Question	Answer	Mark	Guidance
1	$(v =)\ 3t^2 - 12t + 4$	*M1	Attempt at differentiation of s to find v
	$(a =)\ 6t - 12$	*M1	Attempt at differentiation of v to find a
	[When $a = 0$, $t = 2$]	DM1	Solve to find t when $a = 0$ and find v at this time
	$v = -8\ \text{ms}^{-1}$	A1	
	Alternative method for question 1		
	$(v =)\ 3t^2 - 12t + 4$	M1	Attempt at differentiation of s to find v
	$(v =)\ 3(t-2)^2 - 8$ or $t = \frac{-b}{2a} = \frac{12}{6} = 2$	M1	For using the method of completing the square or using the value of '$\frac{-b}{2a}$' to find the t value of the minimum velocity
		M1	Use of the t value at minimum velocity to find v
	$v = -8\ \text{ms}^{-1}$	A1	
		4	

Question	Answer	Mark	Guidance
2(i)	$\frac{(12-V)}{(35-30)}=0.8$ or $12=V+0.8\times 5$	**M1**	Use gradient of graph or constant acceleration formulae to set up an equation in V
	$V=8$	**A1**	
		2	
2(ii)	$\left[25\times 8+5\times 10+15\times 6+\frac{1}{2}\times(U+8)\times 5=375\right]$	**M1**	Attempt to find total distance travelled by the tractor in 50s to set up an equation for U using EITHER areas OR suvat equations OR a combination of areas and suvat In either case total distance must be attempted
		A1FT	Correct equation FT on *their* V from **(i)**
	$U=6$	**A1**	
		3	

Question	Answer	Mark	Guidance
3	$T_A \times \frac{4}{5} + T_B \times \frac{3}{5} + 0.3g = 5$	**M1**	Resolving vertically
	$T_A \times \frac{3}{5} = T_B \times \frac{4}{5}$	**M1**	Resolving horizontally
		A1	Both correct
		M1	Solve for T_A or T_B
	$T_A = 1.6$ N and $T_B = 1.2$ N	**A1**	
	Alternative method for question 3		
	$\left[\frac{5-3}{\sin 90} = \frac{T_A}{\sin 126.9} = \frac{T_B}{\sin 143.1}\right]$	**M1**	Attempt one pair of Lami's equations
		M1	Attempt a second pair of Lami equations
		A1	Equations all correct
		M1	Evaluate T_A or T_B
	$T_A = 1.6$ N and $T_B = 1.2$ N	**A1**	

Question	Answer	Mark	Guidance
3	**Alternative method for question 3**		
	$T_A = 5\cos 36.9 - 3\cos 36.9 = 5\times\frac{4}{5} - 3\times\frac{4}{5}$	**M1**	Resolve along *PA*
	$TB = 5\cos 53.1 - 3\cos 53.1 = 5\times\frac{3}{5} - 3\times\frac{3}{5}$	**M1**	Resolve along *PB*
		A1	Both correct
		M1	Evaluate T_A or T_B
	$T_A = 1.6$ N and $T_B = 1.2$ N	**A1**	
	Alternative method for question 3		
	Forces 2N, T_A and T_B with angles 36.9 and 53.1	**M1**	Attempt to illustrate a triangle of forces
	[$T_A = 2\cos 36.9$, $T_B = 2\cos 53.1$]	**M1**	Use trigonometry in the triangle to find T_A and T_B
		A1	Both correct
		M1	Solve for T_A or T_B
	$T_A = 1.6$ N and $T_B = 1.2$ N	**A1**	
		5	

Question	Answer	Mark	Guidance
4(i)	$P = 3000 \times 30$	M1	Use of $P = Fv$ with F = resistance
	$P = 90000$ W = 90kW	A1	
		2	
4(ii)	PE gained = $25000gh$	B1	Correct expression for PE Allow PE = $25\,000\, g\, d \sin 2$
	Initial KE $= \frac{1}{2} \times 25000 \times 30^2$ [= 11 250 000] Final KE $= \frac{1}{2} \times 25000 \times 25^2$ [= 7 812 500]	B1	For either correct [KE loss = 3 437 500]
	Initial KE = Final KE + $25000gh + \frac{3000h}{\sin 2}$ OR Initial KE = Final KE + $25000gd\sin 2 + 3000d$	M1	For a 4 term work-energy equation, correct dimensions
		A1	Correct work-energy equation involving h or d
	$h = 10.2$ m (10.2318…)	A1	
		5	

Question	Answer	Mark	Guidance
5(i)	$h_A = 20t - \frac{1}{2}\times 10t^2$ or $h_B = \pm\frac{1}{2}\times 10(t-1)^2$	B1	OE $h_A = 20(T+1) - \frac{1}{2}\times 10(T+1)^2$ or $h_B = \pm\frac{1}{2}\times 10T^2$
	[Meet when $20t - \frac{1}{2}\times 10t^2 + \frac{1}{2}\times 10(t-1)^2 = 40$]	*M1	Set up an equation using *their* h_A, *their* h_B and 40
	$10t - 35 = 0$	DM1	Solve for t and attempt to find the height at collision.
	$t = 3.5$ so height at collision = 8.75 m	A1	$T = 2.5$ and height at collision = 8.75 m
	Alternative method for question 5(i)		
	$h_A = 20\times 1 - \frac{1}{2}\times 10\times 1^2 = 15, v = 20 - 10\times 1 = 10$	B1	Finding distance travelled by A and its speed after 1 second
	$H_A + H_B = 25$ $\left(10T - \frac{1}{2}\times 10\times T^2\right) + \frac{1}{2}\times 10\times T^2 = 25$	*M1	T is the time beyond 1s until the particles reach same level H_A and H_B are distances travelled by A and B in T seconds.
	[$10T = 25 \rightarrow T = 2.5$]	DM1	Solve for T and attempt to find the height at collision
	$t = 3.5$ so height = 8.75 m	A1	
		4	

Question	Answer	Mark	Guidance
5(ii)	$v_A = 20 - gt = -15$ **or** $v_A^2 = 20^2 + 2(-g)(8.75)$	**M1**	Use of *their* t or *their* $h \leqslant 20$ from **5(i)** in a constant acceleration formula which would lead to finding v_A
	$v_B = -g(t-1) = -25$ **or** $v_B^2 = 2(g)(40 - 8.75)$	**M1**	Use of *their* $t \pm 1$ or *their* $40 - h$ from **5(i)** in a constant acceleration formula which would lead to finding v_B
	Difference = 10 ms^{-1}	**A1**	CWO
		3	

Question	Answer	Mark	Guidance
6(i)	$4.5 = 0 + \frac{1}{2} \times a \times 5^2$	**M1**	For use of $s = ut + \frac{1}{2}at^2$ to find a
	$a = 0.36$	**A1**	
	$6 \times \frac{24}{25} - F = 3 \times 0.36$	**M1**	Resolving horizontally. Allow use of $\theta = 16.3$
	$F = 4.68$ N	**A1**	
		4	
6(ii)	$R = 3g - 6\sin 16.3 = 3g - 6 \times \frac{7}{25}$ $\quad [= 28.32]$	**B1**	
	$4.68 = \mu \times 28.32$	**M1**	Use of $F = \mu R$
	$\mu = 0.165$ (0.165254…)	**A1**	AG. Allow $\mu = \frac{39}{236}$
		3	

Question	Answer	Mark	Guidance
6(iii)	$v = 5 \times 0.36$ [= 1.8] or $v = \sqrt{(2 \times 0.36 \times 4.5)}\,[= 1.8]$	B1FT	For velocity at $t = 5$ ft on *their* a from **6(i)**
	$3a = -0.165 \times 3g$	M1	Using Newton's second law with new frictional force
	$0 = 1.8 - 0.165gt$ $(t = 1.09)$	M1	Using constant acceleration equations which would lead to a positive value of t
	Total time = 5 + 1.09 = 6.09 s	A1	
		4	

Question	Answer	Mark	Guidance
7(i)		M1	Use of Newton's second law for P or Q or the system
	For P: $T - 0.3g \times \frac{3}{5} = T - 0.3g \sin 36.9 = 0.3a$ For Q: $0.2g - T = 0.2a$ System: $0.2g - 0.3g \times \frac{3}{5} = (0.2 + 0.3)a$ or $0.2g - 0.3g \sin 36.9 = (0.2 + 0.3)a$	A1	Two correct equations Allow use of $\theta = 36.9$
	$[0.2g - 0.18g = 0.5a]$	M1	For solving either the system for a or for solving a pair of simultaneous equations for a or T
	$a = 0.4 \text{ ms}^{-2}$	A1	
	$T = 1.92$ N	A1	
		5	

Question	Answer	Mark	Guidance
7(ii)	$0.8 = 0 + \frac{1}{2} \times 0.4 \times t^2$ a	M1	For use of the constant acceleration equations with *their a* from **7(i)** and $a \neq \pm g$ for a complete method to find t
	$t = 2$ s	A1	
		2	
7(iii)	Speed when Q hits the floor = 2 × 0.4 (= 0.8) or $v = \sqrt{(2 \times 0.4 \times 0.8)}\,[= 0.8]$	B1FT	Using $v = u + at$ with $u = 0$ Allow FT for *their* unsimplified $v = at$ or $v^2 = 2as$ with a from **(i)**, t from **(ii)** and $s = 0.8$
	$-0.3g \times \frac{3}{5} = -0.3g \sin 36.9 = 0.3a$ $[a = -6]$	M1	Using Newton's second law for P to find $a \neq \pm g$
	$0 = 0.8t + \frac{1}{2} \times (-6)t^2\ (t = 0.2666...)$ or $0 = 0.8 - 6T$ ($T = 0.13333 = \frac{2}{15}$ and $t = 2T = 0.26666 = \frac{4}{15}$)	M1	Use of the constant acceleration equation(s) to find the time taken for P to return to the position where the string first became slack.
	Total time = 2 + 0.266... = $2 + \frac{4}{15} = 2.27 = \frac{34}{15}$ s	A1	
		4	