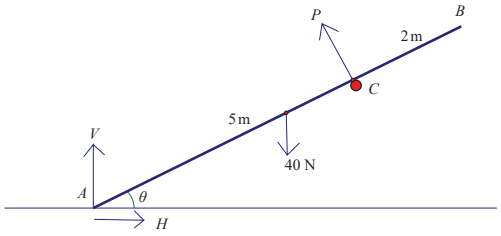
Q	Scheme	Mark	Notes
1a	Use of $v = \frac{dx}{dt}$	M1	At least 2 powers going down by 1. Clear division by t is M0
	$v = 6t^2 - 42t + 60$	A1	Correct only
	Set $v = 0$ and correctly solves to obtain 2 values for t	M1	Complete method to obtain both values (implied by correct answers seen) $\left(0 = t^2 - 7t + 10 = (t-2)(t-5)\right)$
	Obtain $t = 2$ and $t = 5$	A1	Correct only. Allow 2.0, 5.0
		[4]	
1b	Distance $= \lvert x_2 - x_1 \rvert + \lvert x_3 - x_2 \rvert$ $\left(= \lvert 45 - 52 \rvert + \lvert 52 - 41 \rvert\right)$	M1	Correct strategy dependent on their t being in $1 < t < 3$
	$= 11 + 7 = 18$ (m)	A1	Correct only
		[2]	
1c	Use of $a = \frac{dv}{dt}$	M1	Differentiate their v. Clear division by t is M0. A power going down by 1 $(a = 12t - 42)$
	Obtain $6\left(\text{m s}^{-2}\right)$	A1	Must be positive – the Q asks for magnitude
		[2]	
		(8)	

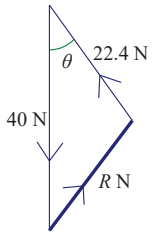
Q	Scheme	Mark	Notes
2a	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	NB: Column vectors are acceptable. Condone wrong order but must be subtracting. Condone 5 in place of 0.5.
	$2\mathbf{i} + 5\mathbf{j} = 0.5\left(\mathbf{v} - \left(3\mathbf{i} + \mathbf{j}\right)\right)$ $\left(\mathbf{v} = 7\mathbf{i} + 11\mathbf{j}\right)$	A1	Correct unsimplified equation Accept as a vector equation or as a pair of equations, one for each component. Accept alternative notations provided the meaning is clear.
	Use of Pythagoras	M1	For their **v** Independent M1 but they must have a **v**
	$\lvert v\rvert = \sqrt{121+49} = \sqrt{170}\ \left(\text{m s}^{-1}\right)$	A1	$13\left(\text{m s}^{-1}\right)$ or better. (13.038…….)
		[4]	
2b	Correct use of trigonometry e.g. $\theta = \tan^{-1}\frac{11}{7} - \tan^{-1}\frac{1}{3}$ $\left(= 57.5 - 18.4\right)$	M1	Condone subtraction in either order. Allow if **both** fractions are the other way up. Alternatives: scalar product $\theta = \cos^{-1}\left(\frac{21+11}{\sqrt{10}\sqrt{170}}\right)$ cosine rule $4\times 29 = 10 + 170 - 2\sqrt{10}\sqrt{170}\cos\theta$
	$\theta = 39.1$	A1	Accept ± 39 or better (39.0938…) 0.68(2) radians is M1A0 Accept $\pm\left(360 - 39\right) = \pm 321$ or better
		[2]	
		(6)	

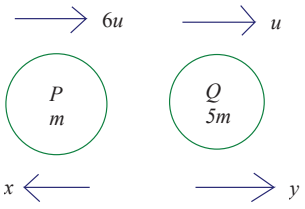
Q	Scheme	Mark	Notes
3a	$F_{\max} = \frac{1}{3} \times 2g\cos\alpha \left(= 5.90...\right)$	M1	Use of $F = \mu R$ Seen or implied. Condone sine / cosine confusion Condone g missing
	WD against friction $= 6 \times$ *their* $F_{\max}$	M1	$\left(= 35.4...(\text{J})\right)$ Seen or implied as part of the 4th M mark
	PE gain $= 2g \times 6 \times \sin\alpha$ $\left(= 6 \times \frac{42}{5} = 50.4\right)$	M1	dimensionally correct. Condone sine / cosine confusion
	Total WD = WD against friction + WD against gravity (gain in PE)	DM1	Dependent on the 3 preceding M marks. Require both terms and no extras
	Total WD $= 85.8\,(\text{J})$ or $86\,(\text{J})$	A1	3 sf or 2 sf only $\left(8\sqrt{10} + 36\right)\frac{g}{7}$ is A0 (incorrect units)
	NB a candidate who resolves parallel to the slope but never multiplies either component by 6 will score the first M1 only		
		[5]	
3b	Work-energy equation (KE gained = loss in GPE - WD against friction)	M1	Must be using work-energy. Need all terms, no extras and dimensionally correct. Condone sign errors Condone sine / cosine confusion.
	$\frac{1}{2} \times 2v^2 = 2g \times 6\sin\alpha - 6 \times \frac{2}{3} g\cos\alpha$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation. They must have started with correct expressions, but follow through on any calculation errors
	$v = 3.87\left(\text{m s}^{-1}\right)$ *or* $3.9\left(\text{m s}^{-1}\right)$	A1	3 sf or 2 sf only
		[4]	
		(9)	

Q	Scheme	Mark	Notes
4a	If the division of the shape involves non-standard shapes (e.g. a trapezium) the centres of mass must be quoted correctly or a correct method used to find the position to score any marks.		
	rectangle / -triangle / +triangle $20a^2$ / $-\frac{9}{2}a^2$ / $\frac{9}{2}a^2$ $2a$ / $3a$ / $2a$ or rectangle / rectangle / Double triangle $3a^2$ / $8a^2$ / $9a^2$ $\frac{1}{2}a$ / $2a$ / $2a$ or rectangle / trapezium / triangle $5a^2$ / $\frac{21}{2}a^2$ / $\frac{9}{2}a^2$ $\frac{1}{2}a$ / $\frac{48}{21}a$ / $2a$	B1 B1	Correct mass ratios for a correct division of the folded template and correct total of $20a^2$ Correct distances from AD seen or implied. B0B1 is possible if they have incorrect masses but a full set of correct distances. e.g. if they use the second alternative but have not doubled the triangle. Or they might have a correct split with an error in one of the areas or an incorrect (or missing) total or equivalent
	Moments about AD or a parallel axis.	M1	Dimensionally consistent. All terms for a correct division of L and no extras. Accept as part of a vector equation
	$40a^3 - \frac{27}{2}a^3 + 9a^3 = 20a^2d$ or $\frac{3}{2}a^3 + 16a^3 + 18a^3 = 20a^2d$ or $\frac{2}{2}a^3 + \frac{48}{2}a^3 + 9a^3 = 20a^2d$	A1	Correct unsimplified equation for their axis. Allow for correct component in a vector equation.
	$d = \frac{71}{40}a$ *	A1*	Obtain given answer from correct working. Need at least one line of working to **collect like terms** e.g. $20d = \frac{71}{2}a$ Final answer must be as printed i.e. $d = \ldots$.
		[5]	
4b	Moments about S	M1	A complete method to get an equation in W and F only. Need all terms and no extras. Dimensionally consistent.
NB If they start by finding the centre of mass for the system they do not score marks until they form the moments equation. If they are clearly using moments about A (e.g. d and $4a$ used as distances in their equation) this is M0 unless they include the reaction at S and resolve to form the required equation. If they say they are using moments about S and have just one incorrect distance allow M1A1A0A0			
	$4W \times \frac{31}{40}a + W \times 3a = F \times 5a$ or $(4W + W)(2.22a - a) = 5aF$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation
	$F = \frac{61}{50}W$	A1	Accept $1.22W$ or $1.2W$
		[4]	
		(9)	

Q	Scheme	Mark	Notes
5a	Use of $P = Fv$	M1	$\frac{10000}{16}\left(=625\right)$ o.e. seen or implied in the working. Allow for $\frac{10}{16}$
	Equation of motion for the system	M1	Dimensionally correct. Need all terms and no extras. Condone sign errors and sine/cosine confusion If they start with separate equations for the van and trailer, just mark the combined equation.
	$F - 400 - 800g\sin\alpha = 800a$	A1 A1	Unsimplified equation in P or F with a most one error Correct unsimplified equation in P or F Use of cosine in place of sine for both vehicles counts as a repeated error and only loses 1 mark
	Obtain deceleration $0.419\left(\text{m s}^{-2}\right)$ or $0.42\left(\text{m s}^{-2}\right)$	A1	3 sf or 2 sf only Answer must be positive.
		[5]	
5b	Equation of motion for the van or the trailer	M1	Dimensionally correct. Need all terms and no extras. Condone sign errors and sine/cosine confusion Use the mass in the *ma* term to decide which part of the system they are using.
	$T - 150 - 200g\sin\alpha = 200a$ or $F - T - 250 - 600g\sin\alpha = 600a$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation
	Obtain tension $206\left(\text{N}\right)$ or $210\left(\text{N}\right)$	A1	3 sf or 2 sf only
		[4]	
		(9)	

Q	Scheme	Mark	Notes
6a			
	Moments about A:	M1	Dimensionally correct. Condone sine / cosine confusion
	$5P = 40 \times \frac{7}{2}\cos\theta$	A1	Correct unsimplified equation
	$P = 22.4$ *	A1*	Obtain **given answer** from correct working. Need to see evidence of $\cos\theta = \frac{4}{5}$
		[3]	
6b	Two equations required. M1A1 for the first equation seen, M1A1 for the second equation. If more than 2 equations mark the two equations used to obtain the resultant, or the best 2 if they do not go on to find the resultant.		
	First equation	M1	e.g. Resolve horizontally Condone sine / cosine confusion
	$H = P\sin\theta \left(=13.44\right)$	A1	Correct unsimplified equation
	Second equation	M1	e.g. Resolve vertically Condone sine / cosine confusion
	$V + P\cos\theta = 40 \left(V = 22.08\right)$	A1	Correct unsimplified equation
	$\left\|R\right\| = \sqrt{H^2 + V^2}$	DM1	solve for $\left\|R\right\|$ Dependent on the 2 preceding Ms
	$\left\|R\right\| = 26 \left(\text{N}\right)$	A1	Or better (25.84879…..) Accept $\frac{24\sqrt{29}}{5}$
		[6]	
Two alternatives on following page			

6balt	First equation	M1	e.g. Resolve parallel Condone sine / cosine confusion
	$X = 40\sin\theta\,(=24)$	A1	Correct unsimplified equation
	Second equation	M1	e.g. Resolve perpendicular Condone sine / cosine confusion
	$Y + P = 40\cos\theta\,(Y = 9.6)$	A1	Correct unsimplified equation
	$\lvert R\rvert = \sqrt{X^2 + Y^2}$	DM1	solve for $\lvert R\rvert$ Dependent on the 2 preceding Ms
	$\lvert R\rvert = 26\,(\text{N})$	A1	Or better (25.84879…..) Accept $\frac{24\sqrt{29}}{5}$
		[6]	
	Alternative equations: $\text{M}(C)\quad 40\times1.5\cos\theta + H\times5\sin\theta = V\times5\cos\theta$ $\text{M}(B)\quad 2P + 7\cos\theta\times V = 7\sin\theta\times H + 3.5\times40\cos\theta$ $\text{M}(G)\quad 1.5P + 3.5\sin\theta\times H = 3.5\cos\theta\times V$		
6balt		M1 A1	3 force diagram seen or implied Forces and angle in correct positions
	Use Cosine Rule	M1	Correct formula used
	$(\lvert R\rvert)^2 = 40^2 + 22.4^2 - 2\times40\times22.4\cos\theta$	A1	Correct unsimplified equation
	Substitute for trig and solve for $\lvert R\rvert$	DM1	Dependent on the 2 preceding Ms
	$\lvert R\rvert = 26\,(\text{N})$	A1	Or better (25.84879…..) Accept $\frac{24\sqrt{29}}{5}$
		[6]	
		(9)	

Q	Scheme	Mark	Notes
7a			If $6u$ and u are in opposite directions, mark as a sign error.
	Use of CLM	M1	Need all 4 terms. Dimensionally consistent. Condone sign errors Condone x in the wrong direction
	$6mu+5mu=5my-mx$ $(11u=5y-x)$	A1	Correct unsimplified equation
	Use of impact law	M1	Used correctly. Dimensionally correct. Condone sign errors
	$x+y=5eu$	A1	Correct unsimplified equation. Signs consistent with their CLM equation
	Solve for x in terms of e and u: $6x=25eu-11u$ or solve for e in terms of y and u: $e=\frac{6y-11u}{5u}$	DM1	Dependent on the first 2 M marks. As far as $kx=..$ Dependent on the previous 2 M marks
	Use $x>0$ $(\Rightarrow y>\frac{11}{5}u)$: $25e>11$	DM1	Use correct inequality for their x
	$\frac{11}{25}<e(\leqslant 1)$	A1	Or equivalent. Condone if 1 not mentioned. Allow with <1. A0 if incorrect upper limit. cso
		[7]	
7b	$x=\frac{2}{3}u$ and $y=\frac{7}{3}u$	B1	Seen or implied
	Total KE lost $=\left(\frac{1}{2}m\times 36u^2+\frac{1}{2}5m\times u^2\right)$ $-\left(\frac{1}{2}m\times x^2+\frac{1}{2}5m\times y^2\right)$	M1	Complete expression. Dimensionally correct. Correct masses connected to correct speeds. Condone subtraction in the wrong order. Allow in x and y
	$=\left(\frac{1}{2}m\times 36u^2+\frac{1}{2}5m\times u^2\right)$ $-\left(\frac{1}{2}m\times\frac{4}{9}u^2+\frac{1}{2}5m\times\frac{49}{9}u^2\right)$	A1ft	Correct unsimplified expression in m and u. Follow their x, y with e substituted
	$=\frac{20}{3}mu^2$	A1	Or single term equivalent. Accept $6.7mu^2$ or better
		[4]	
7c	velocity of Q after collision with wall $=\pm fy$ $\left(=\pm f\times\frac{7}{3}u\right)$	B1ft	Follow their y (in terms of u)
	Second collision if $fy>x$ $\frac{7}{3}fu>\frac{2}{3}u$	DM1	Correct inequality for their x, y Dependent on the B1 and P moving away from the wall
	$\frac{2}{7}<f\leqslant 1$	A1	Correct only Need both limits
		[3]	
		(14)	

Q	Scheme	Mark	Notes
8a	Use symmetry to find time taken: $-7 = 7 - gt$	M1	0r equivalent complete method using *suvat* to find the time taken e.g. find the time for vertical distance = 0
	$t = \frac{14}{g} \left(= 1.428...\right)$	A1	Correct value seen or implied
	Horizontal distance $= 4t$	DM1	Complete method using *suvat* to find the distance. Dependent on the preceding M1
	$= 5.71\left(\text{m}\right)$ or $5.7\left(\text{m}\right)$	A1	3 sf or 2 sf only $\frac{40}{7}$ scores A0 $\frac{56}{g}$ scores A0 (incorrect units)
		[4]	
8a alt	Find speed and angle of projection	M1	Correct use of Pythagoras and trig.
	Speed $= \sqrt{16+49} = \sqrt{65}\ \left(\text{m s}^{-1}\right)$ Direction $= \tan^{-1}\frac{7}{4} \quad \left(= 60.3°\right)$	A1	Both values seen or implied.
	Use of $R = \frac{u^2 \sin 2\alpha}{g}$	DM1	Or equivalent. Dependent on the preceding M1
	$= 5.71\left(\text{m}\right)$ *or* $5.7\left(\text{m}\right)$	A1	3 sf or 2 sf only
		[4]	
8b	$\lvert\mathbf{v}\rvert = 5 \Rightarrow \mathbf{v} = 4\mathbf{i} + 3\mathbf{j}$ or $\mathbf{v} = 4\mathbf{i} - 3\mathbf{j}$	B1	Correct vertical component seen or implied
	$-3 = 3 - gT$	M1	Complete method to find T e.g. $T = \frac{14}{g} - 2 \times \frac{4}{g}$
	$T = 0.612$ or $T = 0.61$	A1	3 sf or 2 sf only $\frac{30}{49}$ scores A0 $\frac{6}{g}$ scores A0 (incorrect units)
		[3]	
8c	$\begin{pmatrix}4\\7\end{pmatrix} \cdot \begin{pmatrix}4\\p\end{pmatrix} = 0$	M1	Or equivalent method to find perpendicular velocity
	$\Rightarrow p = -\frac{16}{7}, \quad \mathbf{v} = 4\mathbf{i} - \frac{16}{7}\mathbf{j}$	A1	Correct vertical component Allow -2.28….
	$\left((-)\frac{16}{7}\right)^2 = 7^2 - 2gh$	DM1	Complete method using *suvat* or energy to form an equation in h only. Dependent on the preceding M1
	$h = 2.23$ or $h = 2.2$	A1	3 sf or 2 sf only cso (negative vertical component seen at some point)
		[4]	
8c alt	$\begin{pmatrix}4\\7\end{pmatrix} \cdot \begin{pmatrix}4\\7-gt\end{pmatrix} = 0$	M1	Or equivalent method to find time when velocity perpendicular
	$t = \frac{65}{7g} \left(= 0.947...\right)$	A1	Correct time
	$h = 7t - \frac{1}{2}gt^2$	DM1	Complete method using *suvat* to form an equation in h only.
	$h = 2.23$ or $h = 2.2$	A1	3 sf or 2 sf only cso
		[4]	
		(11)	