Question	Scheme	Marks
1(a)	Use $\mathbf{r} = \int \mathbf{v}\,\mathrm{d}t$	M1
	Correct integration Eg $\left(t^3 + 6t^2 + 12t\right)\mathbf{i} + \left(\frac{5}{3}t^3 + 5t^2\right)\mathbf{j} + (\mathbf{C})$ Or $(t+2)^3\,\mathbf{i} + \left(\frac{5}{3}t^3 + 5t^2\right)\mathbf{j} + (K)$	A1
	Complete method using $t = 0, \mathbf{r} = -30\mathbf{i} - 45\mathbf{j}$ (m) and substitute $t = 3$ Indefinite integration Use of $t = 0, \mathbf{r} = -30\mathbf{i} - 45\mathbf{j}$ (m) to find constant of integration and substitute $t = 3$. Definite integration Use of $\mathbf{r} = (-30\mathbf{i} - 45\mathbf{j}) + \int_0^3 \mathbf{v}\,\mathrm{d}t$	DM1
	$\mathbf{r} = 87\mathbf{i} + 45\mathbf{j}$ (m)	A1
		(4)
1(b)	Use $\mathbf{a} = \frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$	M1
	Correct differentiation $\mathbf{a} = (6t + 12)\mathbf{i} + (10t + 10)\mathbf{j}$	A1
	Substitute $t = 3$ and find magnitude	DM1
	$\lvert\mathbf{a}\rvert = 50\ (\mathrm{m\,s^{-2}})$	A1
		(4)
1(c)	$3(T+2)^2 = 10T(T+2)$ $(3T + 6 = 10T) \quad (7T^2 + 8T - 12 = 0)$	M1
	$T = \frac{6}{7}$	A1
		(2)
		(10)
	Notes	
1(a)		
M1	Integrate to obtain **r**. Powers increase by 1 in both components. Condone working with separated components. Condone missing brackets with **i-j** notation. M0 for *suvat.*	
A1	Correct integration. Condone missing constant of integration.	
DM1	• Dependent on the preceding M1. • Must have a constant of integration before using $t = 3$ (unless using definite integration) • Must use $(-30\mathbf{i} - 45\mathbf{j})$ • Must substitute $t = 3$ Condone working with separated components. DM0 if substitution of $t = 3$ occurs before finding + C.	

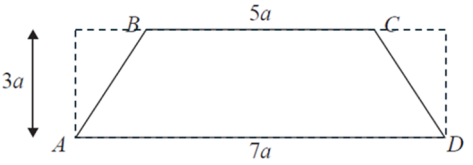
	$\left(t^3+6t^2+12t-30\right)\mathbf{i}+\left(\frac{5}{3}t^3+5t^2-45\right)\mathbf{j}$ $\quad C=\left(-30\mathbf{i}-45\mathbf{j}\right)$ $\left(\left(t+2\right)^3-38\right)\mathbf{i}+\left(\frac{5}{3}t^3+5t^2-45\right)\mathbf{j}$ $\quad K=\left(-38\mathbf{i}-45\mathbf{j}\right)$	
A1	Correct answer, accept column vector $\begin{pmatrix}87\\45\end{pmatrix}$ A0 for poor notation in final answer eg $\begin{pmatrix}87\mathbf{i}\\45\mathbf{j}\end{pmatrix}$ ISW if they continue and find $\lvert\mathbf{r}\rvert$	
1(b)		
M1	Differentiate to obtain **a**. Powers decrease by 1 in both components. Condone working with separated components and missing brackets with **i**-**j** notation. M0 for *suvat*	
A1	Correct differentiation	
M1	Dependent on the preceding M1 Use of Pythagoras seen or implied $\sqrt{30^2+40^2}$	
A1	Correct only	
1(c)		
M1	Correct method using the ratio of **i** and **j** components of **v**. Form an equation in T only. Accept working in t or T.	
A1	0.86 or better. Condone t instead of T.	

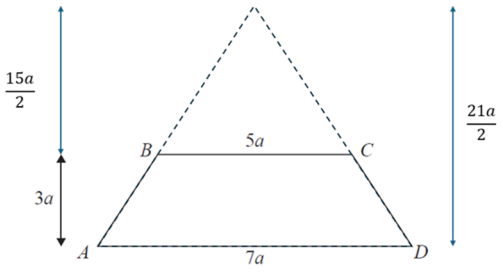
Question	Scheme	Marks
2	Use of Impulse momentum equation	M1
	$\mathbf{I} = 3(x\mathbf{i} + y\mathbf{j}) - 3\times 5\mathbf{i}$ $\left(= 3(x-5)\mathbf{i} + 3y\mathbf{j}\right)$	A1
	$\lvert I\rvert^2 = 9\left((x-5)^2 + y^2\right) = 9\times 82\ (=738)$	M1
	Equation for change in KE	M1
	$\frac{1}{2}\times 3\left(x^2 + y^2 - 25\right) = 138$ $\left(x^2 + y^2 - 25 = 92\right)$	A1
	$(x-5)^2 + y^2 = 82$ $x^2 + y^2 = 117 \Rightarrow 10x = 60$	DM1
	$\mathbf{v} = 6\mathbf{i} + 9\mathbf{j}\ \left(\text{m s}^{-1}\right)$	A1
		(7)
ALT	Use of $I = \begin{pmatrix} 3\sqrt{82}\cos\theta \\ 3\sqrt{82}\sin\theta \end{pmatrix}$ $I = \begin{pmatrix} 3\sqrt{82}\cos\theta \\ 3\sqrt{82}\sin\theta \end{pmatrix} = 3\begin{pmatrix} x \\ y \end{pmatrix} - 3\begin{pmatrix} 5 \\ 0 \end{pmatrix}$	M1 A1
	$\lvert I\rvert^2 = 9\left((x-5)^2 + y^2\right) = 9\times 82$	M1
	Equation for change in KE $\frac{1}{2}\times 3\left(x^2 + y^2 - 25\right) = 138$	M1 A1
	Leads to $\theta = 83.66...$ $x = 5 + 3\sqrt{82}\cos\theta = 6$ $y = 3\sqrt{82}\sin\theta = 9$ $\mathbf{v} = 6\mathbf{i} + 9\mathbf{j}\ \left(\text{m s}^{-1}\right)$	DM1 A1
	Notes	
M1	Find the difference in momenta. Dimensionally correct. Condone subtraction in wrong order. Must use both components. (Ignore $3\sqrt{82}$ if it appears on LHS)	
A1	Correct unsimplified expression for difference in momentum. Condone subtraction the wrong way round.	
M1	Correct use of Pythagoras with $3\sqrt{82}$ and both components of impulse. Ignore poor **i-j** notation, eg $\mathbf{i}^2$ for this mark, if recovered by correct subsequent working.	
M1	Use change in KE to produce an equation in terms of x and y. Dimensionally correct, requires 2 KE terms of correct structure. Condone subtraction in wrong order. Ignore poor **i-j** notation eg $(x\mathbf{i})^2 + (y\mathbf{j})^2$ for this mark, if recovered by correct subsequent working.	

	M0 For use of velocity.	
A1	Correct unsimplified equation A0 for incorrect notation. A0 for subtraction the wrong way round.	
DM1	Dependent on all preceding M marks. Solve for x or y	
A1	Correct velocity only. Accept column vector. ISW if continue to find speed.	

Question	Scheme	Marks
3(a)	Equation of motion for whole system.	M1
	$F-640-1100g\sin\alpha=1100a$	A1 A1
	Use of $P=Fv$ $\quad F=\dfrac{15000}{12}\left(=1250\right)$	M1
	$a=0.16\left(\text{m s}^{-2}\right)$ or $a=0.163\left(\text{m s}^{-2}\right)$	A1
		(5)
3(b)	Work-energy equation for the trailer.	M1
	$\frac{1}{2}\times200\times14^2=240d+200g\times\frac{1}{25}d$	A1 A1
	$\left(AB=\right)62\left(\text{m}\right)$ or $\left(AB=\right)61.6\left(\text{m}\right)$	A1
		(4)
		(9)
	Notes	
3(a)		
	Over-accuracy or under-accuracy is penalised max **once** per complete question. Penalise final A mark in the appropriate part. Use of g = 9.81 or 10 is penalised max **once** per complete question. Penalise final A mark in the appropriate part. If both errors occur, could lose the final two A marks.	
M1	Equation of motion for whole system. All terms required. Dimensionally correct. Condone sign errors and sin/cos confusion. May form two equations of motion (van and trailer) and combine to eliminate *T*. Condone slip with zeroes for M mark. The forces on the LHS must be consistent with the mass in the '*ma*'. Note that $\sin\left(\frac{1}{25}\right)$ is an accuracy error, **not** a method error.	
A1	Unsimplified equation in *F* or *P* with at most one error. Missing *g* from both weight terms counts as 1 error.	
A1	Correct unsimplified equation in *F* or *P*	
M1	Use of $P=Fv$. Condone slip with zeroes for M mark.	
A1	Correct answer, 2 sf or 3 sf.	
3(b)		
M1	Work-energy equation. Condone slip with zeroes for M mark. Dimensionally correct, all terms required and with correct structure: KE, GPE, WD. No repeats. Must use mass of trailer only. Condone sign errors and sin / cos confusion. M0 for *suvat*. Note that $\sin\left(\frac{1}{25}\right)$ is an accuracy error, **not** a method error.	
A1	Unsimplified equation with at most one error.	
A1	Correct unsimplified equation with mass replaced.	
A1	Correct answer, 2 sf or 3 sf No need for $AB=$	

<table>
<tr><th>Question</th><th>Scheme</th><th>Marks</th></tr>
<tr><td>4(a)</td><td>
<table>
<tr><td></td><td>Rectangle</td><td>2 x Triangle</td><td>Trapezium</td></tr>
<tr><td>Mass</td><td>$15a^2$</td><td>$2\times\frac{3}{2}a^2$</td><td>$18a^2$</td></tr>
<tr><td>From AD</td><td>$\frac{3}{2}a$</td><td>a</td><td>d</td></tr>
</table>
</td><td>B1

B1</td></tr>
<tr><td></td><td>Some examples of alternatives
 



<table>
<tr><td></td><td>Large rectangle</td><td>2 removed triangles</td><td>Trapezium</td></tr>
<tr><td>Mass</td><td>$21a^2$</td><td>$2\times\frac{3a\times a}{2}$</td><td>$18a^2$</td></tr>
<tr><td>Distance from AD</td><td>$\frac{3a}{2}$</td><td>$\frac{2}{3}\times 3a = 2a$</td><td>$d$</td></tr>
</table>
<table>
<tr><td></td><td>Large triangle</td><td>Removed triangle</td><td>Trapezium</td></tr>
<tr><td>Mass</td><td>$\frac{147a^2}{4}$</td><td>$\frac{75a^2}{4}$</td><td>$18a^2$</td></tr>
<tr><td>Distance from AD</td><td>$\frac{1}{3}\times\frac{21a}{2}=\frac{7a}{2}$</td><td>$3a+\frac{1}{3}\times\frac{15a}{2}=\frac{11a}{2}$</td><td>$d$</td></tr>
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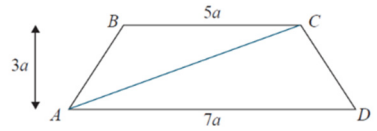
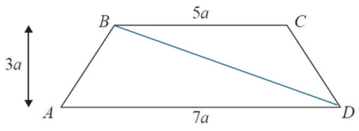




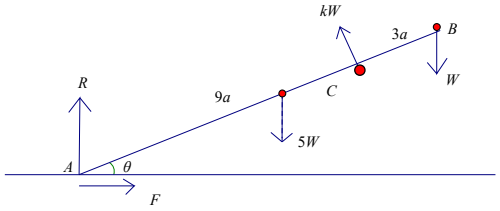
<table>
<tr><td></td><td>Triangle ABC</td><td>Triangle ACD</td><td>Trapezium</td></tr>
<tr><td>Mass</td><td>$\frac{5a\times 3a}{2}=\frac{15}{2}a^2$</td><td>$\frac{7a\times 3a}{2}=\frac{21}{2}a^2$</td><td>$18a^2$</td></tr>
<tr><td>Distance from AD</td><td>$\frac{2}{3}\times 3a = 2a$</td><td>$\frac{1}{3}\times 3a = a$</td><td>$d$</td></tr>
</table>
<table>
<tr><td></td><td>Triangle ABD</td><td>Triangle ACD</td><td>Trapezium</td></tr>
<tr><td>Mass</td><td>$\frac{7a\times 3a}{2}=\frac{21}{2}a^2$</td><td>$\frac{5a\times 3a}{2}=\frac{15}{2}a^2$</td><td>$18a^2$</td></tr>
<tr><td>Distance from AD</td><td>$\frac{1}{3}\times 3a = a$</td><td>$\frac{2}{3}\times 3a = 2a$</td><td>$d$</td></tr>
</table>
</td><td></td></tr>
<tr><td></td><td>Moments about AD</td><td>M1</td></tr>
<tr><td></td><td>$15a^2\times\frac{3}{2}a+3a^2\times a=18a^2d$</td><td>A1</td></tr>
<tr><td></td><td>$\frac{51}{2}a=18d\Rightarrow d=\frac{17a}{12}$ *</td><td>A1*</td></tr>
<tr><td></td><td></td><td>(5)</td></tr>
<tr><td>4(b)</td><td>$\overline{x}=\frac{9}{2}a$</td><td>B1</td></tr>
<tr><td></td><td>Moments about PS or a parallel axis for Lamina</td><td>M1</td></tr>
<tr><td></td><td>From PS: $27a^2\overline{y}=45a^2\times 2.5a-18a^2\left(a+\frac{17}{12}a\right)$

From AD: $27a^2\overline{Y}=45a^2\times 1.5a-18a^2\left(\frac{17}{12}a\right)$</td><td>A1
A1</td></tr>
<tr><td></td><td>$\overline{y}=\frac{69}{27}a=\frac{23}{9}a$</td><td>A1</td></tr>
<tr><td></td><td>Expression for relevant angle</td><td>M1</td></tr>
</table>

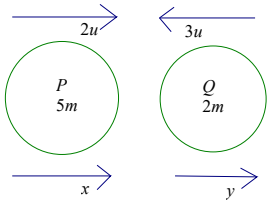
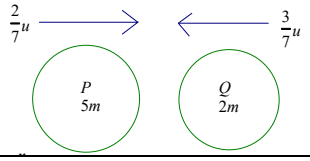
	$\tan\theta° = \dfrac{\bar{y}}{"\left(9a/2\right)"} \quad \left(=\dfrac{46}{81}\right)$	
	$\theta = 29.6$	A1
		(7)
		(12)
	Notes	
4(a)		
B1	Correct mass ratio.	
B1	Correct distances from *AD*, for an appropriate division of *ABCD* Distances may be measured from a parallel axis	
M1	Dimensionally consistent equation with all required terms. Accept working from a parallel axis. Accept an equation embedded in vector form.	
A1	Correct unsimplified equation. Accept embedded in vector form.	
A1*	Obtain given answer from correct working. Working must include simplification or rearrangement (may be seen from table to equation). Answer must be extracted from vector form and have $d =$	
4(b)		
B1	Distance of c of m of lamina from *PQ* seen or implied. May not be seen until the trig ratio.	
M1	Complete method to find c of m of Lamina (remaining mass) from *PS* or a parallel axis. Dimensionally consistent equation containing all required terms. If one distance is from *PS* and the other is from *AD*, treat as an accuracy error.	
A1	Unsimplified equation for *PS* or their parallel axis, with at most one error	
A1	Correct unsimplified equation for *PS* or their parallel axis.	
A1	Correct distance of c of m from *PS*, $2.6a$ or better	
M1	Correct use of trig for a relevant angle where $"\left(9a/2\right)"$ is their distance of the c of m of the lamina from *PQ* and $\bar{y}$ is their **calculated** distance from *PS*. Allow with both a's or neither. Allow reciprocal.	
A1	30 or better (29.59229…) cao	

Question	Scheme	Marks
5(a)	Horizontal motion to find expression for the distance	M1
	$(XY =)u\cos\theta t$	A1
	Method using vertical motion to find relevant equation in t, u, g, θ. Eg • Using vertical distance $=0$ to find expression for time. • Find expression for time to max height and $\times 2$	M1
	Correct unsimplified equation in t, u, g, θ. $u\sin\theta t-\frac{1}{2}gt^2=0$	A1
	Solve to obtain the distance in terms of u, g and θ	DM1
	$XY=u\cos\theta\times\frac{2u\sin\theta}{g}=\frac{u^2\sin 2\theta}{g}$ *	A1*
		(6)
5(b)	$CB=\frac{20^2\times\sin 120°}{g}-12$	M1
	$CB=23(\text{m})$ or $CB=23.3(\text{m})$	A1
		(2)
5(c)	Horizontal motion	M1
	$12=20\cos 60°t$	A1
	Vertical motion $y=20\sin 60°\times 1.2-\frac{1}{2}\times g\times 1.2^2(-5)$	M1
	Height above $D=$ $8.7(\text{m})$ or $8.73(\text{m})$	A1
		(4)
		(12)
	Notes	
	Over-accuracy or under-accuracy is penalised max **once** per complete question. Penalise final A mark in the appropriate part. Use of g = 9.81 or 10 is penalised max **once** per complete question. Penalise final A mark in the appropriate part. If both errors occur they could lose the final two A marks.	
5(a)		
M1	Use horizontal motion to find an expression for the horizontal distance.	
A1	Correct unsimplified equation.	
M1	Method using vertical motion with relevant *suvat* to find an equation in t, u, g, θ (condone use of 9.8). M0 if $t=\frac{2u\sin\theta}{g}$ or $t=\frac{u\sin\theta}{g}$ is quoted (ie if it appears without any evidence of method)	
A1	Correct equation, (condone use of 9.8) Eg • $u\sin\theta t-\frac{1}{2}gt^2=0$	

	• $-u\sin\theta = u\sin\theta - gt$ • $u\sin\theta - gt = 0$ double the time.	
DM1	Dependent on the preceding M marks. Solve to obtain the distance in terms of u, g and θ.	
A1*	Obtain given answer from correct working. Must recover g if 9.8 is used. Must have $XY =$ at this stage.	
5(b)		
M1	Complete method using result in (a), or using horizontal motion from first principles, to find the horizontal distance CB.	
A1	Correct answer, 2sf or 3sf	
5(c)		
M1	Complete method for horizontal motion to obtain an equation in t. If t =1.2 o.e. is seen in earlier working, it must be used in (c) to earn the marks.	
A1	Correct unsimplified equation (t = 1.2)	
M1	Method using *suvat* with vertical motion to obtain a relevant vertical distance. Height of pole not required.	
A1	Correct answer, 2 sf or 3 sf	

Question	Scheme	Marks
6(a)		
	Moments about A	M1
	$5W\times 6a\cos\theta + W\times 12a\cos\theta = 9akW$ $\left(30\times\frac{12}{13}+12\times\frac{12}{13}=9k\right)$	A1 A1
	$\Rightarrow k=\frac{56}{13}$ *	A1*
		(4)
6(b)	First relevant equation	M1
	Correct unsimplified equation Relevant equations: • Vert: $R+kW\cos\theta = 6W$ $\left(R=\frac{342}{169}W\right)$ • Horiz: $F=kW\sin\theta$ $\left(F=\frac{280}{169}W\right)$ • // to AB: $F\cos\theta + R\sin\theta = 6W\sin\theta$ • Perp to AB: $kW + R\cos\theta = 6W\cos\theta + F\sin\theta$ • M(G): $R\cos\theta\times 6a + W\cos\theta\times 6a = F\sin\theta\times 6a + kW\times 3a$ • M(C): $W\cos\theta\times 3a + R\cos\theta\times 9a = 5W\cos\theta\times 3a + F\sin\theta\times 9a$ • M(B): $kW\times 3a + R\cos\theta\times 12a = 5W\cos\theta\times 6a + F\sin\theta\times 12a$	A1
	Second relevant equation	M1
	Correct unsimplified equation	A1
	Use of $F=\mu R$ to form an equation in μ only	DM1
	$\mu=\frac{280}{342}\left(=\frac{140}{171}\right)=0.8187....$	A1
		(6)
		(10)
	Notes	
	Note that an extra g in a resolution or moments equation is an accuracy error and not a method error.	
6(a)		
M1	Complete method eg moments about A. All required terms present and no extra. Dimensionally correct, product of perpendicular force and distance (a and W present throughout). Condone sign errors and sin/cos confusion. Condone R_c (or similar) instead of kW.	
A1	Unsimplified equation with at most one error	
A1	Correct unsimplified equation	
A1*	Obtain given answer from correct working. Trig replaced and R_c (or similar) replaced in terms of k. At least one line of working required	

	between the equation and the given answer. Do not accept embedded value for k.	
6(b)		
M1	First relevant equation. All required terms present and no extra. Dimensionally consistent. Condone sign errors and sin/cos confusion.	
A1	Correct unsimplified equation. Trig does not need to be replaced. Condone R_c (or similar) instead of kW.	
M1	Second relevant equation. To be relevant it must be possible to use with the first equation to find μ (at least one equation must be a horizontal, vertical, parallel or perpendicular resolution). All required terms present and no extra. Dimensionally consistent. Condone sign errors and sin/cos confusion.	
A1	Correct unsimplified equation. Trig does not need to be replaced. Condone R_c (or similar) instead of kW.	
DM1	Depending on the two previous M marks. Use of $F = \mu R$ to reach $\mu =\ldots$	
A1	$\frac{280}{342}\left(=\frac{140}{171}\right) = 0.8187....$ Accept 0.82 or better	

Question	Scheme	Marks
		
7(a)	CLM	M1
	$10mu-6mu=5mx+2my$ $(4u=5x+2y)$	A1
	Impact law	M1
	$y-x=5ue$	A1
	$4u=5x+2x+10ue\left(=7x+10ue\right)$	DM1
	$(x>0\Rightarrow)\ 10ue<4u$	DM1
	$\Rightarrow 0$ „ $e<\frac{2}{5}$ o.e.	A1
		(7)
7(b)	Impulse momentum equation	M1
	$\frac{60}{7}mu=2m\left(3u-(-y)\right)$ or $-\frac{60}{7}mu=5m\left(x-2u\right)$	A1
	Solve to find a correct expression for either x or y $\left(y=\frac{9}{7}u\ ,\ x=\frac{2}{7}u\text{ but may not be seen explicitly}\right)$	DM1
	Use both impulse equations and impact law with their x **and** y to form an equation in e (and u). $5ue=\frac{9}{7}u-\frac{2}{7}u$ Using CLM and impact law from part (a) to form an equation in e (and u). For example $\frac{2u}{7}=\frac{4u-10eu}{7}$	M1
	$e=\frac{1}{5u}\left(\frac{9}{7}u-\frac{2}{7}u\right)=\frac{1}{5}$ *	A1*
		(5)
7(c)		
	Speed of $Q=\frac{1}{3}\times\frac{9}{7}u\ \left(=\frac{3}{7}u\right)$	B1ft
	Magnitude of impulse = $\frac{1}{7}\times\frac{60}{7}mu$	M1
	$=\frac{60}{49}mu$	A1

		(3)
		(15)
	Notes	
7(a)		
M1	Form CLM equation. All terms required. Mass and velocity correctly paired. Dimensionally consistent, condone consistent additional g in each term. Condone sign errors.	
A1	Correct equation or equivalent. Condone consistent additional g in each term. Condone $\pm y$.	
M1	Use Impact Law. Dimensionally correct. Used the right way round (separation and approach must not be interchanged). Condone sign errors.	
A1	Correct equation or equivalent. Directions of P and Q after impact must be consistent with CLM.	
DM1	Dependent on the preceding M marks. Eliminate velocity of Q to form an equation in x, e and u only. $\left(x = \frac{4u - 10eu}{7}\right)$	
DM1	Dependent on all preceding M marks. May be implied by $e < 0.4$ Use direction of P to form an inequality in e (and u). Use correct inequality for their diagram: if they had P changing direction should now be using $x < 0$	
A1	Both ends required 0 „ $e < 0.4$ but condone $0 < e < 0.4$	
7(b)		
M1	Impulse-momentum equation. Dimensionally correct, using the correct mass and velocity pair for a single particle. Must be subtracting momenta but allow incorrect order. May use working in terms of e from (a) $x = \frac{4u - 10eu}{7}$ $y = \frac{25eu + 4u}{7}$	
A1	At least one correct unsimplified equation.	
DM1	Solve impulse-momentum equation to find either $y = \frac{9}{7}u$ or $x = \frac{2}{7}u$	
M1	Complete method to form an equation in e (and u) only with the usual rules for CLM and Impact Law.	
A1*	Obtain given answer from complete and correct working. A0 for 0.2	
7(c)		
B1	Follow $\frac{1}{3} \times$ their y from part (b). If y is given in terms of e then $e = \frac{1}{5}$ must be substituted at some point. Seen or implied. May appear on diagram. Accept $\pm$.	

M1	Complete method using (a) and (b) and working from first principles to find the impulse in the second collision between P and Q. Must see: • Usual rules for CLM and Impact Law to **find** V_p or V_q after second collision. CLM $\frac{10mu}{7}-\frac{6mu}{7}=5mV_p+2mV_q$ Impact Law $\frac{1}{5}\times\left(\frac{2u}{7}+\frac{3u}{7}\right)=V_q-V_p$ • **Then** use of Impulse – momentum equation with usual rules to find magnitude of impulse. Impulse – momentum Either $I=2m\left(\frac{9u}{49}--\frac{3u}{7}\right)$ or $I=5m\left(\frac{2u}{49}-\frac{2u}{7}\right)$	
A1	$1.2mu$ or better (1.2244897…)	