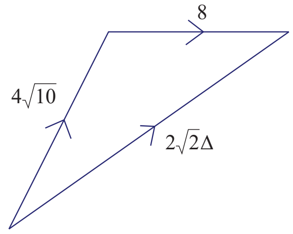
1.	Gain in GPE $= 2.6g \times 20\sin\alpha \left(= 2.6g \times 20 \times \frac{5}{13}\right)$	M1	Or equivalent. Condone sine / cosine confusion
	$F_{max} = \frac{1}{5} \times 2.6g\cos\alpha \left(= \frac{1}{5} \times 2.6g \times \frac{12}{13}\right)$	M1	Or equivalent. Condone sine / cosine confusion
	Work done against friction $= 20F_{max}$	M1	Follow their F_{max}. Must have an expression for F_{max}. Independent of the preceding M1
	Total work done $= 2.6g \times 20\sin\alpha + 4 \times 2.6g\cos\alpha$	DM1	Dependent on preceding M marks Must be adding the two relevant expressions
	$= 290$(J)	A1	2 sf or 3 sf Do not ISW
			NB: Omission of g should be marked as an accuracy error
		[5]	
		(5)	

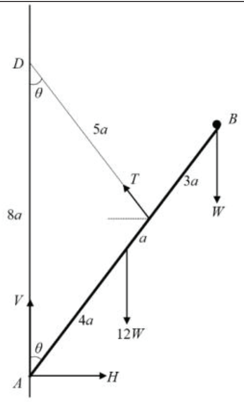
2a	NB If they use $a = 0$ then max score is 1/7 (3rd M1 only)		
	Equation of motion for van + trailer:	M1	First equation: Dimensionally correct. Need all terms. In F or P. Condone sign errors.
	$F-(500+200)=(900+300)a$	A1	Correct unsimplified equation
	Equation of motion for the trailer	M1	Second equation: Dimensionally correct. Need all terms. In F or P. Condone sign errors. Correct mass
	$T-200=300a$	A1	Correct unsimplified equation. Follow their a.
	Equation of motion for van $F-T-500=900a$		There are 3 possible equations. They need 2 of them. M1A1 for each correct unsimplified equation.
	$F=\frac{18000}{12}(=1500)$	M1	Use of $P=Fv$ Need to have substituted relevant values Condone use of 18 in place of 18000 (or incorrect number of zeros)
	Solve for T	DM1	Dependent on previous 3 M marks
	$T=400$	A1	Correct only
			NB: Inclusion of g should be marked as an accuracy error
		[7]	
2b	Equation of motion for van + trailer	M1	Dimensionally correct. Need all terms. Condone sign errors. Condone sine / cosine confusion Alt: Obtains separate equations for van and trailer and eliminates T
	$F-(200+500)-(300+900)g\sin\alpha=0$ $\left(\frac{18000}{v}=700+\frac{1200g}{15}\right)$	A1 A1	Unsimplified equation in F or v with at most one error. Consistent trig confusion is one error. Consistent sign error is one error. Missing g is one error. Correct unsimplified equation in v Allow with trig value not substituted
	$v=12$ or $v=12.1$	A1	2 sf or 3 sf
		[4]	
		(11)	

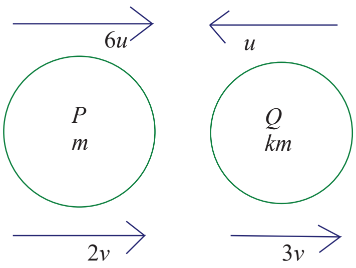
3a	Use $\mathbf{v} = \frac{d\mathbf{r}}{dt}$	M1	Differentiate the vector. At least 3 powers going down
	$\mathbf{v} = \left(3-(t+1)^{-\frac{1}{2}}\right)\mathbf{i} + (2t-6)\mathbf{j}$	A1 A1	one component correct both components correct.
	$(2t-6)=0 \Rightarrow t=3$	M1	Equate their **j** component of velocity to zero and solve for t Must have seen a clear attempt to differentiate
	Speed = $2.5\left(\text{m s}^{-1}\right)$ or equivalent	A1	Must be a scalar. A0 for 2.5**i**
		[5]	
3b	Use $\mathbf{a} = \frac{d\mathbf{v}}{dt}$	M1	Differentiate the vector. Powers going down and at least one constant goes to zero.
	$\mathbf{a} = \frac{1}{2}(t+1)^{-\frac{3}{2}}\mathbf{i} + 2\mathbf{j}$	A1	Or equivalent correct expression Allow if correct derivative implied by correct substitution
	$\left(\mathbf{a} = \frac{4}{\sqrt{125}}\mathbf{i} + 2\mathbf{j}\right)$ $\lvert\mathbf{a}\rvert = \sqrt{\frac{16}{125} + 2^2}$	DM1	Correct use of Pythagoras Dependent on the preceding M1
	$= 2.03\left(\text{m s}^{-2}\right)$ or better	A1	$\frac{2\sqrt{645}}{25}$ or $2.0317\ldots$
		[4]	
3c	For $\mathbf{r} = \mathbf{0}$, $\left(3t+2-2\sqrt{t+1}\right)=0$ and $\left(t^2-6t\right)=0$	M1	No need to consider $t=0$ as this is excluded in the Q
	$t \neq 0 \Rightarrow t = 6$ but $\left(3\times6+2-2\sqrt{6+1}\right)\neq 0$ Hence no solution and does not return	A1	Clear explanation of the given result with no errors seen. e.g. $\left(3t+2-2\sqrt{t+1}\right)=0$ $\Rightarrow 9t^2+8t=0$ has no solution for $t>0$ (need something to indicate impossible)
	There will be other alternatives e.g. Show that the horizontal component of the velocity is always > 2, so no return M1 for correct strategy A1 for correct conclusion with no errors seen and sufficient justification. Conclusion needs to be clear but does not need to be the exact wording from the question. An argument dependent solely on acceleration is unlikely to work – do send to review if you find one worthy of merit.		
		[2]	
		(11)	

4	NB: For the whole of this question, confusion between horizontal and vertical is **not a misread**		
4a	$x = 3$	B1	Seen or implied anywhere Do not accept $x = 3\mathbf{i}$
	Use of $v^2 = u^2 + 2as$	M1	Complete method using *suvat* or energy to form an equation in y. Condone sign errors
	$15^2 = y^2 + 2 \times g \times 10$	A1	Correct unsimplified equation
	$y^2 = 29,\ y = 5.4$ or 5.39	A1	2 sf or 3 sf . If final answer is $y = 5.4\mathbf{j}$ do not penalise inclusion of a vector a second time.
			SC allow 4/4 for $x\mathbf{i} + y\mathbf{j} = 3\mathbf{i} + 5.4\mathbf{j}$
		[4]	
4a alt	$x = 3$	B1	Seen or implied anywhere Do not accept $x = 3\mathbf{i}$
	Equation for conservation of energy	M1	Require all 3 terms and no extras. Dimensionally correct. Condone sign errors. Must include m
	$\frac{1}{2}m \times (3^2 + 15^2) = mg \times 10 + \frac{1}{2}m(x^2 + y^2)$	A1	Correct unsimplified equation – any equivalent form
	$y^2 = 29,\ y = 5.4$ or 5.39	A1	2 sf or 3 sf . If final answer is $y = 5.4\mathbf{j}$ do not penalise inclusion of a vector a second time.
		[4]	
4b	Time from *B* to *C*:	M1	Complete method using *suvat* and their vertical speed. Condone sign errors
	$-15 = 5.39 - gt \quad (t = 2.08)$	A1ft	Correct equation in t only e.g. $10 = 15t - \frac{1}{2}gt^2$ ft on their 5.39 if used
	Horizontal distance $= 3t\ (= \textit{their } x \times \textit{their } t)$	DM1	Complete method using *suvat* and their x value. Dependent on preceding M1
	$(AC =)$ 6.2(m) or 6.24(m)	A1	2 sf or 3 sf NB Penalise over-accuracy only once per question
		[4]	
		(8)	

5a	Impulse-momentum equation.	M1	Dimensionally correct. Subtraction seen or implied. Condone subtraction in wrong order.
	$(\pm\mathbf{I}=)$ $2(\lambda\mathbf{i}+\lambda\mathbf{j})-2(4\mathbf{i})\left(=(2\lambda-8)\mathbf{i}+2\lambda\mathbf{j}\right)$	A1	Or equivalent. Ignore $4\sqrt{10}$ if seen here
	$\left(\lvert\mathbf{I}\rvert^2=\right)160=(2\lambda-8)^2+(2\lambda)^2$	DM1	Use of Pythagoras to obtain an equation in λ. Dependent on the previous M1
	$\left(\Rightarrow 0=\lambda^2-4\lambda-12\right)$	A1	Or any correct unsimplified equation in λ
	$\Rightarrow(\lambda=)6$	A1	Correct only.
	SC Allow 5/5 in (a) if working with **-I**. They will lose marks later.		
		[5]	
5a alt	Form vector triangle for impulse or for momentum.	M1	Dimensionally correct. Must be subtracting. Condone subtraction in wrong order.
	Correct triangle	A1	e.g. 
	$160=64+8\lambda^2-32\sqrt{2}\lambda\times\frac{1}{\sqrt{2}}$	DM1	Use of Cosine Rule to obtain an equation in λ. Dependent on the previous M1
	$\Rightarrow 0=8\lambda^2-32\lambda-96$	A1	Or equivalent equation in λ
	$\Rightarrow(\lambda=)6$	A1	Correct only
		[5]	
5b	$\mathbf{I}=4\mathbf{i}+12\mathbf{j}$	B1ft	Follow their λ $\left(\mathbf{I}=(2\lambda-8)\mathbf{i}+2\lambda\mathbf{j}\right)$ B0 for a column vector. B0 if still in terms of lambda. Ignore second solution for negative lambda if seen
		[1]	
5c	$\tan\theta°=\frac{12}{4}$ or $\cos\theta°=\frac{16}{4\times4\sqrt{10}}$	M1	Correct use of trig or scalar product for the required angle with *their* **I** provided both components are non-zero. Do not allow for the reciprocal
	$\theta=72$	A1	72 or better $(71.56505\ldots)$ from correct work only. Ignore second solution for negative lambda if seen
		[2]	

6a	<table><tr><td></td><td>rectangle</td><td>triangle</td><td>lamina</td></tr><tr><td>area</td><td>$8ka^2$</td><td>$3ka^2$</td><td>$5ka^2$</td></tr><tr><td>From AD</td><td>$4a$</td><td>$2a$</td><td>d</td></tr></table>	B1 B1	Correct area ratio seen or implied Correct distances from AD or a parallel axis seen or implied. Condone if d not used
	Moments about AD	M1	Or a parallel axis. Need all terms. Dimensionally consistent. Condone sign error.
	$8ka^2 \times 4a - 3ka^2 \times 2a = 5ka^2 \times d$	A1	Correct unsimplified equation
	$26a = 5d \Rightarrow d = \dfrac{26}{5}a$ *	A1*	Obtain given answer from correct working. **Must obtain $d = \ldots$**
		[5]	
6b	Moments about PS	M1	Or a parallel axis. Need all terms. Dimensionally consistent. Must be using the 3 correctly with areas, so $5ka^2, 15ka^2, 15ka^2$ is M0. Allow a slip on one value. Condone sign error.
	$5k \times \dfrac{26}{5}a + 2 \times 3 \times 4k \times 4a = (5k + 24k)\bar{x}$	A1 A1	Unsimplified equation with a slip on at most one value Correct unsimplified equation. Allow with common factors cancelled
	$\bar{x} = \dfrac{122}{29}a$	A1	Correct only
	$\bar{y} = ka$	B1	Distance from PQ seen or implied
	$\tan\theta = \dfrac{122}{29k}$	A1ft	Follow their $\bar{x}$. $\left(\dfrac{\bar{x}}{ka}\right)$
		[6]	
		(11)	

7a			NB: This is a "show that" question. The working must give a clear indication of where the lengths in the moments equation come from. Check the diagram. Could be resolving or using similar triangles. Might have resorted to using a calculator to evaluate the angles. Each term should include a trig ratio
	Moments about A	M1	Or an alternative complete method to form an equation in T. Condone sign errors and sine / cosine confusion. Need all terms and dimensionally consistent. (accept with no a)
	$12W\times 4a\sin\theta + W\times 8a\sin\theta = 5a\times T\sin 2\theta$ or $48aW\sin\theta + 8aW\sin\theta = 8aT\sin\theta$ or $48aW\sin\theta + 8aW\sin\theta = 3aT\cos\theta + 4aT\sin\theta$ $\left(48\times\frac{3}{5}W + 8\times\frac{3}{5}W = T\times 10\times\frac{3}{5}\times\frac{4}{5}\right)$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation Allow A1A0 if angle DCB used and not in terms of θ If no trig in the moments equation then M0 – given answer, so no BOD
	$56W = 8T \Rightarrow T = 7W$ *	A1*	Obtain given answer from correct working
		[4]	
7b	First equation e.g. resolve horizontally	M1	Condone sign errors and sine / cosine confusion
	$(\pm)H = T\sin\theta\left(=\frac{21}{5}W\right)$	A1	Correct unsimplified equation Alt: resolving parallel to the rod: $13W\cos\theta = T\cos 2\theta + R\cos\alpha$
	Second equation e.g. resolve vertically	M1	Condone sign errors and sine / cosine confusion
	$(\pm)V + T\cos\theta = 13W\left(V = \frac{37}{5}W\right)$	A1	Correct unsimplified equation Alt resolving perpendicular to the rod: $13W\sin\theta = R\sin\alpha + T\sin 2\theta$
	Another alternative is to use a second moments equation e.g $\text{M}(C): 5a\times R\sin\alpha + W\times 3a\sin\theta = 12W\times a\sin\theta$ $\text{M}(B): R\sin\alpha\times 8a + T\sin 2\theta\times 3a = 12W\times 4a\sin\theta$		
	$\alpha° = \tan^{-1}\frac{3}{4} - \tan^{-1}\frac{H}{V}$ or $\tan^{-1}\frac{V}{H} - \tan^{-1}\frac{4}{3}$	DM1	Complete method to obtain α Dependent on the two preceding M marks Alt gives $R\sin\alpha = \frac{27}{25}W,\ R\cos\alpha = \frac{211}{75}$
	$\alpha = 7.3$	A1	7.29205… or better. Mark 0.127 radians as a misread
		[6]	

8a			
	Use of impact law	M1	Used the right way round. Condone sign errors
	$\frac{3v-2v}{6u+u}=\frac{1}{3}$	A1	Correct unsimplified equation e.g. If see just $\frac{v}{5u}=\frac{1}{3}$ assume a sign slip and allow M1A0A0
	$v=\frac{7}{3}u$	A1	Correct only. CSO
		[3]	
8b	Use of CLM (or equal and opposite impulses)	M1	Dimensionally consistent. Need all terms. Condone sign errors. Condone one slip in matching speeds and masses. Condone consistent omission of *m*.
	$6mu-kmu=3kmv+2mv$ or $6u-ku=3kv+2v$	A1	Correct unsimplified equation Allow the marks if CLM stated correctly in (a) and used here.
	$6-k=3k\times\frac{7}{3}+2\times\frac{7}{3},\quad 8k=\frac{4}{3},\quad k=\frac{1}{6}$	A1	Correct only from correct work only
		[3]	
8c	This method looks at the total time between the two collisions between *P* and *Q*		
	Speed of *Q* after rebound $=f\times 3v\ (=f\times 7u)$	B1ft	Seen or implied ft is for correct use of their *v*
	t_P between collisions $=\frac{6d}{7\times 2v}\left(=\frac{3d}{7v}=\frac{9d}{49u}\right)$	B1ft	Seen or implied For *P* distance 6*d*/7 at 2*v* ft is for correct use of their *v*
	t_Q between collisions $=\frac{d}{3v}+\frac{d}{7\times 3fv}$ $\left(=\frac{d}{7u}+\frac{d}{49fu}\right)$	M1	For *Q* distance *d* at 3*v* and distance *d*/7 at 3*vf*
	$t_Q=t_P\Rightarrow\frac{3d}{7v}=\frac{d}{3v}+\frac{d}{21fv}$	DM1	Equate times and solve for *f* Dependent on preceding M1
	$\frac{3}{7}=\frac{1}{3}+\frac{1}{21f},\quad \frac{2}{21}=\frac{1}{21f},\quad f=\frac{1}{2}$	A1	Correct only from correct working
		[5]	
	See over for alternatives		

8c alt	This method looks at the time between the collision between Q and the wall and the second collision between P and Q		
	Speed of Q after rebound $= f \times 3v\,(= f \times 7u)$	B1ft	Seen or implied ft is for correct use of their v
	Distance apart when Q hits wall $= d - \frac{14u}{3} \times \frac{d}{7u} \left(= \frac{d}{3}\right)$	B1ft	Seen or implied ft is for correct use of their v Distance moved by Q – distance moved by P
	t_P for extra distance $= \frac{4d}{21} \div \frac{14u}{3} \left(= \frac{4d}{21} \div 2v\right)$	M1	Additional time to second collision = extra distance divided by speed of P
	$t_Q = t_P \Rightarrow \frac{4d}{21} \div \frac{14u}{3} = \frac{d}{7} \div 7uf$	DM1	Equate times to second collision and solve for f Dependent on preceding M1
	$\frac{12}{3 \times 2 \times 49} = \frac{1}{49f}, \quad f = \frac{1}{2}$	A1	Correct only from correct working
		[5]	
8c alt	This method looks at how far Q travels after the rebound		
	Speed of Q after rebound $= f \times 3v\,(= f \times 7u)$	B1ft	Seen or implied ft is for correct use of their v
	t_P between collisions $= \frac{6d}{7 \times 2v} \left(= \frac{3d}{7v}\right)$	B1	
	Distance travelled by Q if $f = 1$ $= \frac{3d}{7v} \times 3v = \frac{9}{7}d$	M1	
	$f = \dfrac{\text{actual distance after rebound}}{\frac{9}{7}d - d}$	M1	This is equivalent to $\frac{3d}{7v} \times 3v = \frac{d}{3v} \times 3v + \frac{d}{21fv} \times 3v$ or $\frac{9d}{7} = d + \frac{d}{7f}$
	$= \frac{1}{2}$	A1	
		[5]	
8c alt	This method looks at distances		
	Speed of Q after rebound $= f \times 3v\,(= f \times 7u)$	B1ft	Seen or implied ft is for correct use of their v
	If t_1 is the time for Q to the wall and t_2 is the time between wall and second collision distance travelled by P is $(t_1 + t_2)\frac{14}{3}u$	B1	

	$\left(t_1+t_2\right)\frac{14}{3}u=\frac{6}{7}\times 7ut_1$	M1	Equate distances for *P* and *Q*
	Use $\frac{d}{7}=7uf\times t_2$ and solve	M1	
	Obtain $f=\frac{1}{2}$	A1	
		[5]	