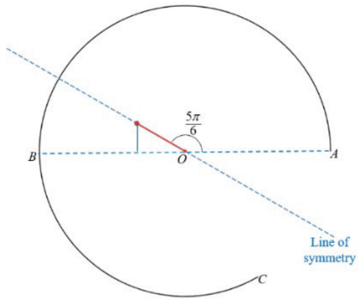
QUESTION NUMBER	SCHEME	MARK
1(a)	Moments equation	M1
	$2m(4\lambda)+3m(2)+7m(4)=12m\bar{x}$	A1
	$\bar{x}=\dfrac{4\lambda+17}{6}$ *	A1*
		(3)
1(b)	Moments equation to find $\bar{y}$	M1
	$2m\lambda+3m(4)+7m(-3)=12m\bar{y}$	A1
	Use of straight line equation to form an equation in λ only: $\dfrac{4\lambda+17}{6}-6\times\dfrac{(2\lambda-9)}{12}=6$	M1
	$(\lambda=)4$	A1
		(4)
		(7)
	Notes for question	
(a)		
M1	Moments about y-axis (or a parallel axis). All terms required. Dimensionally consistent. Condone sign errors.	
A1	Correct equation	
A1*	Obtain given answer from complete and correct working. Allow terms reversed. **N.B**. Must see $\bar{x}=$ .. somewhere.	
(b)		
M1	Moments about x-axis (or a parallel axis). All terms required. Dimensionally consistent. Condone sign errors.	
A1	Correct equation	
M1	Use of straight line equation to form an equation in λ only **N.B.** Must use the given answer for $\bar{x}$ and have found a $\bar{y}$	
A1	Correct answer.	

QUESTION NUMBER	SCHEME	MARKS
	N.B. Accept column vectors throughout the question	
2(a)	Integrate **both** components of **v**	M1
	$$\mathbf{r}=\left(\frac{t^2}{2}-\cos t\right)\mathbf{i}+\left(\sin t-3t\right)\mathbf{j}\quad(+\mathbf{c})$$	A1
	Complete method using $t=0$ and $\mathbf{r}=2\mathbf{i}$ to find $\mathbf{r}$ when $t=\pi$:	M1
	$$\mathbf{r}=\left(\frac{\pi^2}{2}+4\right)\mathbf{i}-3\pi\mathbf{j}$$	A1
		(4)
2(b)	Differentiates **both** components of **v**	M1
	$$\mathbf{a}=\left(1+\cos t\right)\mathbf{i}+\left(-\sin t\right)\mathbf{j}$$	A1
	Use of $\mathbf{F}=m\,\mathbf{a}$ or $F=ma$ and Pythagoras	M1
	$$\lvert\mathbf{F}\rvert=0.5\sqrt{\left(1+\cos t\right)^2+(-\sin t)^2}$$	A1
	Expand and use trig identity to reach given answer $$\lvert\mathbf{F}\rvert=\sqrt{\frac{1+\cos t}{2}}\quad *$$	A1*
		(5)
		(9)
	Notes for question	
(a)		
M1	Integrates both components of **v**. At least one power of t must increase by 1 and at least one trig term must change ($\sin t/\cos t$) overall, rather than in each component.	
A1	Correct unsimplified expression. Allow with no constant of integration.	
M1	**N.B.** Must have attempted to integrate. Complete method using $t=0$ and $\mathbf{r}=2\mathbf{i}$ to find $\mathbf{r}$ when $t=\pi$ Constant of integration is $3\mathbf{i}$	
A1	Correct answer. Trig values must be evaluated.	
(b)		
M1	Differentiates **both** components of **v**. At least one power of t must decrease by 1 and at least one trig term must change ($\sin t/\cos t$) overall, rather than in each component.	
A1	Correct expression for acceleration	
M1	Use $\mathbf{F}=m\mathbf{a}$ or $F=ma$ and Pythagoras with root. **N.B.** Must have attempted to differentiate **v** to find **a** M0 if only one component of **a** is multiplied by 0.5	
A1	Correct expression	
A1*	Expand and use trig identity to obtain the given answer. **N.B.** Must see $\lvert\mathbf{F}\rvert=$ .. somewhere	

QUESTION NUMBER	SCHEME	MARKS
3(a)	Use of $P = Fv$ at least once $\left((D =)\dfrac{P}{18} \text{ or } (D' =)\dfrac{6P}{12} \right)$	M1
	Equation for motion **down** road $D + 900g\sin\theta - R = 0$	M1 A1
	Equation for motion **up** road $D' - 900g\sin\theta - R = 0$	M1 A1
	$P = 2646$: possible answers are 2650 or 2600 or 270g $R = 735$ (exact) or 740 or 75g	A1 A1
		(7)
3(b)	GPE term = $900g(40\sin\theta)\,(= 2400g)$	B1
	WD against R = $40R$	B1
	(Total work-done =) Increase in KE + GPE + WD against R $= \dfrac{1}{2}(900)16^2 - \dfrac{1}{2}(900)12^2 + 900g(40\sin\theta) + 40R$	M1 A1
	=103,320 (exact) So possible answers are only: 103 000 or 100 000 (J) or 103 kJ or 1.03×10^5 (J)	A1
(b) ALT 1	$900g\sin\theta\times40$, seen or implied	B1
	$40R$ seen or implied (R does not need to be substituted)	B1
	Equation of motion: $\dfrac{W}{40} - R - 900g\sin\theta = 900\times\left(\dfrac{16^2 - 12^2}{2\times40}\right)$ **OR:** $\dfrac{W}{40} - \dfrac{6P}{12} = 900\times\dfrac{(16^2 - 12^2)}{2\times40}$	M1A1
	(W =) 103,320 (exact) So possible answers are only: 103 000 or 100 000 (J) or 103 kJ or 1.03×10^5 (J)	A1
		(5)
		(12)
	Notes for question	
(a)		
M1	Use of $P = Fv$ at least once	
M1	Equation of motion **down** the road. Dimensionally correct, correct number of terms, condone sin/cos confusion and sign errors. Trig and D do not need to be replaced.	
A1	Correct unsimplified equation	
M1	Equation of motion **up** the road. Dimensionally correct, correct number of terms, condone sin/cos confusion and sign errors. Trig and D do not need to be replaced.	
A1	Correct unsimplified equation	
A1	One correct value (P or R) 2/3 sf.	

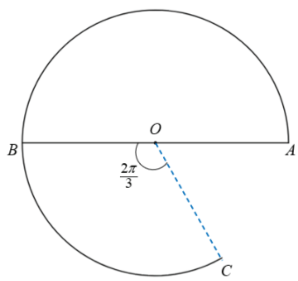
	$P = 2650$ or 2600 or $270g$ $\quad R = 735$ or 740 or $75g$	
A1	Both correct values (P and R)	
(b)		
B1	GPE term seen	
B1	WD against R	
M1	Expression for total work-done by the engine. Dimensionally correct with all required terms present and no extras or double-counting. All terms of correct structure. Condone sign errors.	
A1	Correct unsimplified equation, R does NOT need to be substituted.	
A1	Correct answer 2 or 3 sf.	
(b) ALT 1	For the M mark, if no reference to 40 in the force term is seen or implied then M0: i.e. $F - R - 900g\sin\theta = 900\times\left(\dfrac{16^2-12^2}{2\times 40}\right)$ is M0 unless the F is then multiplied by 40.	

<table>
<tr><th>QUESTION NUMBER</th><th>SCHEME</th><th>MARKS</th></tr>
<tr><td></td><td>N.B. If areas are involved there are no marks available.</td><td></td></tr>
<tr><td>4(a)</td><td>Using arc $ABC + BA$</td><td></td></tr>
<tr><td></td><td>For arc ABC, distance of centre of mass from O


$$d = \frac{a\sin\left(\frac{5\pi}{6}\right)}{\frac{5\pi}{6}} = \frac{3a}{5\pi}$$</td><td>B1</td></tr>
<tr><td></td><td>

	Arc ABC	Line BA	Total
Mass ratio	$\frac{5\pi a}{3}$	$2a$	$a\left(\frac{5\pi}{3}+2\right)$
Distance from BA	$\frac{3a}{10\pi}$	0	$\bar{y}$

</td><td>B1 mass ratios

B1 dist</td></tr>
<tr><td></td><td>Moments about BA or a parallel axis</td><td>M1</td></tr>
<tr><td></td><td>M(BA): $\frac{5\pi a}{3}\times\frac{3a}{10\pi} = a\left(\frac{5\pi}{3}+2\right)\bar{y}$</td><td>A1</td></tr>
<tr><td></td><td>$$\bar{y} = \frac{3a}{2(5\pi+6)} \quad *$$</td><td>A1*</td></tr>
<tr><td></td><td></td><td>(6)</td></tr>
<tr><td>(a) ALT1</td><td>Using arc AB + BA + arc BC</td><td></td></tr>
<tr><td></td><td>

For arc BC, distance of centre of mass from O
$$= \frac{a\sin\left(\frac{\pi}{3}\right)}{\frac{\pi}{3}} = \frac{3\sqrt{3}a}{2\pi}$$
OR for arc AB, distance of centre of mass from O
$$= \frac{a\sin\left(\frac{\pi}{2}\right)}{\frac{\pi}{2}} = \frac{2a}{\pi}$$</td><td>B1</td></tr>
</table>

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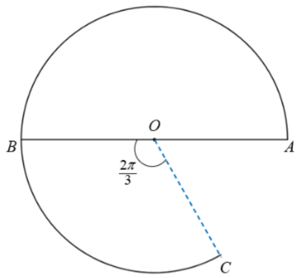
<tr><td></td><td>

	Arc AB	Line BA	Arc BC	Total
Mass ratio	πa	$2a$	$\frac{2\pi a}{3}$	$a\left(\frac{5\pi}{3}+2\right)$
Distance From BA	$\frac{2a}{\pi}$	0	$\frac{9a}{4\pi}$	$\bar{y}$

</td><td>B1 mass ratios

B1 dist</td></tr>
<tr><td></td><td>Moments about BA or a parallel axis</td><td>M1</td></tr>
<tr><td></td><td>M(BA): $\pi a\times\frac{2a}{\pi}-\frac{2\pi a}{3}\times\frac{9a}{4\pi}=a\left(\frac{5\pi}{3}+2\right)\bar{y}$</td><td>A1</td></tr>
<tr><td></td><td>$\bar{y}=\frac{3a}{2(5\pi+6)}$ *</td><td>A1*</td></tr>
<tr><td></td><td></td><td>(6)</td></tr>
<tr><td>(a) ALT 2</td><td>Using Circle $+BA$ $-$arc AC</td><td></td></tr>
<tr><td></td><td>For arc AC, distance of centre of mass from O


$=\frac{a\sin\left(\frac{\pi}{6}\right)}{\frac{\pi}{6}}=\frac{3a}{\pi}$</td><td>B1</td></tr>
<tr><td></td><td>

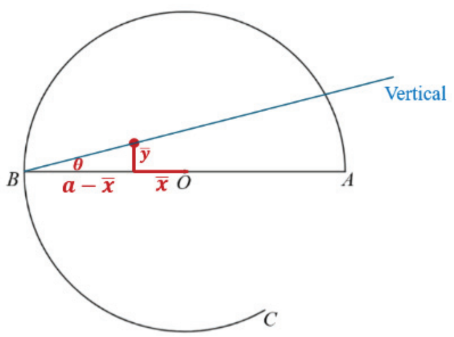
	Circle	Line BA	Arc AC	Total
Mass ratio	$2\pi a$	$2a$	$\frac{\pi a}{3}$	$2\pi a+2a-\frac{\pi a}{3}$
Distance from BA	0	0	$\frac{3a}{2\pi}$	$\bar{y}$

</td><td>B1 mass ratios

B1 dist</td></tr>
<tr><td></td><td>Moments about BA or a parallel axis</td><td>M1</td></tr>
<tr><td></td><td>M(BA): $0+0-(-\frac{\pi a}{3}\times\frac{3a}{2\pi})=\left(2\pi a+2a-\frac{\pi a}{3}\right)\bar{y}$</td><td>A1</td></tr>
<tr><td></td><td>$\bar{y}=\frac{3a}{2(5\pi+6)}$ *</td><td>A1*</td></tr>
<tr><td></td><td>S.C. Moments about an axis through O, perpendicular to the line of symmetry and multiply $\bar{y}$ by $\sin\frac{\pi}{6}$

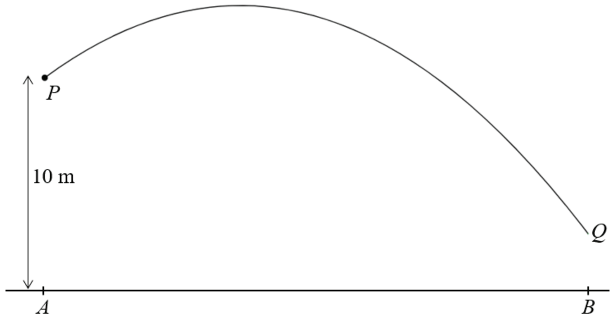
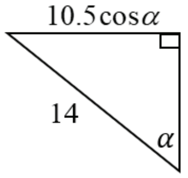
$0+0-\left(-\frac{\pi a}{3}\times\frac{3a}{\pi}\right)=\left(2\pi a+2a-\frac{\pi a}{3}\right)\bar{y}$</td><td>M1

A1</td></tr>
</table>

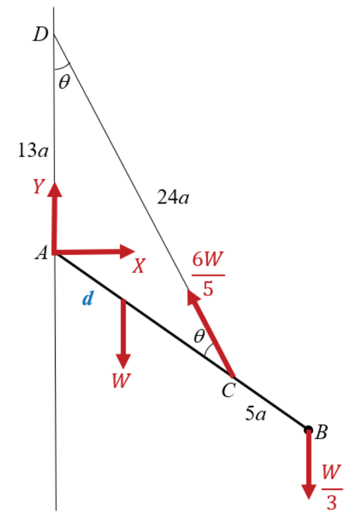
	: $\bar{y} = \dfrac{3a}{2(5\pi+6)}$ *	A1*
		(6)
4(b)		
	M(axis through O): (using arc $ABC + BA$) $\dfrac{5\pi a}{3} \times \left(\dfrac{3a}{5\pi} \times \dfrac{\sqrt{3}}{2}\right) = a\left(\dfrac{5\pi}{3} + 2\right)\bar{x}$ **OR:** M(axis through O): (using circle + BA − AC) $0 + 0 - (-\dfrac{\pi a}{3} \times \dfrac{3a\sqrt{3}}{2\pi}) = \left(2\pi a + 2a - \dfrac{\pi a}{3}\right)\bar{x}$ **OR:** M(axis through O): (arc AB + BA + arc BC) $(\pi a \times 0) + (2a \times 0) + \dfrac{2\pi a}{3} \times \dfrac{3a\sqrt{3}}{4\pi}) = \left(\pi a + 2a + \dfrac{2\pi a}{3}\right)\bar{x}$ **OR:** Using symmetry: $\bar{x} = \bar{y}\tan\dfrac{\pi}{3} = \dfrac{3a\sqrt{3}}{10\pi + 12}$	M1 A1 M1 A1 M1 A1 M1 A1
	Method to find a relevant angle  $\tan\theta = \dfrac{\bar{y}}{a - \bar{x}}$ $= \dfrac{\dfrac{3a}{2(5\pi+6)}}{a - \left(\dfrac{3a\sqrt{3}}{10\pi+12}\right)}$ $\left(= \dfrac{3}{10\pi + 12 - 3\sqrt{3}}\right)$	M1 A1
	$\theta = 4.5$ 1 d.p.	A1
		(5)
4(b) ALT 1	M(axis through B) to find $\bar{x}$	M1
	(using arc $ABC + BA$): $\dfrac{5\pi a}{3} \times \left(a - \left(\dfrac{3a}{5\pi} \times \dfrac{\sqrt{3}}{2}\right)\right) + (2a \times a) = \left(\dfrac{5\pi a}{3} + 2a\right)\bar{x}$	

	OR: (using arc AB + BA + arc BC) $$(\pi a\times a)+(2a\times a)+\frac{2\pi a}{3}\times\left(a-\frac{3a\sqrt{3}}{4\pi}\right)=\left(\frac{5\pi a}{3}+2a\right)\bar{x}$$ **OR:** (using circle + BA − AC) $$(2\pi a\times a)+(2a\times a)-\frac{\pi a}{3}\times\left(a+\frac{3a\sqrt{3}}{2\pi}\right)=\left(\frac{5\pi a}{3}+2a\right)$$	A1
	$$\tan\theta=\frac{\bar{y}}{\bar{x}}$$ $$=\frac{\frac{3a}{2(5\pi+6)}}{a\left(\frac{10\pi+12-3\sqrt{3}}{10\pi+12}\right)}$$ $$=\frac{3}{10\pi+12-3\sqrt{3}}$$	M1 A1
	$\theta=4.5$ 1 d.p.	A1
		(5)
		(11)
	Notes for question	
(a)		
B1	Correct distance from O seen or implied for an arc, $\frac{r\sin\alpha}{\alpha}$ where $\alpha=\frac{\pi}{6},\frac{\pi}{3},\frac{\pi}{2}$ or $\frac{5\pi}{6}$	
B1	Correct mass ratios, including total mass.	
B1	Correct distances. Allow $\pm$.	
M1	Moments about BA or a parallel axis. Condone sin/cos confusion. Must be dimensionally consistent and distances must be resolved **and correct no. of terms in the total mass**	
A1	Correct unsimplified equation.	
A1*	Obtain given answer from complete and correct working. Must see at least one line of working or simplification before reaching the given answer.	
(a) ALT1		
B1	Correct distance from O seen or implied for an arc, $\frac{r\sin\alpha}{\alpha}$ where $\alpha=\frac{\pi}{6},\frac{\pi}{3},\frac{\pi}{2}$ or $\frac{5\pi}{6}$	
B1	Correct mass ratios	
B1	Correct distances	
M1	Moments about BA or a parallel axis. Condone sin/cos confusion. Must be dimensionally consistent.	
A1	Correct unsimplified equation.	

A1*	Obtain given answer from complete and correct working. Must see at least one line of working or simplification before reaching the given answer.	
(b)		
M1	Moments equation about axis perpendicular to BA to find $\bar{x}$ with correct structure. Must be dimensionally consistent.and distances must be resolved **and correct no. of terms in the total mass.**	
A1	Correct unsimplified equation.	
M1	Complete method using trig to find an equation in θ. allow $\tan\theta = \dfrac{-\bar{y}}{a-\bar{x}}$ or $\tan\theta = \dfrac{-\bar{y}}{\bar{x}}$ as appropriate for their $\bar{x}$ and $\bar{y}$ but must be dimensionally consistent. **N.B.** $\bar{x}$ and $\bar{y}$ do NOT need to be substituted for this mark.	
A1	Correct unsimplified equation	
A1	Correct answer to 1dp (**N.B.** 4.488138..is the unrounded value)	

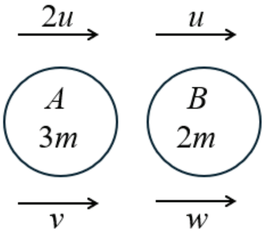
QUESTION NUMBER	SCHEME	MARKS
5		
5(a)	Conservation of energy used to find relevant height	M1
	$\frac{1}{2}m(14)^2 - \frac{1}{2}m(10.5)^2 = mgh$ $\left(h = \frac{343}{8g} = \frac{35}{8}\right)$	A1
	$(BQ =)5.6$ or 5.63 (m)	A1
		(3)
5(b)	Horizontal component of velocity = $10.5\cos\alpha$ seen	B1
	Use direction of motion at Q with $10.5\cos\alpha$ to form an equation in α only  e.g. $\sin\alpha = \frac{10.5\cos\alpha}{14}$ **OR** $14^2 = (10.5\cos\alpha)^2 + (14\cos\alpha)^2$ **OR** $(14\cos\alpha)^2 = (10.5\sin\alpha)^2 + 2g\times 4.375$ **OR** $\begin{pmatrix}10.5\cos\alpha\\10.5\sin\alpha\end{pmatrix}.\begin{pmatrix}10.5\cos\alpha\\-\sqrt{14^2-(10.5\cos\alpha)^2}\end{pmatrix} = 0$ i.e. $(10.5\cos\alpha)^2 - 10.5\sin\alpha\sqrt{14^2-(10.5\cos\alpha)^2} = 0$ **OR** similarly: $(10.5\cos\alpha)^2 - 10.5\sin\alpha\sqrt{(10.5\sin\alpha)^2 + 2g\times 4.375} = 0$ **OR** $(10.5\cos\alpha)^2 - 10.5\sin\alpha\times 14\cos\alpha = 0$	M1

	$\tan\alpha = \frac{3}{4}$ *	A1*
		(3)
5(c)	Complete method to find an equation in the time from *P* to *Q* only (t) using vertical motion e.g. $-14\cos\alpha = 10.5\sin\alpha - gt$ **OR** $10 - 5.625 = -10.5\sin\alpha \times t + \frac{1}{2}gt^2$	M1A1
	Horizontal motion of ball: $AB = 10.5\cos\alpha \times t$ ($AB = 15$)	M1
	Motion of car: $AB = \frac{1}{2}at^2$	M1
	$a = 9.4$ or 9.41 (m s^{-2})	A1
		(5)
		(11)
	Notes for question	
	N.B. Allow use of a different angle for α throughout apart from in the answer to (b).	
(a)		
M1	Method using conservation of energy as directed in the question to find a relevant height. Dimensionally correct, all required terms.Condone sign errors. **N.B.** Award the mark if seen, even if not used. M0 if only *suvat* is used.	
A1	Correct unsimplified equation.	
A1	Correct answer for *BQ* to 2 or 3 sf (45/8 is A0)	
(b)		
B1	Horizontal component of velocity **seen**.	
M1	Use perpendicularity of velocities at *P* and *Q* to form a trig equation in α only. **N.B.** Must see any scalar product evaluated. **N.B.** $\tan\alpha = \frac{10.5}{14}$ is M0.	
A1*	Obtain given answer from complete and correct working. **N.B.** $\tan\theta = \frac{3}{4}$ is A0.	
(c)		
M1	Complete method to find an equation in time from *P* to *Q* only, condone sign errors and sin/cos confusion. **N.B.** M0 if they use $s = 10$ or -10 but allow their $\pm BQ$	
A1	**Correct equation**	
M1	Method using horizontal motion to form an equation in *AB* and t only (t does not need to be substituted)	
M1	Correct method to find an equation in *AB*, t and a (t does not need to be substituted)	
A1	Correct answer, 2/3 sf (exact is 9.408)	

QUESTION NUMBER	SCHEME	MARK
6		
6(a)	Method to form an equation in d (and a)	M1
	E.g. M(A): $\left(W \times d\sin 2\theta\right)+\left(\dfrac{W}{3}\times 18a\sin 2\theta\right)=\left(\dfrac{6W}{5}\times 13a\sin\theta\right)$	A1 A1
	$d=\dfrac{49}{20}a=2.45a$	A1
		(4)
6(b)	First relevant equation	M1
	E.g. Horiz: $\pm X=\dfrac{6W}{5}\sin\theta$	A1
	Second relevant equation	M1
	E.g. Vert: $\pm Y+\dfrac{6W}{5}\cos\theta=W+\dfrac{W}{3}$	A1
	Other possible equations: Parallel to the rod: $\pm P+\dfrac{6W}{5}\cos\theta=W\cos 2\theta+\dfrac{W}{3}\cos 2\theta$ Perp. to the rod: $\pm Q+\dfrac{6W}{5}\sin\theta=W\sin 2\theta+\dfrac{W}{3}\sin 2\theta$ M(B): $\left(\dfrac{6W}{5}\times 5a\sin\theta\right)+\left(Y\times 18a\sin 2\theta\right)+\left(X\times 18a\cos 2\theta\right)=\left(W\times\dfrac{311a}{20}\sin 2\theta\right)$ M(C): $\left(\dfrac{W}{3}\times 5a\sin 2\theta\right)+\left(Y\times 13a\sin 2\theta\right)+\left(X\times 13a\cos 2\theta\right)=W\times\dfrac{211a}{20}\sin 2\theta$ M(D):	

	$13aX = \left(W \times \frac{49a}{20}\sin 2\theta\right) + \left(\frac{1}{3}W \times 18a \sin 2\theta\right)$	
	Pythagoras using X and Y: $\sqrt{\left(\frac{6W\sin\theta}{5}\right)^2 + \left(\frac{4W}{3} - \frac{6W\cos\theta}{5}\right)^2}$ $\left(= \sqrt{\left(\frac{6W}{13}\right)^2 + \left(\frac{44W}{195}\right)^2}\right)$ Pythagoras using P and Q: $\sqrt{\left(W\cos 2\theta + \frac{W}{3}\cos 2\theta - \frac{6W}{5}\cos\theta\right)^2 + \left(W\sin 2\theta + \frac{W}{3}\sin 2\theta - \frac{6W}{5}\sin\theta\right)^2}$ $\left(= \sqrt{\left(\frac{82W}{169}\right)^2 + \left(\frac{428W}{2535}\right)^2}\right)$	**d**M1
	$= 0.51W$ or better $(0.51374\ldots)W$ or $W\sqrt{\frac{772}{2925}}$ or any equivalent surd form.	A1
		(6)
		(10)
	Notes for question	
(a)		
M1	Complete method to find an equation in d only. Correct no. of terms **with correct angle and force pairings.** Dimensionally correct. Condone sin/cos confusion. Trig does not need to be replaced here. W's may be cancelled before the equation is formed. The distance d may be a different letter or written as a multiple of a e.g. ka **N.B.** Allow M1A0A0 if they use say α for 2θ Can score max M1A1A0A0 if they have T instead of $\frac{6W}{5}$ and never replace it. Allow the $\frac{6W}{5} \times 13a\sin\theta$ term to be cancelled down immediately to either $\frac{6W}{5} \times 5a$ or $6Wa$	
A1	Unsimplified equation with at most one error. **N.B.** Count each error on each term.	
A1	Correct unsimplified equation.	
A1	Any equivalent **exact** answer.	
(b)		
M1	First relevant equation. Dimensionally correct. Condone sin/cos confusion but must be using the correct angle.	

	N.B. Trig does not need to be replaced here nor $T = \frac{6W}{5}$	
A1	Correct unsimplified equation with $T = \frac{6W}{5}$.	
M1	Second relevant equation. Dimensionally correct. Condone sin/cos confusion but must be using the correct angle. **N.B.** Trig does not need to be replaced here nor $T = \frac{6W}{5}$	
A1	Correct unsimplified equation with $T = \frac{6W}{5}$.	
dM1	Solve equations to find X and Y and use Pythagoras with square root to find magnitude of the force at A in terms of W *and* θ *only*, **dependent** on both M marks.	
A1	$(0.51374\ldots)W$	

QUESTION NUMBER	SCHEME	MARKS
7		
7(a)	Equation for CLM	M1
	$3m(2u)+2mu=3mv+2mw$	A1
	Use of impact law	M1
	$eu=w-v$	A1
	Solve to reach given answer for speed of B $\frac{u}{5}(8+3e)$ *	A1*
		(5)
7(b)	Speed of B after collision $=\frac{7u}{4}$	B1
	Speed of A after collision $=\frac{3u}{2}$	B1
	Difference in KE before and after in terms of m and u only	M1
	KE Loss $=\frac{1}{2}3m(2u)^2+\frac{1}{2}2m(u)^2-\frac{1}{2}3m\left(\frac{3u}{2}\right)^2-\frac{1}{2}2m\left(\frac{7u}{4}\right)^2$	A1
	Percentage of KE lost $=\frac{\frac{9}{16}mu^2}{7mu^2}\times 100=\frac{225}{28}\%$ $(8.03571\ldots\%)$	A1
		(5)
7(c)	Time taken for B to reach wall $=\frac{d}{\left(\frac{7u}{4}\right)}$ oe	M1
	Rebound speed of $B=\frac{7uf}{4}$	B1
	Remaining time $=\frac{60d}{91u}-\frac{4d}{7u}$ $\left(=\frac{8d}{91u}\right)$ (Time moved by B after hitting the wall)	M1
	Complete method to form an equation in f only: **ALT 1**: $d=\frac{7fu}{4}\left(\frac{8d}{91u}\right)+\frac{3u}{2}\left(\frac{60d}{91u}\right)$ **ALT 2**: $d-\left(\frac{3u}{2}\times\frac{4d}{7u}\right)=\frac{7fu}{4}\left(\frac{8d}{91u}\right)+\frac{3u}{2}\left(\frac{8d}{91u}\right)$	**d**M1

	$f = \dfrac{1}{14}$	A1
		(5)
		(15)
	Notes for question	
(a)		
M1	Equation for CLM. Dimensionally correct, all terms required, correct pairings of masses and velocities.Condone sign errors.	
A1	Correct unsimplified equation.	
M1	Use of impact law. Condone sign errors but must be used the right way round.	
A1	Correct unsimplified equation, signs consistent with CLM.	
A1*	Obtain given answer from correct working. Accept terms in bracket reversed and all over 5.	
(b)		
B1	Seen or implied	
B1	Seen or implied	
M1	Expression for difference in KE in terms of m and u only **using their speeds.** Must be dimensionally correct with all terms present and with the correct structures. Mass and velocity must be correctly paired. Must be $\pm$(initial KE $-$ final KE)	
A1	Correct unsimplified expression for the KE loss	
A1	Correct percentage, accept 8% or better (8.03571…%)	
(c)		
M1	Find, in terms of u and d, the time taken for B to reach wall using their speed of B, seen	
B1	Cao, seen or implied. Allow $-\frac{7uf}{4}$ **N.B.** Allow $f v_B$ if their v_B is correct.	
M1	Remaining time, in terms of u and d, seen or implied, either as an expression or in an equation. **N.B.** Accept unsimplified	
dM1	Complete method to form an equation in f only.**Allow uncancelled d's and u's.** Dependent on both previous M's.	
A1	Accept 0.071 or better (0.07142857…..)	