	E1 E1	Only award if explicit Complete argument	
				2
				8
6 (i)	Component of weight down the plane is $1.5 \times 9.8 \times \frac{2}{7} = 4.2$ N	M1 E1	Use of mgk where k involves an attempt at resolution Accept $1.5 \times 9.8 \times \frac{2}{7} = 4.2$ or $14.7 \times \frac{2}{7} = 4.2$ seen	2
(ii)	Down the plane. Take F down the plane. $4.2 - 6.4 + F = 0$ so $F = 2.2$. Friction is 2.2 N down the plane	M1 A1	Allow sign errors. All forces present. No extra forces. Must have direction. [Award 1 for 2.2 N seen and 2 for 2.2 N down plane seen]	2
(iii)	F up the plane N2L down the plane $4.2 - F = 1.5 \times 1.2$ so $F = 4.2 - 1.8 = 2.4$ Friction is 2.4 N up the plane	M1 A1 A1 A1	N2L. $F = ma$. No extra forces. Allow weight term missing or wrong Allow only sign errors ± 2.4 cao. Accept no reference to direction if $F = 2.4$.	4
(iv)	$2^2 = 0.8^2 + 2 \times 1.2 \times s$ $s = 1.4$ so 1.4 m	M1 A1 A1	Use of $v^2 = u^2 + 2as$ or sequence All correct in 1 or 2-step method	3

(v)	Diagrams	B1	Frictions and coupling force correctly labelled with arrows.	
		B1	All forces present and properly labelled with arrows.	
	either			
	Up the plane	M1	N2L. $F = ma$. No extra forces. Condone sign errors.	
	$10 - 3.5\times 9.8\times \frac{2}{7} - (2.3+0.7) = 3.5a$		Allow total/part weight **or** total/part friction omitted (but not both). Allow mass instead of weight and mass/weight not or wrongly resolved.	
		B1	Correct overall mass and friction	
	$a = -0.8$ so 0.8 m s^{-2}.			
	down the plane	A1	Clear description or diagram	
	For barge B up the plane			
	$T - 2\times 9.8\times \frac{2}{7} - 0.7 = 2\times(-0.8)$	M1	N2L on one barge with **their** $\pm a$ ($\neq 1.2$ or 0). All forces present and weight component attempted. No extra forces. Condone sign errors.	
	$T = 4.7$ so 4.7 N. Tension	A1	cao	
	or (separate equations of motion)		In eom for A **or** B allow weight or friction missing and also allow mass used instead of weight and wt not or wrongly resolved. In other equn weight component attempted and friction term present.	
	Barge A	M1	N2L. Do not allow $F = mga$. No extra forces. Condone sign errors.	
	Barge B	M1	N2L. Do not allow $F = mga$. No extra forces. Condone sign errors.	
		M1	Solving a pair of equns in a and T	
	$a = -0.8$ so 0.8 m s^{-2}.			
	down the plane	A1	Clear description or diagram	
	$T = 4.7$ so 4.7 N. Tension	A1	cao cwo	
				7
				18
7 (i)	$y(0) = 1$	B1		1
	Either			
(ii)	$\frac{1}{2}(20+5) - 5 = 7.5$	M1	Use of symmetry e.g. use of $\frac{1}{2}(20+5)$	
		A1	12.5 o.e. seen	
		A1	7.5 cao	
	or	M1	Attempt at y' and to solve $y' = 0$	
		A1	$k(15 - 2x)$ where $k = 1$ or $\frac{1}{100}$	
		A1	7.5 cao, seen as final answer	
	$y(7.5) = \frac{1}{100}(100 + 15\times 7.5 - 7.5^2)$	M1	FT **their** 7.5	
	$= \frac{25}{16}$ (1.5625) so 1.5625 m	E1	AG [SC2 only showing 1.5625 leads to $x = 7.5$]	5

(iii)	$4.9t^2 = \frac{25}{16}$ (1.5625)	M1	Use of $s = ut + 0.5at^2$ with $u = 0$. Condone use of $\pm 10,\ \pm 9.8,\ \pm 9.81$. If sequence of *suvat* used, complete method required.	
	$t^2 = 0.31887\ldots$ so $t = \pm 0.56469\ldots$	A1	In any method only error accepted is sign error	
	Hence 0.565 s (3 s. f.)	E1	AG. Condone no reference to –ve value. www. 0.565 must be justified as answer to 3 s. f.	3
(iv)	$\dot{x} = \frac{12.5}{0.56469...} = 22.1359...$	M1	or 25 / (2×0.56469..)	
		B1	Use of 12.5 or equivalent	
	so 22.1 m s $^{-1}$ (3 s. f.))	E1	22.1 must be justified as answer to 3 s. f. Don't penalise if penalty already given in (iii).	
	Either			
	Time is $\frac{20}{12.5} \times 0.56469...$ s	M1		
	so 0.904 s (3 s. f.)	A1	cao Accept 0.91 (2 s. f.)	
	or			
	Time is $\frac{20}{22.1359...}$ s	M1		
	= 0.903507… so 0.904 s (3 s. f.)	A1	cao Accept 0.91 (2 s. f.)	
	or			
	(iii) $+ \frac{7.5}{\textbf{their } \dot{x}}$	M1		
	so 0.904 s (3 s. f.)	A1	cao Accept 0.91 (2 s. f.)	5
(v)	$v = \sqrt{\dot{x}^2 + \dot{y}^2}$	M1	Must have attempts at both components	
	$\dot{y}^2 = 0^2 + 2 \times 9.8 \times \frac{25}{16}$ or	M1	Or equiv. $u = 0$. Condone use of $\pm 10,\ \pm 9.8,\ \pm 9.81$.	
	$\dot{y} = 0 + 9.8 \times 0.5646...$		Accept wrong *s* (or *t* in alternative method)	
	= $\frac{245}{8}$ (30.625) or $\dot{y} = \pm 5.539...$	A1	Or equivalent. May be implied. Could come from (iii) if $v^2 = u^2 + 2as$ used there. Award marks again.	
	so $v = \sqrt{490 + 30.625}$ = 22.8172… m s $^{-1}$			
	so 22.8 m s $^{-1}$ (3 s. f.)	A1	cao. www	4
				18

OCR
RECOGNISING ACHIEVEMENT

GCE

Mathematics (MEI)

Advanced Subsidiary GCE **4761**

Mechanics 1

Mark Scheme for June 2010

Q 1		mark	notes
(i)	$v^2 = 0^2 + 2\times 9.8\times 0.75$	M1	Use of $v^2 = u^2 + 2as$ with $u = 0$ and $a = \pm g$. Accept muddled units and sign errors.
		A1	Allow wrong or wrongly converted units not sign errors
	$v = \pm 3.8340...$ so 3.83 m s^{-1} (3. s. f.)	A1	cao [SC2 for 38.3… seen WWW and SC3 for 3.83… seen WWW]
		3	
		3	

Q 2		mark	notes
(i)	Resolving	M1	Resolving in at least 1 of horiz or vert. Accept $\sin \leftrightarrow \cos$. No extra terms.
	$\leftarrow\ 250\sin 70 = 234.92...$ so 235 N (3 s. f.)	A1	Either both expressions correct (neglect direction) or one correct in correct direction
	$\uparrow\ 250\cos 70 = 85.5050...$ so 85.5 N (3 s. f.)	A1	cao Both evaluated and directions correct
		3	
(ii)	$250 \div 2 = 125$ N	B1	Accept $125g$ only if tension taken to be $250g$ in (i)
		1	
		4	

Q 3		mark	notes
(i)	$\begin{pmatrix}-1\\14\\-8\end{pmatrix} + \begin{pmatrix}3\\-9\\10\end{pmatrix} + \mathbf{F} = 4\begin{pmatrix}-1\\2\\4\end{pmatrix}$	M1	N2L. Allow sign errors in applying N2L. Do not condone $\mathbf{F} = m\mathbf{g}$**a.** Allow one given force omitted.
		M1	Attempt to add $\begin{pmatrix}-1\\14\\-8\end{pmatrix}$ and $\begin{pmatrix}3\\-9\\10\end{pmatrix}$
	$\mathbf{F} = \begin{pmatrix}-6\\3\\14\end{pmatrix}$	A1 A1	Two components correct cao
		4	
(ii)	$\mathbf{v} = \begin{pmatrix}-3\\3\\6\end{pmatrix} + 3\begin{pmatrix}-1\\2\\4\end{pmatrix} = \begin{pmatrix}-6\\9\\18\end{pmatrix}$ so $\begin{pmatrix}-6\\9\\18\end{pmatrix}$ m s^{-1}.	M1	$\mathbf{v} = \mathbf{u} + t\mathbf{a}$ with given **u** and **a**. Could go via **s**. If integration used, require arbitrary constant (need not be evaluated)
		A1	cao isw
	speed is $\sqrt{(-6)^2 + 9^2 + 18^2} = 21$ m s^{-1}.	M1	Allow -6^2 even if interpreted as – 36. Only FT **their v**.
		F1	FT their **v** only. [Award M1 F1 for 21 seen WWW]
		4	
		8	

Q 4		mark	notes
(i)	Diagram for P or Q Other diagram	B1 B1 2	Must be properly labelled with arrows Must be properly labelled with arrows consistent with 1st diagram Accept single diagram if clear.
(ii)	Let tension in rope be T N and accn ↑ a m s^{-2} For box P: N2L ↑ $1030 - 75g - T = 75a$ For box Q: N2L ↑ $T - 25g = 25a$	M1 A1 A1 3	N2L applied correctly to either part. Allow $F = mga$ and sign errors. Do not condone missing or extra forces. Direction of a consistent with equation for P. [Condone taking + ve downwards in either equation. +ve direction must be consistent in both equations to receive both A1s]
(iii)	tension is 257.5 N	M1 A1 2	Solving for T **their** simultaneous equations with 2 variables. cao CWO
		7	

Q 5		mark	notes
(i)	$270 - \arctan\left(\frac{6}{4}\right)$ = 213.69… so 214°	M1 A1 2	Award for arctan p seen where $p = \pm\frac{6}{4}$ or $\frac{4}{6}$, or equivalent cao
(ii)	Need $(-4 + 3k)\mathbf{i} + (-6 - 2k)\mathbf{j} = \lambda(7\mathbf{i} - 9\mathbf{j})$ * **either** so $\frac{-4+3k}{-6-2k} = \frac{7}{-9}$. or equivalent $k = 6$ **or** $-4 + 3k = 7\lambda$ $-6 - 2k = -9\lambda$ $k = 6$ **trial and error method**	M1 M1 A1 A1 M1 A1 A1 4	Attempt to get LHS in the direction of $(7\mathbf{i} - 9\mathbf{j})$. Could be done by finding (tangents of) angles. Accept the use of $\lambda = 1$. Attempt to solve **their** *. Allow = $\frac{7}{9}, \frac{9}{7}, -\frac{9}{7}$ Expression correct Award full marks for $k = 6$ found WWW Attempt to solve **their** *. Must have both equations. Correct equations Award full marks for $k = 6$ found WWW M1 any attempt to find the value of k and 'test' M1 Systematic attempt in (the equivalent of) **their** * Award full marks for $k = 6$ found WWW
		6	

Q6		mark	notes
(i)	Vertically		
.	$y = 8t - 4.9t^2$	M1	Use of $s = ut + 0.5at^2$ with $g = \pm 9.8,\ \pm 10$. Accept u = 0 or 14.4… or 14.4 $\sin\theta$ or $u\sin\theta$ but not 12 . Allow use of + 3.6.
		A1	Accept derivation of – 4.9 not clear. cao.
	Horizontally $x = 12t$	B1	
		3	
(ii)	**either**		
	Require $y = -3.6$	M1	Equating **their** y to ±3.6 or equiv. Any form.
	so $-3.6 = 8t - 4.9t^2$		
	Use of formula or $4.9(t-2)(t+\frac{18}{49}) = 0$	M1	A method for solving a 3 term quadratic to give at least 1 root. Allow **their** y and re-arrangement errors.
	Roots are 2 and $-\frac{18}{49}$ (= – 0.367346…)	A1	WWW. Accept no reference to 2nd root [Award SC3 for t = 2 seen WWW]
	Horizontal distance is 12 × 2 = 24	M1	FT **their** x and t.
	so 24 m	F1	FT only **their** t (as long as it is +ve and is not obtained with sign error(s) e.g. –ve sign just dropped)
	or		
	Require $y = -3.6$	M1	Equating **their** y to ±3.6 or equiv. Any form.
	so $-3.6 = 8t - 4.9t^2$		
	Eliminate t between		
	$x = 12t$ and $-3.6 = 8t - 4.9t^2$	M1	Expressions in any form. Elimination must be complete
	so $0 = 3.6 + \frac{8x}{12} - \frac{4.9x^2}{144}$	A1	Accept in any form. May be implied.
	Use of formula or factorise	M1	A method for solving a 3 term quadratic to give at least 1 root. Allow **their** y and re-arrangement errors.
	+ve root is 24 so 24m	F1	FT from **their** quadratic after re-arrangement. Must be +ve.
	or		
	Methods that divide the motion into sections		
	Projection to highest point (A)		
	Highest point to level of jetty (B)		
	Level of jetty to sea (C)		
	Combination of A, B and C may be used	M1	Attempt to find times or distances for sections that give the total horizontal distance travelled
		M1	Correct method for one section to find time or distance
	(A) 0.8163.. s; 9.7959.. m: (B) 0.816…s; 9.7959.. m (C): 0.3673… s; 4.4081… m	A1	Any time or distance for a section correct
		A1	2nd time or distance correct (The two sections must not be A and B)
		A1	cao
		5	
		8	

Q 7		mark	notes
(i)			
(A)	4 m	B1	
(B)	$12 - (-4) = 16$ m	M1	Looking for distance. Need evidence of taking account of +ve and –ve displacements.
		A1	
(C)	$1 < t < 3.5$	B1	The values 1 and 3.5
		B1	Strict inequality
(D)	$t = 1$, $t = 3.5$	B1	Do not award if extra values given.
		6	
(ii)	$v = -8t + 8$	M1	Differentiating
		A1	
	$a = -8$	F1	
		3	
(iii)	$-8t + 8 = 4$ so $t = 0.5$ so 0.5 s	B1	FT **their** v.
	$-8t + 8 = -4$ so $t = 1.5$ so 1.5 s	B1	FT **their** v.
		2	
(iv)	**method 1**		
	Need velocity at $t = 3$		
	$v(3) = -8 \times 3 + 8 = -16$	B1	FT **their** v from (ii)
	either		
	$v = \int 32 \, dt = 32t + C$	M1	Accept $32t + C$ or $32t$. SC1 if $\int_3^4 32 dt$ attempted.
	$v = -16$ when $t = 3$ gives $v = 32t - 112$	A1	Use of **their** -16 from an attempt at v when t=3
	$y = \int (32t - 112) dt = 16t^2 - 112t + D$	M1	FT **their** v of the form $pt + q$ with $p \neq 0$ and $q \neq 0$.
			Accept if at least 1 term correct. Accept no D.
	$y = 0$ when $t = 3$		
	gives $y = 16t^2 - 112t + 192$	A1	cao.
	or		
	$y = -16 \times (t-3) + \frac{1}{2} \times 32 \times (t-3)^2$	M1	Use of $s = ut + \frac{1}{2}at^2$
		A1	Use of **their** -16 (not 0) from an attempt at v when t=3 and 32. Condone use of just t
		M1	Use of $t \pm 3$
		A1	cao
	(so $y = 16t^2 - 112t + 192$)		
	method 2		
	Since accn is constant, the displacement y is a quadratic function. Since we have $y = 0$ at $t = 3$ and $t = 4$		
	$y = k(t-3)(t-4)$	M1	Use of a quadratic function (condone no k)
		A1	Correct use of roots
		B1	k present
	When $t = 3.5$, $y = -4$		
	so $-4 = k \times \frac{1}{2} \times -\frac{1}{2}$	M1	Or consider velocity at $t = 3$
	so $k = 16$ (and $y = 16t^2 - 112t + 192$)	A1	cao. Accept k without y simplified.
		5	
		16	

Q8		mark	notes
(i)	N2L **i** direction $150 = 250a$ $a = 0.6$ so 0.6 m s^{-2}	 M1 A1 2	 Use of N2L. Allow $F = mga$. Accept no reference to direction
(ii)	150 N – **i** direction	B1 B1 2	 Allow correct description or arrow [Accept '– 150 in **i** direction' for B1 B1]
(iii)	For force only in direction perp to **i** $300\sin 40 = 450\sin\theta$ $\theta = 25.37300\ldots$ so 25.4° (3 s. f.) In **i** direction $300\cos 40 + 150 + 450\cos\theta$ 786.4017… so 786**i** N (3 s. f.)	 M1 B1 A1 M1 A1 6	 Resolution of both terms attempted. Allow sin ↔ cos if in both terms. Allow 250 or 250g present. 300sin40 or 450sinθ Accept ± . Accept answer rounding to 25.5. Allow SC1 if seen in this part. Proper resolution attempted of 450 **and** 300. Allow sin ↔ cos if in both terms Accept use of **their** θ or just θ. Either resolution correct. Accept **their** θ or just θ. Accept sin/cos consistent with use for cpt perpendicular to **i.** Accept no reference to direction cao. Allow SC1 WW
(iv)	Using $s = ut + 0.5at^2$ $1 = 0.5a \times 2^2$ $a = 0.5$ Using N2L in **i** direction 786.4017… $– F = 250 \times 0.5$ 661.4017… so 661 N (3 s. f.)	 M1 A1 M1 A1 E1 5	 Appropriate (sequence of) *suvat* [WW M0 A0] Use of $F = ma$ with **their** 786.4 and **their** a. No extra forces. Allow sign errors. All correct using **their** 786.4 and a Use of N2L clearly shown. (Accept 0.5 used WW)
(v)	Using N2L in **i** direction **either** $125 - 200 = 250a_1$ **or** (starting again) $786.4017\ldots – (200 + 661.4017\ldots) = 250\ a_1$ so $a_1 = – 0.3$ Using $v^2 = u^2 + 2\ a_1 s$ $v^2 = 1.8^2 + 2 \times (– 0.3) \times 1.65$ $v = 1.5$ so 1.5 m s^{-1}	 M1 F1 M1 F1 A1 5	 Use of $F = ma$ with **their** values. Allow 1 force missing FT only **their** 786… and **their** 661 Appropriate (sequence of) *suvat* with $u \neq 0$. Must be 'new' a obtained by using N2L. Only FT use of ± **their** a_1 cao
		20	

OCR
RECOGNISING ACHIEVEMENT

GCE

Mathematics (MEI)

Advanced Subsidiary GCE

Unit **4761:** Mechanics 1

Mark Scheme for January 2011

comment

You should expect to follow through from one part to another unless the scheme says otherwise but not follow through within a part unless the scheme specifies this.
Each script must be viewed as a whole at some stage so that
(i) a candidate's writing of letters, digits, symbols on diagrams etc can be better interpreted;
(ii) repeated mistakes can be recognised (e.g. calculator in wrong angle mode throughout – penalty 1 in the script and FT except given answers).

You are advised to 'set width' for most questions but to 'set height' for the following:

Q 1		mark	note
(i)		B1 B1 2	Section from $t = 10$ to $t = 15$ Section from $t = 15$ to $t = 20$. FT connecting from their point when $t = 15$. Ignore graph outside $0 \le t \le 20$.
(ii)	$\frac{-6-14}{10} = -2$ so -2 m s^{-2}	M1 A1 2	Attempt at $\frac{\Delta v}{\Delta t}$
(iii)	**either** Displacement is $\frac{14}{2}\times 7 - \frac{13+5}{2}\times 6$ or $\frac{14}{2}\times 7 - \frac{3\times 6}{2} - 5\times 6 - \frac{5\times 6}{2}$ $= -5$ so 5 m downwards	M1 B1 B1 A1	FT misread from graph or graphing error to all but final A1 cao Attempt at whole area. Condone 'overlap' but not 'gaps'. 'Positive' area expression correct. Condone sign error. 'Negative' area expression correct. Condone overall sign error. Accept –5 m cao

	or Displacement is $14\times10+\frac{1}{2}\times(-2)\times10^2-\ 5\times 6+\ \frac{-6+0}{2}\times5$ $= 140 – 100 – 30 –15 = –5$ so 5 m downwards	 M1 A1 B1 A1 4	 Using *suvat* from 0 to 10 or 15 to 20. Condone 'overlap' but not 'gaps' Subtracting 30 or 15 or 45 Accept –5 m cao
		8	

Q 2		**mark**	**notes**
(i)	$\mathbf{F} = (10 – 8\cos50)\mathbf{i} + 8\sin50\mathbf{j}$ $= 4.85769…\mathbf{i} + 6.128355…\ \mathbf{j}$ so $4.86\mathbf{i} + 6.13\mathbf{j}$ (3 s. f.)	M1 A1 A1 3	Resolution. Accept $s \leftrightarrow c$. Condone resolution in only one direction. Award for a vector with either component correct or consistent $s \leftrightarrow c$ error is only mistake in the vector. Need not be evaluated. cao. Must be in $a\mathbf{i} + b\mathbf{j}$ or column format. Must be correct to 3 s. f.
(ii)	$\lvert\mathbf{F}\rvert = \sqrt{4.85769...^2 + 6.12835...^2} = 7.820101...$ so 7.82 (3 s. f.) angle is $\arctan\frac{4.857...}{6.128...}$ $= 38.40243…$ so 38.4° (3 s. f.)	 B1 M1 F1 3	 FT **their F** Or equivalent. FT **their F.** Accept $\arctan\frac{6.128...}{4.857...}$. Accept complementary angle and ± signs FT only **their** *F*.
		6	

Q 3		mark	notes
(i)	For P: the distance is $8T$	B1	Allow – ve. Allow any form.
	For Q: the distance is $\frac{1}{2}\times 4\times T^2$	B1 2	Allow – ve. Allow any form.
(ii)	Require $8T+\frac{1}{2}\times 4\times T^2=90$	M1	For linking correct expressions or **their** expressions from (i) with 90. Condone sign errors and use of displacement instead of distance. Condone '= 0'implied.
		A1	The expression is correct or correctly derived from **their** (i). Reason not required.
	so $8T + 2T^2 – 90 = 0$ so $T^2 + 4T – 45 = 0$	E1	Must be established. Do not award if **their** 'correct expression' comes from incorrect manipulation.
	This gives $(T – 5)(T + 9) = 0$	M1	Solving to find +ve root. Accept $(T + 5)(T – 9)$.
	so $T = 5$ since $T > 0$	A1 5	Condone 2nd root not found/discussed but not both roots given.
		7	

Q 4		mark	notes
(i)	When $t = 1$, $\mathbf{r} = \begin{pmatrix} 8 \\ 10-2 \end{pmatrix} = \begin{pmatrix} 8 \\ 8 \end{pmatrix}$ $[8\mathbf{i} + (10-2)\mathbf{j} = 8\mathbf{i} + 8\mathbf{j}]$ Bearing OP is 045°	 B1 F1 2	Accept column or $a\mathbf{i} + b\mathbf{j}$ notation May be implied Accept 45°. Accept NE and northeast. Condone $\lvert\mathbf{r}\rvert$ given as well.
(ii)	$\mathbf{v} = \begin{pmatrix} 8 \\ 20t - 6t^2 \end{pmatrix}$ $[8\mathbf{i} + (20t - 6t^2)\mathbf{j}]$ The **i** cpt is always 8 so $\mathbf{v} \neq \mathbf{0}$ for any t	M1 A1 E1 3	Differentiating both components. Condone 1 error if clearly attempting differentiation. Must be a vector answer. Accept any correct argument e.g. based on **i** cpt never 0.
(iii)	$\mathbf{a} = \begin{pmatrix} 0 \\ 20-12t \end{pmatrix}$ $[(20 - 12t)\mathbf{j}]$ $\mathbf{a} = \mathbf{0}$ when $t = \frac{20}{12} = \frac{5}{3}$ so $\frac{5}{3}$ s (1.67 s (3 s. f.))	M1 F1 B1 3	Differentiating as a vector. Condone 1 error if clearly attempting differentiation of **their v**. FT **their v**. cao. Condone obtained from scalar equation.
		8	

Q5		mark	notes
(i)	In direction $\rightarrow$ $0^2 = 1.5^2 + 2 \times a \times 0.375$ so $a = -3$ and deceleration is 3 m s^{-2} N2L on both boxes $\rightarrow$ $-2F = (12+6) \times (-3)$ so $F = 27$	M1 A1 M1 A1 4	Use of $v^2 = u^2 + 2as$ or complete sequence of *suvat.* CWO. Accept ± 3 and ignore accel or decal. N2L. Correct mass. Condone $F = mga$. Allow F on LHS. FT **their** a. Accept sign errors. No extra terms. cao Condone this obtained from an equation with consistent signs not justified.
(ii)	Suppose the force in the rod is a tension T N2L gives box A $\rightarrow$ $T - 27 = 12 \times (-3)$ [box B $\rightarrow$ $-T - 27 = 6 \times (-3)$] so $T = -9$ and the force has magnitude 9 N It is a thrust (tension is +ve).	 M1 F1 E1 3	 N2L. $F = ma$. Correct mass. The '27' and the '3' must have the same sign. Ignore the sign of 'T'. FT only for mod(their 27) in place of '27' and/or mod(their 3) in place of '3' in this sign pattern. No extra terms. Accept $T = \pm 9$. FT only for mod(their 27) in place of '27' and/or mod(their 3) in place of '3'. cao Only accept thrust with $T = \pm 9$ and a sound argument.
		7	

Q 6		mark	notes
(i)	Let tension be T N N2L $\rightarrow$ $T - 6 = 4 \times 3$ T = 18 so 18 N	 M1 A1 A1 3	 Condone $F = mga$. Condone resistance omitted or an extra force. Allow only sign error(s). cao
(ii)	Let acceleration be a m s^{-2} $25\cos 40 - 6 = 4a$ a = 3.28777.. so 3.29 m s^{-2} (3 s. f.)	 M1 M1 A1 3	 Attempt at resolution of 25 N. Allow $s \leftrightarrow c$. Allow $F = mga$ and sign error(s). No extra forces. Both forces present. cao
(iii)	Let tension be T N up the slope $T + 6 - 4 \times 9.8 \times \sin 35 = 0$ T = 16.48419… so 16.5 N (3 s. f.)	 M1 B1 A1 3	 Resolving along slope. Allow 6 N omitted. If different direction used all required forces present (except 6 N). Allow $s \leftrightarrow c$. No extra forces. Allow sign errors. Condone g omitted. If resolution is along plane, weight term correct. If resolution in another direction, one resolution correct.
(iv) (A)		 B1 B1 2	 At least two of tension, weight and NR marked correctly with arrows and labels (accept *mg*, *W*, *T* and words etc). All correct. No extra forces. Accept *mg*, *W*, *T* and words etc. Condone resolved parts as well only if clearly indicated as such by e.g. using dotted lines.
(B)	**continued**		

Q6 (iv) (B)	up the slope $25\cos\theta + 6 - 4g\sin 35 = 0$ so $25\cos\theta = 16.48414...$ so $\theta = 48.7483....$ so 48.7° (3 s. f.)	M1 A1 A1 3	No extra forces. Allow $s \leftrightarrow c$. All forces present and required resolutions attempted. Allow sign errors. Condone *g* omitted. Condone *g* omitted. cao [If they use **their** (iii): M1 Equating **their** (iii) to an attempt at resolving 25. Allow $s \leftrightarrow c$. No extra forces. A1 FT **their** *T* from (iii) A1 cao]
(C)	Resolve perp to slope $R + 25\sin\theta - 4\times 9.8\times\cos 35 = 0$ *R* = 13.315248.. so 13.3 N (3 s. f.)	M1 A1 A1 3	All forces present and resolutions attempted. No extra forces. Allow $s \leftrightarrow c$. FT their angle. Condone *g* omitted. FT their angle. Condone *g* omitted. cao
		17	

Q7		**mark**	**notes**
(i) (A)	$x = Ut\cos 68.5°$	B1 1	
(i) (B)	$y = Ut\sin 68.5° - 4.9\times t^2$	M1 A1 2	Allow '*u*' = *U*. Allow $s \leftrightarrow c$. Allow *g* as *g*, ±9.8, ±9.81, ±10. Allow +2. Accept not 'shown'. Do not allow +2. Allow e.g + 0.5 × (- 9.8) × t^2 instead of – 4.9t^2. Accept *g* not evaluated
	continued		

Q7 (ii)	**either** At D, $y = 0$ so $U\sin 68.5°T - 4.9\times T^2 = 0$ $\Rightarrow T\left(U\sin 68.5° - 4.9T\right) = 0$ so $T = 0$ (at C) or $T = \dfrac{U\sin 68.5°}{4.9}$ (at D) **or** Use (i)(A) and put $x = 10$ with $t = T$ to get $UT\cos 68.5° = 10$	 M1 M1 E1 M1 M1 E1 B1 4	 Equating correct y to 0 or **their** y to correct value. Attempting to factorise (or solve). Allow ÷ T without comment. Properly shown. Accept no ref to $T = 0$. Accept $T = 0$ given as well without comment. Find time to top Double time to the top
(iii)	Eliminating T from the results in (ii) gives $U\cos 68.5°\times\dfrac{U\sin 68.5°}{4.9} = 10$ so $U = 11.98729\ldots$ so 12.0 (3 s. f.)	 M1 M1 E1 3	 Substituting, using correct expressions or **their** expressions from (ii). Attempt to solve for U^2 or U. Some evidence seen. e.g. $142.8025.. < U^2 < 145.2025...$ with clear statement, or 11.9… seen with clear statement or 11.98… seen. Accept 11.98… seen for full marks.
(iv)	**continued**		

(iv)	Require $Ut\sin 68.5° - 4.9t^2 = -2$	M1	Equating correct y to -2 or **their** y to correct value. Allow use of U, 11.987… or 12. Allow implicit '= 0'
	Solving $4.9t^2 - Ut\sin 68.5° - 2 = 0$	M1	Dep on 1st M1. Attempt to solve a 3 term quadratic to find at least the +ve root. Allow if two correct roots seen WW.
	$t = -$ 0.1670594541… , 2.4431591… (Using 12: – 0.1669052502.. , 2.445478886..)	A1	Accept only + ve root given
			Alternative method of e.g. finding time to highest point and then time to the ground. M1 all times attempted, at least one by a sound method. M1 both methods sound and complete. A1.
	Require $U\cos 68.5° \times 2.44… - 10$ = 0.7336…. so 0.734 m (3 s. f.) (Using 12 consistently, 0.7552… so 0.755 (3 s. f.))	M1 A1	Dep on first M1. Allow **their** expression for x. Allow ' – 10' omitted. cao. Accept $0.73 \le x \le 0.76$
		5	
(v)	Eliminate t from (i) (B)		
	using $t = \dfrac{x}{U\cos 68.5°}$ from (i)(A)	M1	May be implied. FT their (i).
	so $y = x\tan 68.5° - \dfrac{4.9x^2}{U^2(\cos 68.5°)^2}$	E1	Clearly shown.
	We require $y = 0$ when $x = 10$	M1	Must see attempt to solve. Or use $x = 10.73…$ when $y = -2$.
	so $U = 11.98729…$ so 12.0 (3 s. f.)	E1	Must see evidence of fresh calculation or statement that they have now got the same expression for evaluation.
		4	
		19	

OCR
RECOGNISING ACHIEVEMENT

GCE

Mathematics (MEI)

Advanced Subsidiary GCE

Unit **4761:** Mechanics 1

Mark Scheme for June 2011

Oxford Cambridge and RSA Examinations

comment

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Each script must be viewed as a whole at some stage so that
(i) a candidate's writing of letters, digits, symbols on diagrams etc can be better interpreted;
(ii) repeated mistakes can be recognised (e.g. calculator in wrong angle mode throughout – penalty 1 in the script and FT except given answers).

You are advised to 'set height' in *scoris*, particularly for question 7(ii). Questions 5 and 8(v) also spread onto two pages.

Q 1		**m a r k**	notes
	$v^2 = 11^2 + 2\times(-9.8)\times 2.4$	M1	Use of $v^2 = u^2 + 2as$ or complete sequence of correct *suvat*. Accept sign errors in substitution.
		A1	All correct
	v = 8.6 so 8.6 m s $^{-1}$.	A1	cao [Award all marks if 8.6 seen WWW] Do not condone ±8.6.
		3	

Q 2		mark	comment
	either for u first: $8 = \frac{1}{2}(u + 2.25) \times 32$ $u = -1.75$ so 1.75m s^{-1} $2.25 = -1.75 + 32a$ $a = 0.125$ so 0.125 m s^{-2} Directions of u and a are defined	 M1 A1 M1 F1 F1 5	 Using $s = \frac{1}{2}(u + v)t$ Use of any appropriate *suvat* with **their** values and correct signs Sign must be consistent with their u, FT from their value of u Establish directions of both u and a in terms of A and B. May be shown by a diagram, eg showing A and B and a line between them together with an arrow to show the positive direction. Without a diagram, the wording must be absolutely clear: eg do not accept left/right, forwards/backwards without a diagram or more explanation. Dependent on both M marks.
	Or for a first: $8 = 2.25 \times 32 - \frac{1}{2} \times a \times 32^2$ $a = 0.125$ so 0.125 m s^{-2} $2.25 = u + 32 \times 0.125$ $u = -1.75$ so 1.75m s^{-1} Directions of u and a are defined	 M1 A1 M1 F1 F1 5	 Using $s = vt - \frac{1}{2}at^2$ Use of any appropriate *suvat* with **their** values and correct signs Sign must be consistent with their a, FT from their value of a Establish directions of both u and a in terms of A and B. May be shown by a diagram, eg showing A and B and a line between them together with an arrow to show the positive direction. Without a diagram, the wording must be absolutely clear: eg do not accept left/right, forwards/backwards without a diagram or more explanation. Dependent on both M marks.
	Or *using simultaneous equations* Set up one relevant equation with a and u. Set up second relevant equation with a and u. Solving to find $u = -1.75$ so 1.75m s^{-1} Solving to find $a = 0.125$ so 0.125 m s^{-2} Directions of u and a are defined	 M1 M1 A1 F1 F1 5	 Using **one** of $v = u + at$, $s = ut + \frac{1}{2}at^2$ and $v^2 = u^2 + 2as$ Using **another** of $v = u + at$, $s = ut + \frac{1}{2}at^2$ and $v^2 = u^2 + 2as$ FT from their value of u or a, whichever found first Establish directions of both u and a in terms of A and B. May be shown by a diagram, eg showing A and B and a line between them together with an arrow to show the positive direction. Without a diagram, the wording must be absolutely clear: eg do not accept left/right, forwards/backwards without a diagram or more explanation. Dependent on both M marks.
		5	

Q 3		mark	Notes
(i)	$-6 = -2 \times 3$ so $y = 3 \times 3 = 9$ and $z = -4 \times 3 = -12$	M1 A1 2	May be implied Both correct [Award 2 for both correct answers seen WW]
(ii)	$\begin{pmatrix}-2\\3\\-4\end{pmatrix}+\begin{pmatrix}3\\-5\\-1\end{pmatrix}=5\mathbf{a}$	M1	Use of Newton's 2nd Law in vector form for all 3 cpts of attempted resultant Treat use of wrong vectors as MR.
		B1	Correct LHS
	$\mathbf{a}=\begin{pmatrix}0.2\\-0.4\\-1\end{pmatrix}$ so accn is $\begin{pmatrix}0.2\\-0.4\\-1\end{pmatrix}$ m s^{-2}	A1	The acceleration may be written as a magnitude in a given direction.
	Magnitude is $\sqrt{0.2^2+(-0.4)^2+(-1)^2}$	M1	FT **their** values. Condone missing brackets. Condone no – signs.
	= 1.09544… so 1.10 m s^{-2}, (3 s. f.)	F1 5	Accept 1.1. Accept surd form. Must come from a vector with 3 non-zero components for **a**
		7	

Q 4		mark	Comment
(i)		B1 B1 2	Any one force in correct direction correctly labelled with arrow **or** all forces with correct directions and arrows. A force may be replaced by its components if labelled correctly eg *m*gcos20°, *m*gsin20°. All correct (Accept words for labels and weight as *W*, *mg*, 147 (N)) No extra or duplicate forces. Do not allow force **and** its components unless components are clearly distinguished, eg by broken lines.
(ii)	**Either** Up the plane $P\cos 20 - 15 \times 9.8 \times \sin 20 = 0$ $P = 53.50362\ldots$ so 53.5 (3 s. f.)	 M1 A1 A1 3	 Attempt to resolve at least one force up plane. Accept mass not weight. No extra forces. If other directions used, all forces must be present but see below for resolving vertically and horizontally. Accept only error as consistent $s \leftrightarrow c$. Cao
	Or Vertically and horizontally $R\cos 20° = 15g, \quad R\sin 20° = P$ Eliminate R $P = \dfrac{15g}{\cos 20°} \times \sin 20°$ $P = 53.5$ (3.s.f.)	 M1 A1 A1 3	 Attempt to resolve all forces both horizontally and vertically and attempt to combine into a single equation. No extra forces. Accept $s \leftrightarrow c$. Accept mass not weight. Accept only error as consistent $s \leftrightarrow c$. Cao
	Or Triangle of forces Triangle drawn and labelled $\dfrac{P}{15g} = \tan 20°$ $P = 53.5$ (3.s.f.)	 M1 A1 A1 3	 All sides must be labelled and in correct orientation; three forces only; condone no arrows Oe Cao
		5	

Q 5		m a r k	notes
	Usual notation **either** consider height: Attempt to substitute for u and a in $s = ut + \frac{1}{2}at^2$ $y = 30\sin 35\ t - 4.9t^2$ Need $y = 0$ for time of flight T giving $T = \dfrac{30\sin 35}{4.9}$ (= 3.511692…)	 M1 A1 B1 A1	 Accept: g as g, ±9.8, ±9.81, ±10; $u = 30$; s ↔ c . Derivation need not be shown cao. Any form. May not be explicit.
	Or Consider time to top Attempt to substitute for u and a in $v = u + at$ $v = 30\sin 35 - 9.8t$ Need $v = 0$ and to double for time of flight T giving $T = \dfrac{30\sin 35}{4.9}$ (= 3.511692…)	 M1 A1 B1 A1	 Accept: g as g, ±9.8, ±9.81, ±10; $u = 30$; s ↔ c . Derivation need not be shown cao. Any form. May not be explicit.
	then $x = 30\cos 35\ T$ so $x = 30\cos 35 \times \dfrac{30\sin 35}{4.9}$ (= 86.29830…) Required time for sound is x/343 Total time is 3.511692… + 0.251598… = 3.76329… so 3.76 s (3 s. f.)	 M1 F1 M1 A1	 Accept s ↔ c if consistent with above FT for their time Condone consistent s ↔ c error (which could lead to correct answer here). FT from their x cao following fully correct working throughout question.
		8	

Q6		mark	notes
			Column vectors may be used throughout; lose 1 mark once if **j** components put at top or if fraction line included. . Notation used must be clear.
	Either using *suvat*:		
(i)	Use of $\mathbf{v} = \mathbf{u} + t\mathbf{a}$	M1	substitution required. Must be vectors.
	$\mathbf{v} = 4\mathbf{i} - 2t\mathbf{j}$	A1	
	Use of $\mathbf{r} = (\mathbf{r}_0 +) \ t\mathbf{u} + \frac{1}{2} t^2\mathbf{a}$	M1	substitution required. $\mathbf{r}_0$ not required. Must be vectors.
	$+ 3\mathbf{j}$	B1	May be seen on either side of a meaningful equation for **r**
	$\mathbf{r} = 4t\mathbf{i} + (3 - t^2)\mathbf{j}$	A1	Accept $\mathbf{r} = 3\mathbf{j} + 4t\mathbf{i} - \frac{1}{2} \times 2 \times t^2 \ \mathbf{j}$ oe written in a correct notation. Isw, providing not reduced to scalar: (see 12c in marking instructions)
		5	
	Or using integration:		
	$\mathbf{v} = \int \mathbf{a} dt$	M1	Attempt at integration. Condone no '+**c**'. Must be vectors.
	$\mathbf{v} = 4\mathbf{i} - 2t\mathbf{j}$	A1	cao
	$\mathbf{r} = \int \mathbf{v} dt$	M1	Integrate their **v** but must contain 2 components. Must be vectors.
	$+ 3\mathbf{j}$	B1	May be seen on either side of a meaningful equation for **r**
	$\mathbf{r} = 4t\mathbf{i} + (3 - t^2)\mathbf{j}$	A1	Accept $\mathbf{r} = 3\mathbf{j} + 4t\mathbf{i} - \frac{1}{2} \times 2 \times t^2 \ \mathbf{j}$ oe written in a correct notation. Isw, providing not reduced to scalar: (see 12e in marking instructions)
		5	
		5	
(ii)	$\mathbf{v}(2.5) = 4\mathbf{i} - 5\mathbf{j}$	B1	FT **their v**
	Angle is $(90+) \arctan\frac{5}{4}$	M1	Award for arctan attempted oe. FT **their** values. Allow argument to be ± (**their i** cpt)/(**their j** cpt) or ± (**their j** cpt)/(**their i** cpt). Allow this mark if bearing of position vector attempted.
	= 141.34019… so 141° (3 s. f.)	A1	cao
		3	
		8	

Q7		mark	notes
(i)	$\frac{-20}{2} = -10$ -10 m s^{-2}	M1 A1 2	Use of a suitable triangle to attempt at $\Delta v / \Delta t$ for suitable interval. Accept wrong sign. cao. Allow both marks if correct answer seen.
(ii) (A) **(B)**	Signed area under graph $\frac{1}{2} \times 2 \times 20 = 20$	M1 A1	Using the relevant area or other complete method
	either using areas Signed area $2 \le t \le 5$ is $\frac{1}{2} \times \big((5-2)+(4.5-2.4)\big) \times (-4) = -10.2$ Signed area $5 \le t \le 6$ is $\frac{1}{2} \times 1 \times 8 = 4$ Total displacement is 13.8 m	 B1 B1 B1	 Allow + 10.2. cao but FT from their 20 in part (A)
	or using *suvat* From $t = 0$ to $t = 2.4$: 19.2 From $t = 4.5$ to $t = 6$: 3.0 From $t = 2.4$ to $t = 4.5$: -8.4 Total : 13.8	 B1 B1 B1	 Both required and both must be correct.
		5	
(iii)	$a = 4t - 14$ $a(0.5) = -12$ so -12 m s^{-2}	M1 A1 A1 3	Differentiate. Do not award for division by t.
(iv)	Model A gives -4 m s^{-1} For model B we need v when $a = 0$ $v\left(\frac{7}{2}\right) = -4.5$ so model B is 0.5 m s^{-1} less	B1 M1 A1 F1 4	May be implied by other working Using (iii) or an argument based on symmetry or sketch graph that $a = 0$ when $t = 3.5$ Accept values without more or less

(v)			Do not penalise poor notation
	Displacement is $\int_0^6 \left(2t^2 - 14t + 20\right) \mathrm{d}t$	M1	Limits not required.
	$= \left[\frac{2t^3}{3} - 7t^2 + 20t\right]_0^6$	A1	Limits not required. Accept 2 terms correct.
		M1	Substitute limits
	= 12 so 12 m.	A1	cao. Accept bottom limit not substituted.
		4	
		18	

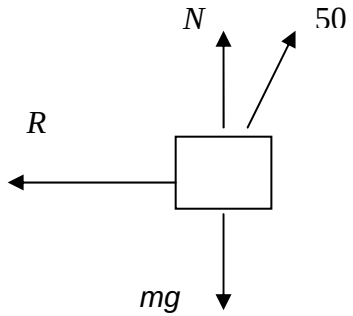
Q 8		mark	notes
(i)	25 N	B1 1	Condone no units. Do not accept -25 N.
(ii)	50 cos25 = 45.31538… so 45.3 N (3 s. f.)	M1 A1 2	Attempt to resolve 50 N. Accept s ↔ c . No extra forces. cao but accept – 45.3.
(iii)	Resolving vertically $R + 50 \sin 25 - 8 \times 9.8 = 0$ R = 57.26908… so 57.3 N (3 s. f.)	M1 A1 A1 3	All relevant forces with resolution of 50 N. No extras. Accept s ↔ c . All correct.
(iv)	Newton's 2nd Law in direction DC $50\cos 25 - 20 = 18a$ a = 1.4064105… so 1.41 m s^{-2} (3 s. f.)	M1 A1 A1 3	Newton's 2nd Law with m = 18. Accept $F = mga$. Attempt at resolving 50 N. Allow 20 N omitted and s ↔ c . No extra forces. Allow only sign error and s ↔ c . cao
Q8 (v)	continued Resolution of weight down the slope	 B1	 mgsin5° where m = 8 or 10 or 18, wherever first seen
	either Newton's 2nd Law down slope overall $18 \times 9.8 \times \sin 5 - 20 = 18a$ a = – 0.2569… Newton's 2nd Law down slope. Force in rod can be taken as tension or thrust. Taking it as tension T gives For D: $10 \times 9.8 \times \sin 5 - 15 - T = 10a$ (For C: $8 \times 9.8 \times \sin 5 - 5 + T = 8a$) T = – 3.888… = - 3.89 N (3 s. f.) The force is a thrust	 M1 A1 M1 F1 A1 A1	 $F = ma$. Must have 20 N and m = 18. Allow weight not resolved and use of mass. Accept s ↔ c and sign errors (including inconsistency between the 15 N and the 5 N). cao $F = ma$. Must consider the motion of either C or D and include: component of weight, resistance and T. No extra forces. Condone sign errors and s ↔ c . Do not condone inconsistent value of mass. FT only applies to a, and only if direction is consistent. '+T' if T taken as a thrust '-T' if T taken as a thrust If T taken as thrust, then T = +3.89. Dependent on T correct

	or Newton's 2nd Law down slope. Force in rod can be taken as tension or thrust. Taking it as tension T gives For C: $8\times9.8\times\sin5-5+T=8a$ For D: $10\times9.8\times\sin5-15-T=10a$ a = – 0.2569… T = – 3.888… = - 3.89 N (3s.f.) The force is a thrust	M1 M1 A1 A1 F1 A1	$F = ma$. Must consider the motion of C and include: component of weight, resistance and T. No extra forces. Condone sign errors and s ↔ c. Do not condone inconsistent value of mass. $F = ma$. Must consider the motion of D and include: component of weight, resistance and T. No extra forces. Condone sign errors and s ↔ c. Do not condone inconsistent value of mass. Award for either the equation for C or the equation for D correct. '$-T$' if T taken as a thrust '$+T$' if T taken as a thrust First of a and T found is correct. If T taken as thrust, then T = +3.89. The second of a and T found is FT Dependent on T correct
	then After 2 s: $v = 3 + 2 \times a$ v = 2.4860303.. so 2.49 m s^{-1} (3 s. f.)	 M1 F1 9	 Allow sign of a not followed. FT their value of a. Allow change to correct sign of a at this stage. FT from magnitude of **their** a but must be consistent with its direction.
		18	

Question			Answer	Marks	Guidance
1	*(A)*		False This is a speed-time graph not one for displacement-time	M1 A1	**Notice** that the runner may have returned to his starting place or may not; the graph does not contain the information to tell you which is the case. **Accept** statements only if they are true and relevant, e.g.: There is no information about direction of travel There is no evidence to suggest he has turned round Distance is given by the area under the graph but this is not the same as displacement Speed is not a vector and so the area under the graph says nothing about the direction travelled It just (or only) shows speed-time **Do not accept** statements that are, or may be, untrue: eg The particle moves only in the positive direction **Do not accept** statements that are true but irrelevant: eg The distance travelled is the area under the graph **Condone** This is a speed time graph not one for distance-time
1	*(B)*		True	B1	Ignore subsequent working
1	*(C)*		True	B1	Ignore subsequent working
1	*(D)*		False The area under the graph is 420 not 400 **[6]**	M1 A1	Accept area up to time 55 s is 400 m The calculation in the false example must be correct

Question			Answer	Marks	Guidance
2	(i)		$v = \int (6t - 12)\,\mathrm{d}t$	M1	Attempt to integrate
			$v = 3t^2 - 12t + c$	A1	Condone no c if implied by subsequent working (eg adding 9 to the expression)
			$c = 9$	A1	
			$t = 3 \Rightarrow v = 3 \times 3^2 - 12 \times 3 + 9 = 0$	E1	Or by showing that $(t - 3)$ is a factor of $3t^2 - 12t + 9$
				[4]	
2	(ii)		$s = \int (3t^2 - 12t + 9)\,\mathrm{d}t$	M1	Attempt to integrate Ft from part (i)
			$s = t^3 - 6t^2 + 9t - 2$	A1	A correct value of c is required. Ft from part (i).
			When $t = 2$, $s = 0$. (It is at the origin.)	B1	Cao
				[3]	
3	(i)		**P** + **Q** + **R** = 0**i** + 0**j**	B1	Accept answer zero (ie condone it not being in vector form)
				[1]	
3	(ii)	*(A)*	The particle is in equilibrium	B1	If "equilibrium" is seen give B1 and ignore whatever else is written. Allow, instead, "acceleration is zero", "the particle has constant velocity" and other equivalent statements. Do not allow "The forces are balanced", "The particle is stationary" as complete answers
		(B)	The hiker returns to her starting point	B1	Do not allow "The hiker's displacement is zero"
				[2]	

Question			Answer	Marks	Guidance
4	(i)		At C: $s = ut + \frac{1}{2}at^2$		
			$500 = 5 \times 20 + 0.5 \times a \times 20^2$	M1	M1 for a method which if correctly applied would give a.
			$a = 2$ (ms^{-2})	A1	Cao
					Special case If 800 is used for s instead of 500, giving $a = 3.5$, treat this as a misread. Annotate it as SC SC and give M1 A0 in this part
				[2]	
4	(ii)		At B: $v^2 - u^2 = 2as$	M1	M1 for a method which if correctly applied would give either v or t Apply FT from incorrect a from part (i) for the M mark only
			$v^2 - 5^2 = 2 \times 2 \times 300$		
			$v = 35$ Speed is 35 m s^{-1}	A1	Cao. No FT from part (i) except for SC1 for 46.2 following $a = 3.5$ after the use of $s = 800$.
			At B: $v = u + at$		
			$35 = 5 + 2 \times t$		
			$t = 15$ Time is 15 s	A1	Cao. No FT from part (i) except for SC1 for 11.7 following $a = 3.5$ after the use of $s = 800$.
				[3]	

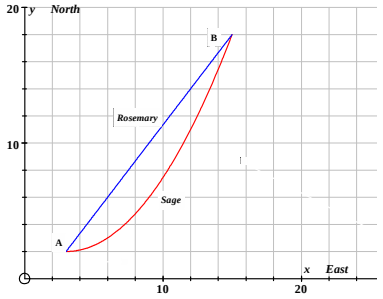
Question			Answer	Marks	Guidance
5	(i)			B2 **[2]**	Subtract one mark for each error, omission or addition down to a minimum of zero. Each force must have a label and an arrow. Accept *T* for 50 N. Units not required. If a candidate gives the tension in components: Accept if the components are a replacement for the tension Treat as an error if the components duplicate the tension However, accept dotted lines for the components as not being duplication
5	(ii)		Horizontal equilibrium : $R = 50\sin 30° = 25$	M1 A1 **[2]**	May be implied. Allow sin-cos interchange for this mark only Award both marks for a correct answer after a mistake in part (i) (eg omission of *R*)
5	(iii)		Vertical equilibrium $N + 50\cos 30° = 10g$ $N = 54.7$ to 3 s.f.	M1 A1 **[2]**	Relationship must be seen and involve all 3 elements. No credit given in the case of sin-cos interchange Cao
5	(iv)		Resultant $= \sqrt{25^2 + 54.7^2}$ Resultant is 60.1 N	M1 A1 **[2]**	Use of Pythagoras. Components must be correct but allow ft from both (ii) and (iii) for this mark only Cao

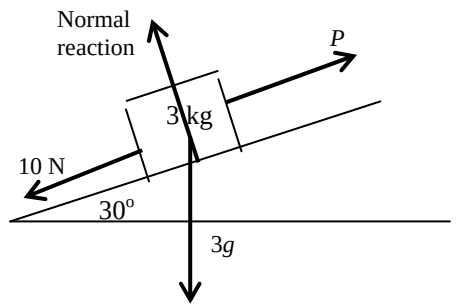
Question			Answer	Marks	Guidance
6	(i)		**Either**		
			Both components of initial speed Horiz $31\cos 20°$ (29.1) Vert $31\sin 20°$ (10.6)	B1	No credit if sin-cos interchanged The components may be found anywhere in the question
			Time to goal $= \dfrac{50}{31\cos 20°}$	M1	Attempt to use horizontal distance ÷ horizontal speed
			$= 1.716$ ... s	A1	
			$h = 31 \times \sin 20° \times 1.716 + 0.5 \times (-9.8) \times (1.716)^2$	M1	Use of one (or more) formula(e) to find the required result(s) relating to vertical motion within a correct complete method. Finding the maximum height is not in itself a complete method.
			$h = 3.76$ (m)	A1	Allow 3.74 or other answers that would round to 3.7 or 3.8 if they result from premature rounding
			So the ball goes over the crossbar	E1	Dependent on both M marks. Allow follow through from previous answer
			Or		
			Both components of initial speed	B1	May be found anywhere in the question. No credit if sin-cos interchange
			$h = 31\sin 20° \times t - 4.9t^2$	M1	
			Substitute $h = 2.44 \Rightarrow t = (0.26 \text{ or}) \ 1.90$	A1	If only 0.26 is given, award A0
			Substitute $t = 1.90$ in $x = 31\cos 20° \times t$	M1	Allow this mark for substituting $t = 0.26$
			$x = 55.4$	A1	Allow $x = 7.6$ following on from $t = 0.26$
			Since $55.4 > 50$ the ball goes over the crossbar	E1	Dependent on both M marks. Allow FT from their value for 55.4.
			Or		
			Both components of initial speed	B1	May be found anywhere in the question. No credit if sin-cos interchanged
			$h = 31\sin 20° \times t - 4.9t^2$	M1	
			Substitute $h = 2.44 \Rightarrow t = (0.26 \text{ or}) \ 1.90$	A1	
			Time to goal $= \dfrac{50}{31\cos 20°}$	M1	Attempt to use horizontal distance ÷ horizontal speed
			$= 1.716$ ... s	A1	
			Since $1.90 > 1.72$ the ball goes over the crossbar	E1	Dependent on both M marks. Allow follow through from previous answer

Question			Answer	Marks	Guidance
			Or		
			Use of the equation of the trajectory	M1	
			$y = x\tan 20° - \dfrac{9.8x^2}{2\times 31^2 \times \cos^2 20°}$	A1	Correct substitution of $\alpha = 20°$
				A1	Fully correct
			Substituting $x = 50$	M1	
			$\Rightarrow y = 3.76$	A1	
			So the ball goes over the crossbar	E1	Dependent on both M marks. Follow through from previous answer
6	(ii)		Any one reasonable statement	B1	**Accept** The ground is horizontal The ball is initially on the ground Air resistance is negligible Horizontal acceleration is zero The ball does not swerve There is no wind The particle model is being used The value of g is 9.8 **Do not accept** g is constant
				[1]	

Question			Answer	Marks	Guidance
7	(i)		Total mass of train $= 800\ 000$ kg	B1	Allow 800 (tonnes)
			Total resistance $= 5R + 17R (= 22R)$	B1	
			Newton's 2nd Law in the direction of motion	M1	The right elements must be present, consistent with the candidate's answers above for total resistance and mass . No extra forces.
			$121\ 000 - 22R = 800\ 000 \times 0.11$		
			$22R = 121\ 000 - 88\ 000 \quad R = 1500$	E1	Perfect answer required
				[4]	
7	(ii)	(*A*)	**Either** (Last truck)		
			Resultant force on last truck $= 40\ 000 \times 0.11$	B1	Award this mark for $40\ 000 \times 0.11$ (= 4400) or 40×0.11 seen
			Use of Newton's 2nd Law	M1	The right elements must be present and consistent with the answer above; no extra forces.
			$T - 1500 = 40\ 000 \times 0.11$	A1	Fully correct equation, or equivalent working
			$T = 5900$ The tension is 5900 N.	A1	Cao
					Special case Award SC2 to a candidate who, instead, provides a perfect argument that the tension in the penultimate coupling is 11 800 N.
			Or (Rest of the train)		
			Resultant force on rest of train $= 760\ 000 \times 0.11$	B1	Award this mark for $760\ 000 \times 0.11$ (= 83 600) or 760×0.11 seen
			Use of Newton's 2nd Law	M1	The right elements must be present consistent with the answer above; no extra forces.
			$121000 - 31500 - T = 760000 \times 0.11$	A1	Fully correct equation, or equivalent working
			$T = 5900$ The tension is 5900 N.	A1	Cao
				[4]	

Question			Answer	Marks	Guidance
7	(ii)	(*B*)	**Either** (Rest of the train)		
			Newton's 2nd Law is applied to the trucks	M1	The right elements must be present; no extra forces
			$S - 25\ 500 = 680\ 000 \times 0.11$	A1	
			$S = 100\ 300$ The tension is 100 300 N.	A1	Cao
			Or (Locomotive)		
			Newton's 2nd Law is applied to the locomotive	M1	The right elements must be present; no extra forces
			$121\ 000 - S - 5 \times 1500 = 120\ 000 \times 0.11$	A1	
			$S = 100\ 300$ The tension is 100 300 N.	A1	Cao
			Or (By argument)		
			Each of the 17 trucks has the same mass, resistance and acceleration.	M1	
			So the tension in the first coupling is 17 times that in the last coupling	A1	
			$T = 17 \times 5900 = 100\ 300$	A1	Cao. For this statement on its own with no supporting argument allow SC2
				[3]	
7	(iii)		Resolved component of weight down slope		
			$= 800\ 000 \times 9.8 \times \frac{1}{80}$	B1	$m \times 9.8 \times \frac{1}{80}$ where m is the mass of the object the candidate is considering. Do not award if g is missing. Evaluation need not be seen
			$= 98\ 000$ N		
			Let the acceleration be a m s^{-2} up the slope.		
			Newton's 2nd Law to the whole train,	M1	The right elements must be present consistent with the candidate's component of the weight down the slope. No extra forces allowed
			$121\ 000 - 33\ 000 - 98\ 000 = 800\ 000a$	A1	
			$a = -0.0125$	A1	Cao but allow an answer rounding to –0.012 or -0.013 following earlier premature rounding.
			Magnitude 0.0125 m s^{-2}, down the slope		The negative sign must be interpreted so "Down the slope" or "decelerating" must be seen
				[4]	

Question			Answer	Marks	Guidance
7	(iv)		Taking the train as a whole, Force down the slope = Resistance force $800\ 000 \times 9.8 \times \sin\beta = 33\ 000$ $\beta = 0.24°$	M1 A1 A1 **[3]**	Equilibrium of whole train required The evidence for this mark may be obtained from a correct force diagram Allow missing g for this mark only
8	(i)		A: $t = 0$, $\mathbf{r} = \begin{pmatrix} 3 \\ 2 \end{pmatrix}$, B: $t = 2$, $\mathbf{r} = \begin{pmatrix} 15 \\ 18 \end{pmatrix}$ $\begin{pmatrix} 15 \\ 18 \end{pmatrix} - \begin{pmatrix} 3 \\ 2 \end{pmatrix} = \begin{pmatrix} 12 \\ 16 \end{pmatrix}$ $\sqrt{12^2 + 16^2} = 20$ The distance AB is 20 km.	B1 B1 B1 **[3]**	Award this mark automatically if the displacement is correct Finding the displacement. Follow through from position vectors for A and B Cao
8	(ii)		$\mathbf{v} = \dfrac{\mathrm{d}\mathbf{r}}{\mathrm{d}t} = \begin{pmatrix} 6 \\ 8 \end{pmatrix}$ which is constant	B1 **[1]**	Any valid argument. Accept $\begin{pmatrix} 6 \\ 8 \end{pmatrix}$ with no comment. Do not accept $a = 0$ without explanation.
8	(iii)			B1 B1 B1 **[3]**	Points A and B plotted correctly, with no FT from part (i), and the line segment AB for the *Rosemary*. No extra lines or curves. For the *Sage*, a curve between A and B. B0 for two line segments. Nothing extra. No FT from part (i). Passes through (9, 6) Condone no labels

Question			Answer	Marks	Guidance
1	(i)			B1 B1 B1 **[3]**	3 marks –1 / error or omission Forces must have arrows and labels Accept "weight" and "friction"
1	(ii)		$R = 3g\cos 30° = 25.46... = 25.5$ (to 3 significant figures)	B1 **[1]**	Accept 25 or 26
1	(iii)		$P = 10 + 3g\sin 30°$ $P = 24.7$	M1 A1 **[2]**	Correct elements must be present Cao
2	(i)		$\mathbf{v} = \mathbf{u} + \mathbf{a}t$ Velocity $\mathbf{v} = \begin{pmatrix} 2 \\ 0 \end{pmatrix} + t\begin{pmatrix} -1 \\ 1 \end{pmatrix}$ **(** $= \begin{pmatrix} 2-t \\ t \end{pmatrix}$ **)** When $t = 8$, $\mathbf{v} = \begin{pmatrix} -6 \\ 8 \end{pmatrix}$ speed $\sqrt{(-6)^2 + 8^2} = 10$ m s^{-1}	M1 A1 A1 A1 **[4]**	May be implied by either of the next two answers but not the final answer. Evidence of use of vectors in question necessary. May be implied by the final answer Cao but condone no units Give SC2 for 10 without working

Question			Answer	Marks	Guidance
2	(ii)		$\mathbf{r} = \mathbf{r}_0 + \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$	M1	Use of correct equation with substitution. Condone omission of $\mathbf{r}_0$. Or equivalent equation
			$\mathbf{r} = \begin{pmatrix} 0 \\ -2 \end{pmatrix} + \begin{pmatrix} 2 \\ 0 \end{pmatrix} \times 8 + \frac{1}{2} \times \begin{pmatrix} -1 \\ 1 \end{pmatrix} \times 8^2$	A1	Condone omission of $\mathbf{r}_0$. Follow through for their value of $\mathbf{v}$
			$\mathbf{r} = \begin{pmatrix} -16 \\ 30 \end{pmatrix}$	A1	Cao but may be implied by a correct final answer.
			Distance = 34 m	A1 **[4]**	Allow for 35.77... from $\mathbf{r} = \begin{pmatrix} -16 \\ 32 \end{pmatrix}$ and 37.57... from $\mathbf{r} = \begin{pmatrix} -16 \\ 34 \end{pmatrix}$
3	(i)		$s = ut + \frac{1}{2}at^2$	M1	Substitution required
			$7.2 = \frac{1}{2} \times a \times 6^2$	A1	
			$a = 0.4\,\text{ms}^{-2}$	A1 **[3]**	Cao
3	(ii)		$F = ma$	M1	Attempt at Newton's second law
				M1	Attempt at resolving both S and T
			$300\cos 30° + 175\cos 15° - R = 1000 \times 0.4$	A1	(Correct elements present and no extras); follow through for a
			$R = 28.8\,\text{N}$	A1 **[4]**	Cao
3	(iii)		The resistance perpendicular to the line of motion has been ignored.	B1 **[1]**	Allow There is also a sideways resistance force

Question			Answer	Marks	Guidance
4	(i)		**Either** $s = \frac{1}{2}(u+v)t$ Take O as the origin.	M1	Use of one relevant equation, including substitution
			$30 = \frac{1}{2} \times (u+9) \times 10$		
			$u = -3$	A1	
			$v = u + at$	M1	Use of a second relevant equation including substitution
			$9 = -3 + 10a$		
			$a = 1.2$	A1	
			or $v = u + at \Rightarrow u + 10a = 9$	M1	Use of one relevant equation, including substitution
			$s = ut + \frac{1}{2}at^2 \Rightarrow u + 5a = 3$	M1	Use of a second relevant equation including substitution
			Solving simultaneously: $a = 1.2$	A1	
			$u = -3$	A1	
			or $s = vt - \frac{1}{2}at^2$	M1	Use of one relevant equation, including substitution
			$\Rightarrow a = 1.2$	A1	
			$v = u + at$	M1	Use of a second relevant equation including substitution
			$\Rightarrow u = -3$	A1	
				[4]	
4	(ii)		**Either** $s = ut + \frac{1}{2}at^2$		
			Solving for P: $-5 = -3t + \frac{1}{2} \times 1.2t^2$	M1	Quadratic equation with $s = -5$
			$0.6t^2 - 3t + 5 = 0$		
			Discriminant $= 3^2 - 4 \times 0.6 \times 5 = -3$	M1	Considering the discriminant or equivalent
			No real roots for t ($\Rightarrow$ Particle is never at P)	E1	Cao without wrong working in the whole question.

Question			Answer	Marks	Guidance
			Or Find when $v = 0$	M1	
			$v = u + at$, $v = 0 \Rightarrow t = 2.5$		
			$s = ut + \frac{1}{2}at^2$ and $t = 2.5$	M1	Or use $v^2 = u^2 + 2as$
			$\Rightarrow s = -3.75 > -5$	E1	Cao without wrong working in the whole question. Comparison necessary
			Special cases when their $u > 0$ and their $a > 0$	SC1 SC1	"It is always going to the right" Demonstration that it is at –5 for two negative times.
				[3]	
5	**(i)**		Vertical motion: $s = ut + \frac{1}{2}at^2$		
			At water: $-1.225 = 0 \times t + \frac{1}{2} \times (-9.8) \times t^2$	M1	Condone sign errors
			$\Rightarrow t = 0.5$ s	A1	Signs must be consistent
				[2]	
5	**(ii)**		Horizontal component of velocity = 20 m s^{-1}	B1	
			Vertical component = $0.5 \times 9.8 = 4.9$ m s^{-1}	B1	Follow through for "their t x 9.8"
			Speed $= \sqrt{20^2 + 4.9^2} = 20.6$	M1	Use of Pythagoras on previous two answers
			$\tan\alpha = \frac{4.9}{20}$	M1	Use of an appropriate trig ratio with their figures for **v**. Must be explicit if final answer is incorrect.
			$\alpha = 13.8°$	A1	Cao
				[5]	

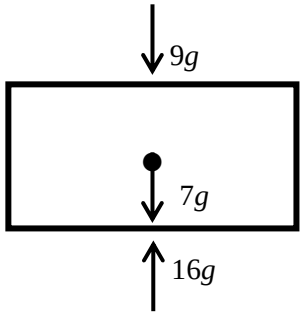
Question			Answer	Marks	Guidance
6	(i)	(*A*)	Distance travelled = Area under the graph	M1	Attempt to find area
			$\frac{1}{2}\times 4\times 8+\frac{1}{2}\times 4\times(8+12)+4\times 12$	M1	Splitting into suitable parts
			104 m	A1	Cao
					Allow all 3 marks for 104 without any working
6	(i)	(*B*)	**Either**		
			Working backwards from distance when $t=12$	M1	
			$12-\frac{(104-100)}{12}$	M1	Allow this mark for 0.33… Follow through from their total distance
			11.67 s	A1	Cao
			Or		
			Working forwards from when $t=8$	M1	
			$8+\frac{(100-56)}{12}$	M1	Allow this mark for 3.67… Follow through from their distance at time 8s
			11.67 s	A1	Cao
				[6]	
6	(ii)		Substituting $t=8$ gives $v=\frac{5}{2}\times 8-\frac{1}{8}\times 8^2=12$	B1	
				[1]	

Question			Answer	Marks	Guidance
6	(iii)		Distance $= \int_0^{12}\left(\frac{5t}{2}-\frac{t^2}{8}\right)\mathrm{d}t$	M1	Integrating *v*. Condone no limits.
			$\left[\frac{5t^2}{4}-\frac{t^3}{24}\right]_0^{12}$	A1	Condone no limits
			$[180-72]$ $(-[0])$	M1	Substituting $t=12$
			108 m	A1	
				[4]	
6	(iv)		Model P: distance at $t=11.35$ is 96.2	B1	Cao
			Model Q: distance at $t=11.35$ is $\left[\frac{5t^2}{4}-\frac{t^3}{24}\right]_0^{11.35}=100.1$	M1	Substituting 11.35 in their expression from part **(iii)**
			Model Q places the runner closer	E1	Cao from correct previous working for both models
				[3]	
6	(v)		Model P: Greatest acceleration $\frac{8}{4}=2$ m s^{-2}	B1	
			Model Q: $a=\frac{\mathrm{d}v}{\mathrm{d}t}=\frac{5}{2}-\frac{t}{4}$	M1	Differentiating *v*
				A1	
			Model Q: Greatest acceleration is 2.5 m s^{-2}	B1	Award if correct answer seen
				[4]	

Question			Answer	Marks	Guidance
7	(i)	(*A*)	The pulley is smooth	B1 **[1]**	Award for "smooth" seen.
7	(i)	(*B*)	Horizontal equilibrium: $T\sin\theta = T\sin\phi$ $\Rightarrow \theta = \phi$	M1 E1 **[2]**	Attempt at horizontal equilibrium. Allow sin-cos interchange. The argument must be based on forces. Do not allow if sin-cos interchange
7	(ii)		Call M the mid point of AB. AM = 1, AC=1.4, $\angle\mathbf{AMC} = 90°$ Pythagoras $\Rightarrow$ $\mathbf{MC} = \sqrt{1.4^2 - 1^2} = \sqrt{0.96}$ $\cos\theta = \frac{\sqrt{0.96}}{1.4} = \frac{\sqrt{24}}{7}$	M1 E1 **[2]**	Setting up triangle and use of trigonometry If decimals are matched, at least 3 figures must be given
7	(iii)		Vertical equilibrium $2T\cos\theta = 50$ $T = 35.7$ N	M1 A1 A1 **[3]**	Use of vertical equilibrium Accept $T\cos\theta = 25$ as an equivalent statement Cao
7	(iv)		$1.2^2 + 1.6^2 = 2^2$ $\Rightarrow \angle\text{ACB} = 90°$ $\cos\alpha = 0.6,\ \cos\beta = 0.8$	 B1 B1 **[2]**	 Use of Pythagoras, or equivalent Both No marks for sin-cos interchange

Question			Answer	Marks	Guidance
7	(v)		**Either resolving horizontally and vertically**		
			$T_1 \cos\alpha = T_2 \cos\beta$	M1	Attempt at horizontal equation. Allow consistent sin-cos interchange
			$T_1 \sin\alpha + T_2 \sin\beta = 50$	M1	Attempt at vertical equation. Allow consistent sin-cos interchange
			$0.6T_1 = 0.8T_2$ $0.8T_1 + 0.6T_2 = 50$	A1	Substitution in both equations. Dependent on both M marks. Cao
			Solving simultaneously	M1	Dependent on both the previous M marks
			$T_1 = 40,\ T_2 = 30$	A1	Cao
			Or resolving in the direction of the strings		
			Resolving in both directions	M1	A serious attempt to use this method. Allow sin-cos interchange
			$T_1 = 50\sin\alpha$	M1	
			$\Rightarrow T_1 = 50 \times 0.8 = 40$	A1	
			$T_2 = 50 \times \sin\beta$	M1	
			$\Rightarrow T_2 = 50 \times 0.6 = 30$	A1	
			Or triangle of forces		
			Use of a triangle of forces	M1	The triangle must be closed and have a right angle opposite the weight
			Labels	M1	The sides must be correctly annotated
			Angles	M1	The angles must be correctly annotated
			$T_1 = 50 \times 0.8 = 40$	A1	Cao Dependent of first M mark
			$T_2 = 50 \times 0.6 = 30$	A1	Cao Dependent of first M mark
				[5]	

Question			Answer	Marks	Guidance
7	(vi)		Attempt to find ∠CAB	M1	May be implied by the remaining answers
			Tension in AC is 50 N (it takes all the weight)	B1	
			Tension in BC is zero (it is slack)	B1	
				[3]	

Question			Answer	Marks	Guidance
1				 B1 B1 B1 **[3]**	One mark for each force with correct magnitude and direction Deduct 1 mark only for *g* missing 16g ↑ 7g ↓ 9g ↓ If all three forces are correct but there is at least one extra force, deduct 1 mark and so give 2 marks. Otherwise ignore extra forces. Note For 16*g* ↑ 16*g* ↓ Award B1 B0 B0
2	(i)		Initial speed is 25 m s^{-1}	B1 **[1]**	

Question			Answer	Marks	Guidance
2	(ii)		Vertical motion: $y = 20t - 4.9t^2$	M1	Forming an equation or expression for vertical motion
			When $y = 0$,	M1	Finding t when the height is 0
			$T = (0 \text{ or }) \dfrac{20}{4.9} = 4.08$ s	A1	
			$R = 15 \times 4.08... = 61.22$	F1	Allow $15\times$ their T Note If horizontal and vertical components of the initial velocity are interchanged treat it as a misread; if no other errors are present this gives 3 marks.
				[4]	
			Alternative Using time to maximum height		
			Vertical motion: $v = 20 - 9.8t$	M1	Forming an equation or expression for vertical motion
			Flight time = 2 × Time to top	M1	Using flight time is twice time to maximum height or equivalent for range.
			$T = 2 \times \dfrac{20}{9.8} = 4.08$ s	A1	
			$R = 15 \times 4.08... = 61.22$	F1	Allow $15\times$ their T
			Alternative Using formulae		
			Finding angle of projection $\alpha = \arctan\left(\dfrac{20}{15}\right) = 53.1°$	M1	Only award this mark if there is a clear intention to use this method
			$R = \dfrac{2u^2 \sin\alpha\cos\alpha}{g} = \dfrac{2 \times 25^2 \times \sin 53.1° \times \cos 53.1°}{9.8}$	M1	Allow the alternative form $R = \dfrac{u^2 \sin 2\alpha}{g}$ with substitution
			$R = 61.2$	A1	
			$T = \dfrac{2u\sin\alpha}{g} = 4.08$	A1	

Question			Answer	Marks	Guidance
2	(iii)	(*A*)	Flight time $= \frac{15}{4.9}$ Range $= 20 \times \frac{15}{4.9} = 61.22$	B1 **[1]**	Allow FT from part (ii) for a correct argument that they should be the same
2	(iii)	(*B*)	No eg angle of projection 45^o	M1 A1 **[2]**	Attempt at disproof or counter-example. There must be some reference to the angle. Complete argument

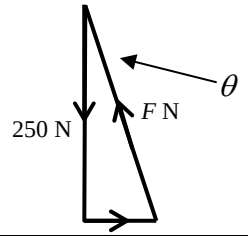
Question			Answer	Marks	Guidance
3	(i)		**p** $\sqrt{(-1)^2+(-1)^2+5^2}=\sqrt{27}$ **q** $\sqrt{(-1)^2+(-4)^2+2^2}=\sqrt{21}$ **r** $\sqrt{2^2+5^2+0^2}=\sqrt{29}$ Greatest magnitude: **r**	M1 A1 **[2]**	Use of Pythagoras Note Magnitudes are 5.196, 4.583 and 5.385 respectively
3	(ii)		Weight $=\begin{pmatrix}0\\0\\-4\end{pmatrix}$ $\mathbf{p}+\mathbf{q}+\mathbf{r}+\mathbf{weight}=\begin{pmatrix}0\\0\\3\end{pmatrix}$ $0.4\mathbf{a}=\begin{pmatrix}0\\0\\3\end{pmatrix}$ Magnitude of acceleration is 7.5 m s^{-2} Direction is vertically upwards	B1 B1 B1 B1 **[4]**	Condone $g=9.8$ giving weight is $\begin{pmatrix}0\\0\\-3.92\end{pmatrix}$ N. Accept 4↓. $g=9.8$ gives $\begin{pmatrix}0\\0\\3.08\end{pmatrix}$ Relevant attempt at Newton's 2nd Law. The total force must be expressed as a vector in some form. For this mark allow the weight to be missing, in the wrong component or to have the wrong sign. Condone *mg* in place of *m* for this mark only. CAO apart from using $g=9.8 \Rightarrow a=7.7$

Question	Answer	Marks	Guidance
4	Equate **i** and **j** components of **v**	M1	The candidate recognises that the **i** and **j** components must be equal.
	$16-t^2=31-8t$	A1	An equation is formed.
	$t^2-8t+15=0$		
	$(t-3)(t-5)=0$		
	$t=3$ or 5	A1	May be implied by later working.
	When $t=3$, $\mathbf{v}=7\mathbf{i}+7\mathbf{j}$	B1	
	Speed when $t=3$ is $7\sqrt{2}=9.9$ m s^{-1}	B1	
	The values of the **i** and **j** components must both be positive for the bearing to be 045^o .	B1	This mark is dependent on obtaining A1 for the result $t=3$ or 5 . It is awarded if the speed for the case when $t=5$ is not included (since $t=5 \Rightarrow \mathbf{v}=-9\mathbf{i}-9\mathbf{j}$ and the bearing is 225^o).
			Note Candidates who obtain **r** and equate the east and north components should be awarded SC1 for the whole question.
		[6]	

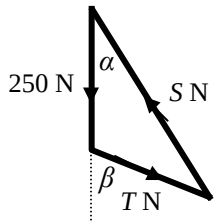
Question			Answer	Marks	Guidance
4			**Alternative Trial and error**		
			The i and j components of v must be equal	M1	The candidate recognises that the **i** and **j** components must be equal.
			The **i** and **j** components of **v** must both be positive for the bearing to be 045^o.	B1	This can be demonstrated during the question either by a suitable convincing diagram including 45^o, or by a suitable convincing argument
			At least one value of t is substituted	A1	Trial and error is used
			$t = 3$	A1	$t = 3$ is found by trial and error
			When $t = 3$, $\mathbf{v} = 7\mathbf{i} + 7\mathbf{j}$	B1	
			Speed when $t = 3$ is $7\sqrt{2} = 9.9$ m s^{-1}	B1	
					Note Candidates who obtain **r** and equate the east and north components should be awarded SC1 for the whole question.
				[6]	

Question			Answer	Marks	Guidance
5	(i)		If the acceleration is to the right		
			Overall $30 - F = (4+6) \times 2$	M1	Newton's 2nd Law in one direction. No extra forces allowed and signs must be correct.
			$F = 10$	A1	
			If the acceleration is to the left	M1	For considering second direction. No extra forces allowed and signs must be correct.
			$F = 50$	A1	
				[4]	
5	(ii)		6 kg block $30 - T = 6 \times 2$	M1	Newton's 2nd law with correct elements on either block
			$\Rightarrow T = 18$	A1	CAO No follow through from part (i)
			In the other case $T = 42$	A1	CAO No follow through from part (i)
				[3]	

Question			Answer	Marks	Guidance
6	(i)		$v = 0 \Rightarrow 3(t-2)(t-4) = 0$	M1	Setting $v = 0$ (may be implied)
			$T_1 = 2,\ T_2 = 4$	A1	Accept t = 2 and t = 4
				[2]	
6	(ii)		$x = \int v\mathrm{d}t$	M1	Use of integration
			$x = 24t - 9t^2 + t^3 + c:\ c = 0$	A1	Condone omission of c
			$t = 2 \Rightarrow x = 48 - 36 + 8 = 20$	E1	CAO
			$t = 4 \Rightarrow x = 96 - 144 + 64 = 16$	A1	CAO
				[4]	

Question			Answer	Marks	Guidance
7	(i)		 **Or equivalent**	B1 B1 B1 **[3]**	Shape of triangle; ignore position of θ if marked in diagram 2 marks -1 per error but penalise no arrows only once and penalise no labels only once. Condone *T* written for *F*. In the case of a force diagram showing F, 25 and 250 allow maximum of 2 marks with -1 per error but penalise no arrows only once and penalise no labels only once
7	(ii)		$\tan\alpha = \frac{25}{250}$ 25 N $\Rightarrow \alpha = 5.7°$ $F = \sqrt{25^2 + 250^2}$ $F = 251.2$ Distance $= 30\tan\alpha = 30\times 0.1 = 3$ m	M1 A1 M1 A1 B1 **[5]**	M1 for recognising and using α in the triangle Use of Pythagoras At least 3 significant figures required CAO
			Alternative $F\cos\theta = 250$ $F\sin\theta = 25$ $\tan\theta = \frac{25}{250}$ $\Rightarrow \theta = 5.7°$ $F\cos 5.7° = 250$ $F = 251.2$ Distance $= 30\tan\alpha = 30\times 0.1 = 3$ m	 M1 A1 M1 A1 B1	 At least 3 significant figures required CAO

Question			Answer	Marks	Guidance
7	(iii)		Vertical equilibrium	M1	M1 for attempt at resolution in an equation involving both *S* and *T*; condone sin-cos errors for the M mark only
			$\uparrow \ S\cos\alpha \ = T\cos\beta + 250 \ \downarrow$	A1	
			Horizontal equilibrium $S\sin\alpha = T\sin\beta$	A1	
				[3]	
7	(iv)		$S\sin 8.5° = T\sin 35° \Rightarrow S = 3.8805T$	M1	Using one equation to make *S* or *T* the subject in terms of the other
			$(3.8805T)\cos 8.5° = T\cos 35° + 250$	M1	Substituting in the other equation
			$T = 82.8$	A1	CAO
			$S = 321.4$	A1	CAO
				[4]	
			Alternative		**Use of linear simultaneous equations**
			$S\sin 8.5° - T\sin 35° = 0$ $S\cos 8.5° - T\cos 35° = 250$		
			$S\sin 8.5°\cos 35° - T\sin 35°\cos 35° = 0$ $S\cos 8.5°\sin 35° - T\cos 35°\sin 35° = 250\sin 35°$		
			$S(-\sin 8.5°\cos 35° + \cos 8.5°\sin 35°) = 250\sin 35°$	M1	Valid method that has eliminated terms in either *S* or *T* (execution need not be perfect)
			$S = 321.4$	A1	CAO First answer
			Substituting in either equation	M1	Substituting to find the second answer
			$\Rightarrow T = 82.8$	A1	CAO Second answer

Question			Answer	Marks	Guidance
7	(iv)		Alternative Triangle of forces		
				M1	Either Drawing and using a triangle of forces Or Quoting and using Lami's Theorem
			$\frac{S}{\sin 145°} = \frac{T}{\sin 8.5°} = \frac{250}{\sin 26.5°}$	M1	Correct form of these equations
			$S = 321.4$	A1	CAO
			$T = 82.8$	A1	CAO

Question			Answer	Marks	Guidance
7	(v)		Abi's weight is $40g = 392$ N	M1	Consideration of Abi's weight
			When $\alpha = 60°$, $S\cos 60° > 250 \Rightarrow S > 500$	M1	Consideration of vertical forces on the object. Condone no mention of Bob's rope
			The tension in rope A would be greater than Abi's weight and so she would be lifted off the ground	A1	The argument must be of high quality and must include consideration of the tension in Bob's rope
				[3]	
			Alternative		
			If Abi is on the ground, the maximum possible tension in rope A is Abi's weight of 392 N	M1	Consideration of Abi's weight
			So the maximum upward force on the object is $392 \times \cos 60° = 192$ N		
			This is less than the weight of the object, and the tension in Bob's rope is pulling the box down.	M1	Consideration of vertical forces on the object. Condone no mention of Bob's rope Or the box accelerated downwards
			So Abi would be lifted off the ground	A1	The argument must be of high quality and must include consideration of the tension in Bob's rope

Question			Answer	Marks	Guidance
8	(i)		$v = u + at$	M1	Use of a suitable constant acceleration formula
			$5 = 0 + a \times 10 \Rightarrow a = 0.5$	A1	Notice The value of a is not required by the question so may be implied by subsequent working
			$F = ma \Rightarrow 120 - R = 40 \times 0.5$	M1	Use of Newton's 2nd Law with correct elements
			$R = 100\,\text{N}$	E1	
				[4]	
8	(ii)	(*A*)	$F = ma \Rightarrow -100 = 40a$	M1	Equation to find a using Newton's 2nd Law
			$\Rightarrow a = -2.5$	A1	
			When $t = 1.6$ $v = 5 + (-2.5) \times 1.6 = 1\ \text{ms}^{-1}$	A1	CAO
				[3]	
8	(ii)	(*B*)	When $t = 6$, it is stationary. $v = 0\ \text{ms}^{-1}$	B1	
				[1]	

Question			Answer	Marks	Guidance
8	(iii)		Motion parallel to the slope:	B1	Component of the weight down the slope, ie $40g\sin 15°$ (= 101.457…)
			$200 - 40g\sin 15° = 40a$	M1	Equation of motion with the correct elements present. No extra forces.
			$a = 2.463...$		This result is not asked for in the question
			$v^2 - u^2 = 2as \Rightarrow 8^2 = 2 \times 2.46... \times s$	M1	Use of a suitable constant acceleration formula, or combination of formulae. Dependent on previous M1.
			$\Rightarrow s = 12.989...$ rounding to 13.0 m	E1	Note If the rounding is not shown for *s* the acceleration must satisfy $2.452... < a < 2.471...$
				[4]	
8	(iv)		Let *a* be acceleration up the slope		
			$-40 \times 9.8 \times \sin 15° = 40a$	M1	Use of Newton's 2nd Law parallel to the slope
			$a = -2.536...$, ie 2.536 m s^{-2} down the slope	A1	Condone sign error
			$s = ut + \frac{1}{2}at^2$		
			$-12.989... = 8t + \frac{1}{2} \times (-2.536...)t^2$	M1	Dependent on previous M1. Use of a suitable constant acceleration formula (or combination of formulae) in a relevant manner.
			$1.268...t^2 - 8t - 12.989... = 0$	A1	Signs must be correct
			$t = \dfrac{8 \pm \sqrt{64 - 4 \times 1.268... \times (-12.989...)}}{2 \times 1.268...}$	M1	Attempt to solve a relevant three-term quadratic equation
			$t = -1.339...$ or $7.647...$, so 7.65 seconds	A1	
				[6]	

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