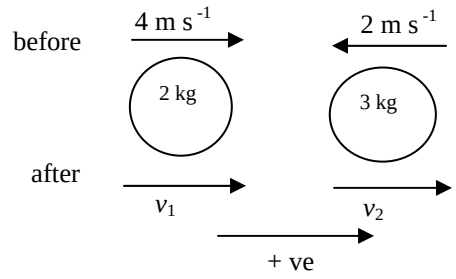
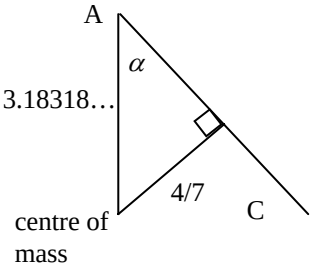
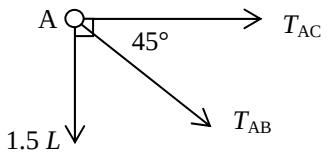
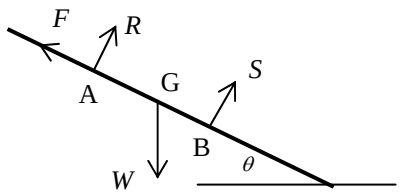
Q 1		mark		Sub
(a) (i)	240 **i** N s $\rightarrow$	B1		1
(ii)				
		M1	Equating to **their** 240 **i** in this part	
(A)	240 **i** = 70 **i** +50 **v** so **v** = 3.4 **i** m s^{-1}	A1	FT 240 **i**	
(B)	240 **i** = 70u **i** – 50u **i**	M1	Must have u in both RHS terms and opposite signs	
	u = 12 so **v** = – 12 **i** m s^{-1}	A1	FT 240 **i**	
(C)	240 **i** = 280(**i** + **j**) +50$\mathbf{v}_B$	M1	FT 240 **i** Must have all terms present	
	so $\mathbf{v}_B$ = (-0.8 **i** – 5.6 **j**) m s^{-1}	A1	cao	6
(b) (i)				
	NEL $\frac{v_2 - v_1}{-2-4} = -0.5$	M1	NEL	
	so $v_2 - v_1 = 3$	A1	Any form	
	PCLM $8 - 6 = 2v_1 + 3v_2$	M1	PCLM	
		A1	Any form	
	Solving v_2 = 1.6 so 1.6 m s^{-1} $\rightarrow$	A1	Direction must be clear (accept diagram)	
	v_1 = – 1.4 so 1.4 m s^{-1} $\leftarrow$	A1	Direction must be clear (accept diagram). [Award A1 A0 if v_1 & v_2 correct but directions not clear]	6
(ii)				
	1.6 m s^{-1}	B1	FT **their** 1.6	
	at 60° to the wall (glancing angles both 60°)	B1		
	No change in the velocity component parallel to the wall as no impulse	E1	Must give reason	
	No change in the velocity component perpendicular to the wall as perfectly elastic	E1	Must give reason	4
	total	17		

Q 2		mark		Sub
(i)	We need $\frac{mgh}{t} = \frac{850\times 9.8\times 60}{20} = 24\,990$ so approx 25 kW	M1 E1	Use of $\frac{mgh}{t}$ Shown	2
(ii)	Driving force – resistance = 0 $25000 = 800v$ so v = 31.25 and speed is 31.25 m s^{-1}	B1 M1 A1	May be implied Use of $P = Fv$	3
(iii)	Force is $\frac{25000}{10} = 2500$ N N2L in direction of motion $2500 - 800 = 850a$ a = 2 so 2 m s^{-2}	B1 M1 A1	 Use of N2L with all terms	3
(iv)	$0.5\times 850\times 20^2 = 0.5\times 850\times 15^2$ $+25000\times 6.90$ $-800x$ x = 122.6562… so 123 m (3 s. f.)	M1 B1 B1 B1 A1 A1	W-E equation with KE and power term One KE term correct Use of Pt .Accept wrong sign WD against resistance. Accept wrong sign All correct cao	6
(v)	**either** $0.5\times 850\times v^2 = 0.5\times 850\times 20^2$ $-850\times 9.8\times \frac{105}{20}$ -800×105 $v^2 = 99.452...$ so 9.97 m s^{-1} **or** N2L + ve up plane $-(800 + 850g\times 0.05) = 850a$ a = -1.43117… $v^2 = 20^2 + 2\times(-1.43117...)\times 105$ $v^2 = 99.452...$ so 9.97 m s^{-1}	M1 M1 A1 B1 A1 M1 A1 M1 A1 A1	W-E equation inc KE, GPE and WD GPE term with attempt at resolution Correct. Accept expression. Condone wrong sign. WD term. Neglect sign. cao N2L. All terms present. Allow sign errors. Accept ± Appropriate *uvast*. Neglect signs. All correct including consistent signs. Need not follow sign of a above. cao	5
		19		

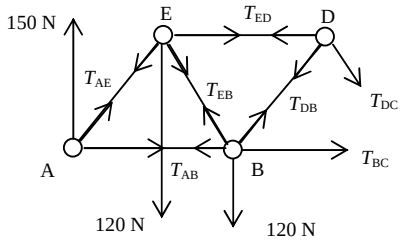
Q 3		mark		Sub
(i)	$28\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = 16\begin{pmatrix}2\\2\end{pmatrix} + 2\begin{pmatrix}5\\0\end{pmatrix} + 2\begin{pmatrix}6\\1\end{pmatrix} + 2\begin{pmatrix}5\\2\end{pmatrix} + 2\begin{pmatrix}0\\5\end{pmatrix} + 2\begin{pmatrix}1\\6\end{pmatrix} + 2\begin{pmatrix}2\\5\end{pmatrix}$ $\bar{x} = 2.5$ $\bar{y} = 2.5$	M1 B1 B1 A1 A1	Complete method Total mass correct 3 c. m. correct (or 4 x- or y-values correct) [Allow A0 A1 if only error is in total mass] [If $\bar{x} = \bar{y}$ claimed by symmetry and only one component worked replace final A1, A1 by B1 explicit claim of symmetry A1 for the 2.5]	5
(ii)	$\bar{x} = \bar{y}$ $28\bar{x} = 16\times 2 + 6\times 4 + 2\times 0 + 2\times 1 + 2\times 2$ $\bar{x} = \frac{31}{14}$ (2.21428…) $\bar{z} = \frac{8\times(-1) + 4\times(-2)}{28} = -\frac{4}{7}$ (- 0.57142…) Distance is $\sqrt{\left(\frac{31}{14}\right)^2 + \left(\frac{31}{14}\right)^2 + \left(\frac{4}{7}\right)^2}$ = 3.18318.. so 3.18 m (3 s. f.)	B1 M1 A1 A1 A1 M1 F1	Or by direct calculation Dealing with 'folded' parts for $\bar{x}$ or for $\bar{z}$ At least 3 terms correct for $\bar{x}$ All terms correct allowing sign errors Use of Pythagoras in 3D on **their** c.m.	8
(iii)	 $\sin\alpha = \frac{4}{7}/3.18318..$ so α = 10.3415… so 10.3° (3 s. f.)	M1 B1 M1 A1	c.m. clearly directly below A Diagram showing α and known lengths (or equivalent). FT their values. Award if final answer follows **their** values. Appropriate expression for α. FT **their** values. cao	4
	total	17		

Q 4		mark		Sub
(a) (i)	Moments c.w. about A $2R = 5L$ so $R = 2.5L$ Resolve $\rightarrow$ $U = 0$ Resolve $\uparrow$ $V + R = L$ so $V = -1.5L$	 E1 E1 M1 E1	 Resolve vertically or take moments about B (or C)	4
(ii)	 For equilibrium at A $\uparrow$ $T_{AB}\cos 45 + 1.5L = 0$ so $T_{AB} = -\frac{3\sqrt{2}L}{2}$ so $\frac{3\sqrt{2}L}{2}$ N (C) in AB $\rightarrow$ $T_{AC} + T_{AB}\cos 45 = 0$ so $T_{AC} = \frac{3L}{2}$ so $\frac{3L}{2}$ N (T) in AC At C $\downarrow$ $L + T_{BC}\cos\theta = 0$ $\tan\theta = 3/2 \Rightarrow \cos\theta = 2/\sqrt{13}$ so $T_{BC} = -\frac{\sqrt{13}L}{2}$ so $\frac{\sqrt{13}L}{2}$ N (C) in BC	 M1 M1 A1 F1 M1 B1 A1 F1	 Equilibrium at a pin-joint Attempt at equilibrium at A or C including resolution with correct angle (2.12L (3 s. f.)) (1.5L) Must include attempt at angle (1.80 L (3 s. f.)) Award for T/C correct from their internal forces. Do not award without calcs	8
(b) (i)		B1	All forces present with arrows and labels. Angles and distances not required.	1
(ii)	c.w.moments about B $R \times 3 - W \times 1\cos\theta = 0$ so $R = \frac{1}{3}W\cos\theta$	M1 A1 A1	If moments about other than B, then need to resolve perp to plank as well Correct	3
(iii)	Resolve parallel to plank $F = W\sin\theta$ $\mu = \frac{F}{R} = \frac{W\sin\theta}{\frac{1}{3}W\cos\theta} = 3\tan\theta$	B1 M1 A1	 Use of $F = \mu R$ and their F and R Accept any form.	3
	total	19		

Q 1		mark		Sub
(i)	$16 = 0.4v$ so 40 m s^{-1}	M1 A1	Use of $I = \Delta mv$	2
(ii)	PCLM ↑ + ve $0.4\times32 - 0.6u = 0.4v_P + 0.6\times4$ NEL ↑ +ve $\frac{4 - v_P}{-u - 32} = -0.1$ Solving u = 18 $v_P = -1$ so 1 m s^{-1} downwards	M1 A1 M1 A1 E1 A1 A1	Use of PCLM Any form Use of NEL. Allow sign errors. Any form Must be obtained from a pair of correct equations. If given u = 18 used then v_P = -1 must be obtained from 1 equation and both values tested in the second equation cao. Accept use of given u = 18 cao	7
(iii)	Considering the momenta involved $0.5\begin{pmatrix}-3.6\\5.2\end{pmatrix} = 0.2\begin{pmatrix}3\\4\end{pmatrix} + 0.3\mathbf{v}_D$ $\mathbf{v}_D = \begin{pmatrix}-8\\6\end{pmatrix}$ so a = –8 and b = 6 Gradients of the lines are $\frac{4}{3}$ and $\frac{6}{-8}$ Since $\frac{4}{3}\times\frac{6}{-8} = -1$, they are at 90°	M1 B1 B1 A1 A1 A1 M1 E1	PCLM applied. May be implied. LHS momentum of C correct Complete equation. Accept sign error. cao cao Any method for the angle Clearly shown	8
				17

Q 2		mark		Sub
(i)	Moments about C $240 \times 2 = 3R_D$ $R_D = 160$ so 160 N Resolve vertically $R_C + R_D = 240$ $R_C = 80$ so 80 N	 M1 A1 M1 F1	 Moments about C or equivalent. Allow 1 force omitted Resolve vertically or moments about D or equivalent. All forces present. FT from **thei**r R_D only	4
(ii) (A)	Moments about D $240 \times 1 = 4T \sin 40$ T = 93.343… so 93.3 N (3 s. f.)	 M1 M1 A1 A1	 Moments about D or equivalent Attempt at resolution for RHS RHS correct	4
(ii) (B)	In equilibrium so horizontal force needed to balance cpt of T. This must be friction and cannot be at C.		Need reference to horizontal force that must come from friction at D.	1
(iii) (A)	Moments about B $3 \times 240 \times \cos 30 = 6P$ $P = 60\sqrt{3}$ (103.92…..) P inclined at 30° to vertical Resolve horizontally. Friction force F $F = P \sin 30$ so $F = 30\sqrt{3}$ (51.961…)	 M1 E1 B1 M1 A1	 All terms present, no extras. Any resolution required attempted. Accept decimal equivalent Seen or equivalent or implied in (iii) (A) or (B). Resolve horizontally. Any resolution required attempted Any form	5

(iii) (B)	Resolve vertically. Normal reaction R			
	$P\cos 30 + R = 240$	M1	Resolve vertically. All terms present.and resolution attempted	
		A1		
	Using $F = \mu R$	M1		
	$\mu = \dfrac{30\sqrt{3}}{240 - 60\sqrt{3} \times \dfrac{\sqrt{3}}{2}}$	A1	Substitute **their expressions** for F and R	
	$= \dfrac{30\sqrt{3}}{240 - 90} = \dfrac{\sqrt{3}}{5}$ = 0.34641 so 0.346 (3 s. f.)	A1	cao. Any form. Accept 2 s. f. or better	
				5
				19

Q 3		mark		Sub
(a) (i)	$80\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = 48\begin{pmatrix}6\\2\end{pmatrix} + 12\begin{pmatrix}1\\-3\end{pmatrix} + 20\begin{pmatrix}11\\9\end{pmatrix}$ $80\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = \begin{pmatrix}520\\240\end{pmatrix}$ $\bar{x} = 6.5$ $\bar{y} = 3$	M1 B1 B1 E1 A1	Correct method for c.m. Total mass correct One c.m. on RHS correct [If separate components considered, B1 for 2 correct] cao	5
(ii)	Consider x coordinate $520 = 76\times 6.4 + 4x$ so $x = 8.4$	M1 B1 A1	Using additive principle o. e. on x cpts Areas correct. Allow FT from masses from (i) cao	3
(iii)	y coordinate is 1 so we need $240 = 76\bar{y} + 4\times 1$ and $\bar{y} = 3.10526...$ so 3.11 (3 s. f.)	B1 M1 A1	Position of centre of square cao	3
(b) (i)	Moments about C $4R = 120\times 3 + 120\times 2$ so 4 R = 600 and R = 150	M1 E1	Moments equation. All terms present	2
(ii)		B1		
	A↑ $150 + T_{AE}\cos 30 = 0$ $T_{AE} = -100\sqrt{3}$ so $100\sqrt{3}$ N (C) E↓ $120 + T_{AE}\cos 30 + T_{EB}\cos 30 = 0$ $T_{EB} = 20\sqrt{3}$ so $20\sqrt{3}$ N (T)	M1 A1 M1 F1 F1	Equilibrium at a pin-joint Any form. Sign correct. Neglect (C) Equilibrium at E, all terms present Any form. Sign follows working. Neglect (T). T/C consistent with answers	

				6
(iii)	Consider $\rightarrow$ at E, using (ii) gives ED as thrust	E1	Clearly explained. Accept 'thrust' correctly deduced from wrong answers to (ii).	1
				20

Q 4		mark		Sub
(i)	$\frac{0.5\times 20\times 8^2 - 0.5\times 20\times 5^2 + 510}{6}$ = 150 W	M1 B1 A1 A1	Use of P = WD/t ΔKE. Accept ± 390 soi All correct including signs	4
(ii) (A)	$20g\times\frac{3}{5}x - 5gx$ 7gx (68.6x) gain	M1 B1 A1 A1	Use of mgh on both terms Either term (neglecting signs) $\pm 7gx$ in any form. cao	4
(B)	11gx	B1		1
(C)	$0.5\times 25\times 4^2 = 7gx + 11gx = 18gx$ x = 1.13378… so 1.13 m (3 s. f.)	M1 B1 A1	Use of work-energy equation. Allow 1 RHS term omitted. KE term correct cao. Except follow wrong sign for 7gx only.	3
(iii)	**either** $0.5\times 35\times v^2 - 0.5\times 35\times 16$ $= 15g\times 0.5 - 11g\times 0.5 - 12g\times 0.5$ $v^2 = 13.76$ so v = 3.70944… so 3.71 m s^{-1} (3 s. f.) **or** $15g - T = 15a \qquad T - 12g - 11g = 20a$ so $a = -2.24$ $v^2 = 4^2 + 2\times(-2.24)\times 0.5$ so 3.71 m s^{-1} (3 s. f.)	M1 B1 A1 A1 M1 A1 M1 A1	Use of work-energy. KE, GPE and WD against friction terms present. ΔGPE correct inc sign (1.5g J loss) All correct cao N2L in 1 or 2 equations. All terms present cao Use of appropriate (sequence of) *uvast* cao	4
				16

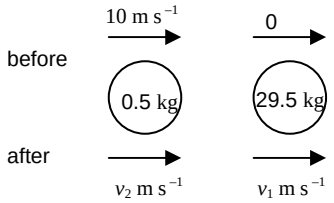
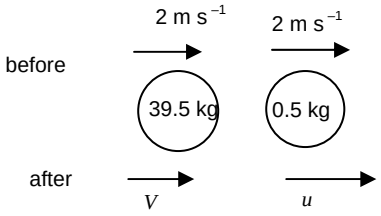
Q 1		mark		Sub
(a) (i) (A)	PCLM $\rightarrow$ +ve $2\times4-6\times2=8v$ $v = -0.5$ so 0.5 m s^{-1} in opposite direction to initial motion of P	M1 A1 A1	Use of PCLM and correct mass on RHS Any form Direction must be negative and consistent or clear. Accept use of a diagram.	3
(B)	$0.5\times2\times4^2+0.5\times6\times2^2-0.5\times8\times(-0.5)^2$ = 27 J	M1 A1	Use of KE. Must sum initial terms. Must have correct masses FT **their** (A) only	2
(ii) (A)	PCLM $\rightarrow$ +ve $2\times4-6\times2=2v_P+6v_Q$ $v_P+3v_Q=-2$ NEL $\rightarrow$ +ve $\frac{v_Q-v_P}{-2-4}=-\frac{2}{3}$ $v_Q-v_P=4$ $v_Q=0.5$ so 0.5 m s^{-1} in orig direction of P $v_P=-3.5$ so 3.5 m s^{-1} in opp to orig dir of P	M1 A1 M1 A1 A1 A1	Use of PCLM Any form NEL Any form cao. Direction need not be made clear. cao. Direction must be negative and consistent or clear (e.g diag)	6
(B)	$\rightarrow$ +ve $2\times-3.5-2\times4=-15$ N s so 15 N s in opp to orig direction	M1 A1	Use of change in momentum with correct mass. FT (A). Dir must be clear (e.g. diag)	2
(b)	Let $\alpha=\arcsin(12/13)$ and $\beta=\arcsin(3/5)$ Parallel: $26\cos\alpha=u\cos\beta$ so $26\times\frac{5}{13}=u\times\frac{4}{5}$ and u = 12.5 Perp: $e=\frac{u\sin\beta}{26\sin\alpha}$ $=\frac{12.5\times\frac{3}{5}}{26\times\frac{12}{13}}=\frac{5}{16}$	M1 A1 A1 M1 F1 F1	PCLM parallel to plane attempted. At least one resolution correct NEL on normal components attempted. FT **their** u FT **their** u	6
				19

Q 2		mark		Sub
(i)	Diagrams	B1	Internal force at B must be shown	
	cw moments about A $2\times 90 - 3R_B = 0$	M1	1st moments equation attempted for either force.	
	$R_B = 60$ so 60 N upwards	A1	Accept direction not specified	
	cw moments about R: $T\downarrow$ $75\times 1 + 3T - 60\times 0.5 = 0$	M1	2nd moments equation for other force. All forces present. No extra forces.	
		A1	Allow only sign errors	
	$T = -15$ so 15 N upwards	A1	Direction must be clear (accept diag)	6
(ii)	cw moments about A $90\times 2\cos 30 - V\times 3\cos 30 - U\times 3\cos 60 = 0$	M1	Moments equation with resolution. Accept terms missing	
		A1	All correct. Allow only sign errors.	
	giving $60\sqrt{3} = U + V\sqrt{3}$	E1	Clearly shown	3
(iii)	Diagram	B1	*U* and *V* correct with labels and arrows	1
(iv)	ac moments about C $75\times 2\cos 30 + 3.5V\cos 30 - 3.5U\cos 60 = 0$	M1	Moments equation with resolution. Accept term missing	
		B1	At least two terms correct (condone wrong signs)	
	$\frac{300}{7}\sqrt{3} = U - V\sqrt{3}$	A1	Accept any form	
	Solving for *U* and *V*	M1	Any method to eliminate one variable	
	$U = \frac{360\sqrt{3}}{7}$ (= 89.0768…)	A1	Accept any form and any reasonable accuracy	
	$V = \frac{60}{7}$ (= 8.571428…)	F1	Accept any form and any reasonable accuracy [Either of *U* and *V* is cao. FT the other]	
	Resolve $\rightarrow$ on BC *F* = *U*	M1		
	so frictional force is $\frac{360\sqrt{3}}{7}$ N (= 89.1 N (3 s. f.))	F1		8
				18

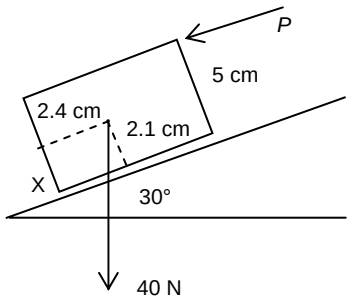
Q 3		mark		Sub
(a)	$20000 = (R + 900g \times 0.1) \times 16$	M1	Use of $P = Fv$, may be implied.	
		B1	Correct weight term	
		A1	All correct	
	R = 368 so 368 N	A1		4
(b) (i)	$F_{\max} = \mu mg\cos\alpha$	B1	Correct expression for $F_{\max}$ **or** wt cpt down slope (may be implied and in any form)	
	Force down slope is weight cpt $mg\sin\alpha$	B1	Identifying $\sin\alpha$ as $5/13$ or equivalent	
	Require $\mu mg\cos\alpha \geq mg\sin\alpha$			
	so $\mu \geq \tan\alpha = \frac{5}{12}$	E1	Proper use of $F \leq \mu R$ or equivalent.	
			[$\mu = \tan\alpha$ used WW; SC1]	3
(ii)	**either**			
	$0.5 \times 11 \times v^2$	M1	Use of work energy with at least three required terms attempted	
	$= 11g \times 1.5 \times \frac{5}{13} + 0.2 \times 11g \times 1.5 \times \frac{12}{13} + 9$	B1	Any term RHS. Condone sign error.	
		B1	Another term RHS. Condone sign error.	
		A1	All correct . Allow if trig consistent but wrong	
	$v^2 = 18.3717...$			
	v = 4.2862… so 4.29 m s $^{-1}$ (3 s. f.)	A1	cao	
	or			5
	+ ve up the slope			
	$-11g \times \frac{5}{13} - 0.2 \times 11g \times \frac{12}{13} - 6 = 11a$	M1	Use of N2L	
		B1	Any correct term on LHS	
	a = - 6.1239 m s^{-2}	**A1**		
	v^2 = - 3a	**M1**	use of appropriate *uvast*	
	v = 4.286 m s^{-1}	**A1**	c.a.o.	
(iii)	**continued overleaf**			

3	**continued**			
(iii)	**either**			
	Extra GPE balances WD against resistances	M1	Or equivalent	
	$mgx\sin\alpha$	B1		
	$= 6(x+3) + 0.2\times 11g\times\cos\alpha(x+3)$	B1	One of 1st three terms on RHS correct	
		B1	Another of 1st 3 terms on RHS correct	
		A1	All correct. FT **their** *v* if used.	
	x = 4.99386… so 4.99 m (3 s. f.)	A1	cao.	6
	or	M1	Allow 1 term missing	
	$0.5\times 11\times 18.3717...$	B1	KE. FT **their** *v*	
	$= (1.5+x)\times 11g\times\frac{5}{13} - 6(1.5+x)$	B1	Use of 1.5 + *x* (may be below)	
	$-(1.5+x)\times 0.2\times 11g\times\frac{12}{13}$	B1	WD against friction	
		A1	All correct	
	x = 4.99386… so 4.99 m (3 s. f.)	A1	cao.	
	or			
	+ ve down the slope			
	$11g\times {}^{5}\!/_{13} - 0.2\times 11g\times {}^{12}\!/_{13} - 6 = 11a$	M1	N2L with all terms present	
		A1	all correct except condone sign errors	
	$a = 1.4145...$ m s^{-2}	**A1**		
	$4.286^2 = 2a(1.5+x)$	**M1**	use of appropriate *uvast*	
		B1	for (1.5 + *x*) (may be implied)	
	x = 4.99	A1	c.a.o.	
				18

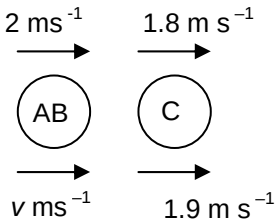
Q 4		mark		Sub
(i)	$100\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix}=10\begin{pmatrix}5\\0\end{pmatrix}+30\begin{pmatrix}10\\15\end{pmatrix}+30\begin{pmatrix}20\\15\end{pmatrix}+30\begin{pmatrix}25\\30\end{pmatrix}$	M1	Correct method for c.m.	
		B1	Total mass correct	
		B1	One c.m. on RHS correct [If separate components considered, B1 for 2 correct]	
	$100\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix}=\begin{pmatrix}1700\\1800\end{pmatrix}$			
	$\bar{x}=17$	A1	cao	
	$\bar{y}=18$	A1	cao. [Allow SC 4/5 for $\bar{x}=18$ and $\bar{y}=17$]	5
(ii)	$(17,18,20)$	B1	*x*- and *y*- coordinates. FT from (i).	
		B1	*z* coordinate	2
(iii)	cw moments about horizontal edge thro' D	M1	Or equivalent with all forces present	
	x component			
	$P\times 20-60\times(20-17)=0$	B1	One moment correct (accept use of mass or length)	
		B1	correct use of **their** $\bar{x}$ in a distance	
	P = 9	A1	FT only **their** $\bar{x}$	4
(iv)	Diagram	B1	Normal reaction must be indicated acting vertically upwards at edge on O*z* and weight be in approximately the correct place.	1
(v)	On point of toppling ac moments about edge along O*z*	M1	Or equivalent with all forces present	
	$30\times Q-60\times 17=0$	B1	Any moment correct (accept use of mass or length)	
	Q = 34	F1	FT only **their** $\bar{x}$	
	Resolving horizontally *F* = *Q*	B1		
	As 34 > 30, slips first	B1	FT **their** Q correctly argued.	5
				17

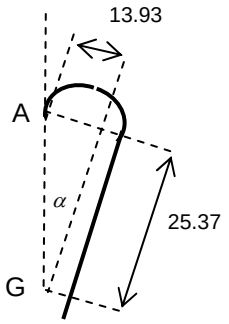
Q 1		mark		sub
(i)				
	$10\times0.5=0.5v_2+29.5v_1$	M1 A1	PCLM and two terms on RHS All correct. Any form.	
	$\frac{v_1-v_2}{0-10}=-0.8$	M1 A1	NEL Any form	
	$v_1 = 0.3$ so $V_1 = 0.3$ $v_2 = -7.7$ so $V_2 = 7.7$ m s^{-1} in opposite to original direction	A1 A1 F1	Speed. Accept $\pm$. Must be correct interpretation of clear working	7
(ii) (A)	$10\times0.5=30V$ so $V=\frac{1}{6}$	M1 A1 A1	PCLM and coalescence All correct. Any form. Clearly shown. Accept decimal equivalence. Accept no direction.	3
(B)	Same velocity No force on sledge in direction of motion	E1 E1	Accept speed	2
(iii)		B1		
	$2\times40=0.5u+39.5V$ $u-V=10$ Hence $V = 1.875$	M1 A1 B1 A1	PCLM, masses correct Any form May be seen on the diagram. Accept no reference to direction.	5
		17		

Q 2		mark	comment	sub
(i)	$X = R\cos 30$ (1) $Y + R\sin 30 = L$ (2)	B1 M1 A1	Attempt at resolution	3
(ii)	ac moments about A $R - 2L = 0$ Subst in (1) and (2) $X = 2L\frac{\sqrt{3}}{2}$ so $X = \sqrt{3}L$ $Y + 2L \times \frac{1}{2} = L$ so $Y + L = L$ and $Y = 0$	B1 M1 E1 E1	Subst **their** $R = 2L$ into **their** (1) or (2) Clearly shown Clearly shown	4
(iii)	(Below all are taken as tensions e. g. T_{AB} in AB)	B1 B1	Attempt at all forces (allow one omitted) Correct. Accept internal forces set as tensions or thrusts or a mix	2
(iv)	$\downarrow$ A $T_{AD}\cos 30\ (-Y) = 0$ so $T_{AD} = 0$	M1 E1	Vert equilibrium at A attempted. $Y = 0$ need not be explicit	2
(v)	Consider the equilibrium at pin-joints A $\rightarrow$ $T_{AB} - X = 0$ so $T_{AB} = \sqrt{3}L$ (T) C $\downarrow$ $L + T_{CE}\cos 30 = 0$ so $T_{CE} = \frac{-2L}{\sqrt{3}}$ so $\frac{2L}{\sqrt{3}}\left(= \frac{2L\sqrt{3}}{3}\right)$ (C) C $\leftarrow$ $T_{BC} + T_{CE}\cos 60 = 0$ so $T_{BC} = -\left(-\frac{2\sqrt{3}L}{3}\right) \times \frac{1}{2} = \frac{\sqrt{3}L}{3}$ (T)	M1 B1 B1 B1 B1 B1 F1	At least one relevant equilib attempted (T) not required Or equiv from **their** diagram Accept any form following from **their** equation. (C) not required. Or equiv from **their** diagram FT **their** T_{CE} or equiv but do not condone inconsistent signs even if right answer obtained. (T) not required. T and C consistent with **their** answers and **their** diagram	7
(vi)	$\downarrow$ B $T_{BD}\cos 30 + T_{BE}\cos 30 = 0$ so $T_{BD} = -T_{BE}$ so mag equal and opp sense	M1 E1	Resolve vert at B A statement required	2
		20		

Q 3		mark		sub
(i)	(10, 2, 2.5)	B1		1
(ii)	By symmetry $\bar{x} = 10$, $\bar{y} = 2$ $(240+80)\bar{z} = 80\times 0 + 240\times 2.5$ so $\bar{z} = 1.875$	B1 B1 B1 M1 A1	 Total mass correct Method for c.m. Clearly shown	5
(iii)	$\bar{x} = 10$ by symmetry $(320+80)\begin{pmatrix}\bar{x}\\ \bar{y}\\ \bar{z}\end{pmatrix} = 320\begin{pmatrix}10\\ 2\\ 1.875\end{pmatrix} + 80\begin{pmatrix}10\\ 4\\ 3\end{pmatrix}$ $\bar{y} = 2.4$ $\bar{z} = 2.1$	E1 M1 B1 B1 E1 E1	Could be derived Method for c.m. *y* coord c.m. of lid *z* coord c.m. of lid shown shown	6
(iv)	 c.w moments about X $40\times 0.024\cos 30 - 40\times 0.021\sin 30$ = 0.41138… so 0.411 N m (3 s. f.)	B1 B1 B1 E1	Award for correct use of dimensions 2.1 and 2.4 or equivalent 1st term o.e. (allow use of 2.4 and 2.1) 2nd term o.e. (allow use of 2.4 and 2.1) Shown [Perpendicular method: M1 Complete method: A1 Correct lengths and angles E1 Shown]	4
(v)	0.41138… - 0.05*P* = 0 *P* = 8.22768…… so 8.23 (3 s. f.)	M1 A1	Allow use of 5 Allow if cm used consistently	2
		18		

Q 4		mark		sub
(i)	$F_{max} = \mu R$ $R = 2g \cos 30$ so $F_{max} = 0.75 \times 2 \times 9.8 \times \cos 30 = 12.730...$ so 12.7 N (3 s. f.) **either** Weight cpt down plane is $2g\sin 30 = 9.8$ N so no as $9.8 < 12.7$ **or** Slides if $\mu < \tan 30$ But $0.75 > 0.577\ldots$ so no	M1 B1 A1 B1 E1 B1 E1	Must have attempt at R with mg resolved [Award 2/3 retrospectively for limiting friction seen below] The inequality must be properly justified The inequality must be properly justified	5
(ii) (A)	Increase in GPE is $2 \times 9.8 \times (6 + 4\sin 30) = 156.8$ J	M1 B1 A1	Use of mgh $6 + 4 \sin 30$	3
(B)	WD against friction is $4 \times 0.75 \times 2 \times 9.8 \times \cos 30 = 50.9222...$ J	M1 A1	Use of WD = Fd	2
(C)	Power is $10 \times (156.8 + 50.9222\ldots)/60$ $= 34.620\ldots$ so 34.6 W (3 s. f.)	M1 A1	Use P = WD/t	2
(iii)	$0.5 \times 2 \times 9^2$ $= 2 \times 9.8 \times (6 + x \sin 30)$ $+ \ 0.5 \times 2 \times 4^2$ -90 so x = 3.8163…. so 3.82 (3 s. f.)	M1 B1 A1 A1 A1	Equating KE to GPE and WD term. Allow sign errors and one KE term omitted. Allow 'old' friction as well. Both KE terms. Allow wrong signs. All correct but allow sign errors All correct, including signs. cao	5
		17		

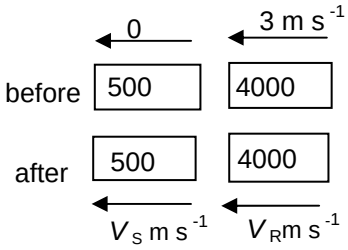
Q 1				
(a) (i)	Impulse has magnitude $2\times 9 = 18$ N s speed is $\frac{18}{6} = 3$ m s^{-1}.	B1 B1		2
(ii)	PCLM $\rightarrow$ $3\times 6 - 1\times 2 = 8v$ v = 2 so 2 m s^{-1} in orig direction of A	M1 A1 E1	Use of PCLM + combined mass RHS All correct Must justify direction (diag etc)	3
(iii)	$\rightarrow$ $2\times 2 - 2\times -1 = 6$ N s	M1 A1	Attempted use of m**v** - m**u** for 6 N s dir specified (accept diag)	2
(iv) (A)		B1	Accept masses not shown	1
(B)	PCLM $\rightarrow$ $2\times 8 + 10\times 1.8 = 8v + 10\times 1.9$ v = 1.875	M1 A1 A1	PCLM. All terms present Allow sign errors only	3
(C)	NEL $\frac{1.9 - 1.875}{1.8 - 2} = -e$ so e = 0.125	M1 A1 F1	Use of NEL with **their** v Any form. FT **their** v FT **their** v (only for $0 < e \leq 1$)	3
(b)	Using $v^2 = u^2 + 2as$ $v = \sqrt{2\times 10\times 9.8} = 14$ rebounds at $14\times\frac{4}{7}$ = 8 m s^{-1} No change to the horizontal component Since both horiz and vert components are 8 m s^{-1} the angle is 45°	B1 M1 F1 B1 A1	Allow ±14 Using **their** *vertical* component FT from **their** 14. Allow ± Need not be explicitly stated cao	5
		19		

Q 2				
(i)	$\theta = \frac{\pi}{2}$ gives CG $= \frac{8\sin\frac{\pi}{2}}{\frac{\pi}{2}} = \frac{16}{\pi}$ $\left(-\frac{16}{\pi}, 8\right)$ justified	B1 E1 E1		3
(ii)	$(8\pi + 72)\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = 8\pi\begin{pmatrix}-\frac{16}{\pi}\\ 8\end{pmatrix} + 72\begin{pmatrix}36\\ 0\end{pmatrix}$ $\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = \begin{pmatrix}25.3673...\\ 2.06997...\end{pmatrix} = \begin{pmatrix}25.37\\ 2.07\end{pmatrix}$ (4 s. f.)	M1 B1 A1 A1 E1 E1	Method for c.m. Correct mass of 8 . or equivalent 1st RHS term correct 2nd RHS term correct [If separate cpts award the A1s for *x*- and *y*- cpts correct on RHS]	6
(iii)	 $\tan\alpha = \frac{13.93}{25.37}$ α = 28.7700… so 28.8° (3 s. f.)	B1 M1 M1 A1 A1	General position and angle (lengths need not be shown) Angle or complement attempted. arctan or equivalent. Attempt to get 16 – 2.0699… Obtaining 13.93… cao Accept use of 2.0699… but not 16. cao	5
(iv)	c. w. moments about A $12\times13.93 - 16F = 0$ so F = 10.4475…	M1 A1 A1	[FT use of 2.0699…] Moments about any point, all forces present (1.5525... if 2.0699… used)	3
		17		

Q 3				
(i)	Moments c.w. about B $200\times0.6-0.8R_A=0$ R_A = 150 so 150 N Resolve or moments R_B = 50 so 50 N	 M1 A1 M1 F1	 Accept about any point. Allow sign errors.	 4
(ii)	Moments c.w. about D $-0.8R_C+1.2\times200=0$ R_C = 300 ↑ Resolve or moments R_D = 100 ↓	 M1 A1 M1 A1 E1	 Or equiv. Accept about any point. All terms present. No extra terms. Allow sign errors. Neglect direction Or equiv. All terms present. No extra terms. Allow sign errors. Neglect direction Both directions clearly shown (on diag)	 5
(iii)	Moments c.w. about P $0.4\times200\cos\alpha-0.8R_Q=0$ R_Q = 96 so 96 N resolve perp to plank $R_P=200\cos\alpha+R_Q$ R_P = 288 so 288 N	 M1 A1 A1 M1 A1 A1	 Or equiv. Must have some resolution. All terms present. No extra terms. Allow sign errors. Correct [No direction required but no sign errors in working] Or equiv. Must have some resolution. All terms present. No extra terms. Allow sign errors. Correct [No direction required but no sign errors in working]	 6
(iv)	Need one with greatest normal reaction So at P Resolve parallel to the plank $F=200\sin\alpha$ so F = 56 $\mu=\frac{F}{R}$ $=\frac{56}{288}=\frac{7}{36}$ (= 0.194 (3 s. f.))	 B1 B1 M1 A1	 FT their reactions Must use **their** F and R cao	 4
		19		

Q 4				
(i)	**either**			
	$0.5\times20\times0.5^2+20\times9.8\times4$	M1	KE or GPE terms	
		B1	KE term	
		B1	GPE term	
	= 786.5 J	A1	cao	
	or			
	$a = {}^{1}\!/_{32}$	B1		
	$T-20g=20\times{}^{1}\!/_{32}$	M1	N2L. All terms present.	
	T = 196.625	A1		
	WD is $4T$ = 786.5 so 786.5 J	A1	cao	4
(ii)	$20g\times0.5=10g$ so 98 W	M1	Use of $P = Fv$ or ${}^{\Delta\text{WD}}\!/_{\Delta t}$	
		A1	All correct	
		A1		3
(iii)	GPE lost is $35\times9.8\times3=1029$ J	B1		
	KE gained is $0.5\times35\times(3^2-1^2)=140$ J	M1	Δ KE	
		A1	The 140 J need not be evaluated	
	so WE gives WD against friction is	M1	Use of WE equation	
	1029 – 140 = 889 J	A1	cao	5
(iv)	**either**			
	$0.5\times35\times3^2+35\times9.8\times0.1x=150x$	M1	WE equation. Allow 1 missing term. No extra terms.	
		B1	One term correct (neglect sign)	
		B1	Another term correct (neglect sign)	
		A1	All correct except allow sign errors	
	x = 1.36127… so 1.36 m (3 S. F.)	A1	cao	
	or			
	$35g\times0.1-150=35a$	M1	Use of N2L. Must have attempt at weight component. No extra terms.	
		A1	Allow sign errors, otherwise correct	
	a = – 3.3057…	A1	cao	
	$0 = 9 - 2ax$	M1	Use of appropriate *uvast* or sequence	
	x = 1.36127… so 1.36 m (3 S. F.)	A1	cao	5
		17		

4762 Mechanics 2

Q1		Mark	Comment	Sub
(a) (i)	**either** In direction of the force $I = Ft = mv$ so $1500 \times 8 = 4000v$ giving $v = 3$ so 3 m s^{-1} **or** N2L gives $a = \frac{1500}{4000}$ $v = 0 + \frac{1500}{4000} \times 8$ giving $v = 3$ so 3 m s^{-1}	 M1 A1 A1 M1 A1 A1	 Use of $Ft = mv$ Appropriate use of N2L **and** *uvast*	3
(ii)	 PCLM $12000 = 4000V_R + 500V_S$ so $24 = 8V_R + V_S$ NEL $\frac{V_S - V_R}{0 - 3} = -0.2$ so $V_S - V_R = 0.6$ Solving $V_R = 2.6,\ V_S = 3.2$ so ram 2.6 m s^{-1} and stone 3.2 m s^{-1}	 M1 A1 M1 A1 A1 F1	 Appropriate use of PCLM Any form Appropriate use of NEL Any form Either value	6
(iii)	$0.5 \times 4000 \times 3^2 - 0.5 \times 4000 \times 2.6^2 - 0.5 \times 500 \times 3.2^2$ = 1920 J	M1 B1 A1	Change in KE. Accept two terms Any relevant KE term correct (FT their speeds) cao	3
(b)	see over			

1		Mark	Comment	Sub
(b) (i)	72**i** N s $8(9\cos 60\mathbf{i} + 9\sin 60\mathbf{j})$ = ($36\mathbf{i} + 36\sqrt{3}\mathbf{j}$) N s	B1 E1	Neglect units but must include direction Evidence of use of 8 kg , 9 m s^{-1} and 60°	2
(ii)	$72\mathbf{i} + (36\mathbf{i} + 36\sqrt{3}\mathbf{j}) = 12(u\mathbf{i} + v\mathbf{j})$ Equating components 72 + 36 = 12*u* so *u* = 9 $36\sqrt{3} = 12v$ so $v = 3\sqrt{3}$	M1 M1 A1	PCLM. Must be momenta both sides Both	3
(iii)	**either** $4\times 18 = 8\times 9$ so equal momenta so 60/2 = 30° **or** $\arctan\left(3\sqrt{3}/9\right) = \arctan\left(1/\sqrt{3}\right) = 30°$	M1 A1 M1 A1	Must be clear statements cao FT **their** *u* and *v*. cao	2
		19		

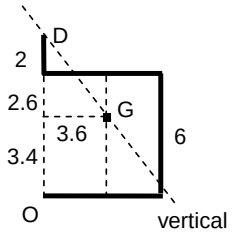
Q 2		Mark	Comment	Sub
(i) (A)	$0.5\times 80\times 3^2 = 360$ J	M1 A1	Use of KE	2
(B)	$360 = F\times 12$ so *F* = 30 so 30 N	M1 F1	*W* = *Fd* attempted FT **their** WD	2
(ii)	Using the WE equation $0.5\times 80\times 10^2 - 0.5\times 80\times 4^2$ $= 80\times 9.8\times h - 1600$ *h* = 6.32653… so 6.33 (3 s. f.)	M1 M1 B1 A1 A1	Attempt to use the WE equation. Condone one missing term Δ KE attempted 1600 with correct sign All terms present and correct (neglect signs) cao	5
(iii) (A)	We have driving force *F* = 40 so 200 = 40*v* and *v* = 5 so 5 m s^{-1}	B1 M1 A1	May be implied Use of *P* = *Fv*	3
(B)	From N2L, force required to give accn is $F - 40 = 80\times 2$ so *F* = 200 *P* = 200×0.5 = 100 so 100 W	M1 A1 A1 M1 A1	Use of N2L with all terms present (neglect signs) All terms correct correct use of P = Fv cao	5
		17		

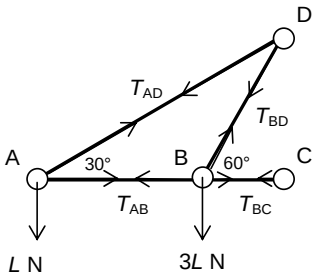
Q 3		Mark	Comment	Sub
(i)	For $\bar{z}$ $(2\times20\times100+2\times50\times120)\bar{z}$ $=2\times2000\times50+2\times6000\times60$ so $\bar{z}$ = 57.5 and $\bar{y}$ = 0	M1 B1 B1 A1 B1	Method for c.m. Total mass of 16000 (or equivalent) At least one term correct NB This result is given below. NB This result is given below. Statement (or proof) required. N.B. If incorrect axes specified, award max 4/5	5
(ii)	$\bar{y}$ and $\bar{z}$ are not changed with the folding For $\bar{x}$ $100\times120\times0+2\times20\times100\times10=16000\bar{x}$ so $\bar{x}=\frac{40000}{16000}=2.5$	E1 M1 B1 E1	A statement, calculation or diagram required. Method for the c.m. with the folding Use of the 10 Clearly shown	4
(iii)	Moments about AH. Normal reaction acts through this line c.w. $P\times120-72\times(20-2.5)=0$ so P = 10.5	M1 B1 B1 A1 A1	 May be implied by diagram or statement $20-2.5$ or equivalent All correct cao	5
(iv)	$F_{\max}=\mu R$ so $F_{\max}=72\mu$ For slipping before tipping we require $72\mu<10.5$ so $\mu<0.1458333...$ $(\frac{7}{48})$	M1 A1 M1 A1	Allow $F=\mu R$ Must have clear indication that this is max F Accept $\leq$. Accept **their** $F_{\max}$ and R. cao	4
		18		

Q 4		Mark	Comment	Sub
(i)	Centre of CE is 0.5 m from D a.c. moment about D $2200 \times 0.5 = 1100$ so 1100 N m c.w moments about D $R \times 2.75 - 1100 = 0$ R = 400 so 400 N	B1 M1 E1 M1 B1 A1	Used below correctly Use of **their** 0.5 0.5 must be clearly established. Use of moments about D in an equation Use of 1100 and 2.75 or equiv	6
(ii)	c.w moments about D $W \times 1.5 - 1100 - 440 \times 2.75 = 0$ so W = 1540	M1 A1 E1	Moments of all relevant forces attempted All correct Some working shown	3
(iii) (A)	c.w. moments about D $1.5 \times 1540 \cos 20 - 1.75T$ $-1100 \cos 20 - 400 \times 2.75 \cos 20 = 0$ T = 59.0663… so 59.1 N (3 s. f.)	M1 M1 A1 B1 A1 A1	Moments equation. Allow one missing term; there must be some attempt at resolution. At least one res attempt with correct length Allow sin $\leftrightarrow$ cos Any two of the terms have cos 20 correctly used (or equiv) 1.75 T All correct cao Accept no direction given	6
(iii) (B)	**either** Angle required is at 70° to the normal to CE so $T_1 \cos 70 = 59.0663...$ so $T_1 = 172.698...$ so 173 N (3 s.f.) **or** $400 \cos 20 \times 2.75 + 1100 \cos 20$ $= 1540 \cos 20 \times 1.5 - T \sin 20 \times 1.75$ T = 172.698… so 173 N (3s.f.)	B1 M1 A1 M1 A1 A1	FT (iii) (A) Moments attempted with all terms present All correct (neglect signs) FT(iii)(A)	3
		18		

4762 Mechanics 2

Q 1		mark	comment	sub
(a) (i)	In **i** direction: $6u - 12 = 18$ so u = 5 i.e. 5**i** m s^{-1}	M1 E1	Use of I-M Accept $6u - 12 = 18$ as total working. Accept 5 instead of 5**i**.	
	either In **i** direction: $0.5v + 12 = 0.5 \times 11$ $v = -13$ so -13**i** m s^{-1} **or** 6 × 5 + 0.5 v = 6 × 3 + 0.5 × 11 v = – 13 so – 13**i** m s^{-1}	M1 B1 A1 M1 A1 A1	Use of I-M Use of + 12**i** or equivalent Accept direction indicated by any means PCLM Allow only sign errors Accept direction indicated by any means	5
(ii)	Using NEL: $\frac{11-3}{-13-5} = -e$ $e = \frac{4}{9}$ $(0.\dot{4})$	M1 F1 F1	Use of NEL. Condone sign errors but not reciprocal expression FT only **their** -13 (even if +ve) FT only **their** -13 and only if –ve (allow 1 s.f. accuracy)	3
(iii)	In **i** direction: $-2 \times 7 = 0.5v - 0.5 \times 11$ v = -17 so -17 **i** m s^{-1} **or** – 2 **i** = 0.5 a so a = – 4 **i** m s^{-2} v = 11**i** – 4**i** × 7 v = -17 so -17 **i** m s^{-1}	M1 M1 A1 A1 M1 A1 M1 A1	Use of **I** = **F***t* Use of **I** = *m*(**v** –**u**) For ± 17 cao. Direction (indicated by any means) Use of **F** = *m***a** For ± 4 Use of **uvas***t* cao. Direction (indicated by any means)	4
(b)	u **i** + ev **j** $\tan\alpha = \frac{v}{u}$, $\tan\beta = \frac{ev}{u}$ $\tan\beta = e\left(\frac{v}{u}\right) = e\tan\alpha$	B1 B1 M1 B1 E1	For u For ev Use of tan. Accept reciprocal argument. Accept use of **their** components Both correct. Ignore signs. Shown. Accept signs not clearly dealt with.	5
		17		

Q 2		mark	comment	sub
(i)	$(2+3\times6)\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix}=6\begin{pmatrix}3\\0\end{pmatrix}+6\begin{pmatrix}6\\3\end{pmatrix}+6\begin{pmatrix}3\\6\end{pmatrix}+2\begin{pmatrix}0\\7\end{pmatrix}$ $20\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix}=\begin{pmatrix}18+36+18\\18+36+14\end{pmatrix}=\begin{pmatrix}72\\68\end{pmatrix}$ $\bar{x}=3.6$ $\bar{y}=3.4$	M1 B1 B1 B1 E1 A1	Method for c.m. Total mass correct For any of the 1st 3 RHS terms For the 4th RHS term cao [If separate cpts, award the 2nd B1 for 2 *x*- terms correct and 3rd B1 for 2×7 in *y* term]	6
(ii)	 $\arctan\left(\frac{3.6}{2+(6-3.4)}\right)=\arctan\left(\frac{3.6}{4.6}\right)$ so 38.047… so 38.0° (3 s. f.)	B1 B1 M1 B1 A1	Diagram showing G vertically below D 3.6 and **their** 3.4 correctly placed (may be implied) Use of arctan on **their** lengths. Allow reciprocal of argument. Some attempt to calculate correct lengths needed 2 + (6 – **their** 3.4) seen cao	5
(iii)	moments about D $5\times3.6=6\times T_{BP}$ so tension in BP is 3 N Resolve vert: $3+T_{DQ}=5$ so tension in DQ is 2 N	M1 F1 M1 F1	moments about D. No extra forces FT **their** values if calc 2nd Resolve vertically or moments about B. FT **their** values if calc 2nd	4
(iv)	We require *x*-cpt of c.m. to be zero **either** $(20+L)\bar{x}=20\times3.6-\frac{1}{2}L^2$ **or** $2\times6\times(0.5\times6)+6\times6-0.5\times L^2=0$ *L* = 12	M1 B1 A1 A1	A method to achieve this with all cpts For the $0.5\times L^2$ All correct	4
		19		

Q 3		mark	comment	sub
(a) (i)		B1 B1	Internal forces all present and labelled All forces correct with labels and arrows (Allow the internal forces set as tensions, thrusts or a mixture)	2
(ii)	A ↑ T_{AD} sin 30 – L = 0 so T_{AD} = 2L so 2L N (T) A → T_{AB} + T_{AD} cos 30 = 0 so T_{AB} = $-\sqrt{3}L$ so $\sqrt{3}L$ N (C) B ↑ T_{BD} sin 60 – 3L = 0 so T_{BD} = $2\sqrt{3}L$ so $2\sqrt{3}L$ N (T) B → T_{BC} + T_{BD} cos 60 –T_{AB} = 0 so T_{BC} = $-2\sqrt{3}L$ so $2\sqrt{3}L$ N (C)	M1 A1 M1 F1 M1 A1 M1 F1 E1	Equilibrium equation at a pin-joint attempted 1st ans. Accept + or –. Second equation attempted 2nd ans. FT any previous answer(s) used. Third equation attempted 3rd ans. FT any previous answer(s) used. Fourth equation attempted 4th ans. FT any previous answer(s) used. All T/C consistent [SC 1 all T/C correct WWW]	9
(b)	Leg QR with frictional force F ← moments c.w. about R $U \times 2l\sin 60 - Wl\cos 60 = 0$ Horiz equilibrium for QR $F = U$ Hence $\frac{1}{2}W = \sqrt{3}F$ and so $F = \frac{\sqrt{3}}{6}W$	 M1 A1 A1 M1 E1 M1 E1	Accept only 1 leg considered (and without comment) Suitable moments equation. Allow 1 force omitted a.c. moments c.w. moments A second correct equation for horizontal or vertical equilibrium to eliminate a force (U or reaction at foot) [Award if correct moments equation containing only W and F] * This second equation explicitly derived Correct use of 2nd equation with the moments equation Shown. CWO but do not penalise * again.	7
		18		

Q 4		mark	comment	sub
(a) (i)	Tension is perp to the motion of the sphere (so WD, $Fd\cos\theta$ = 0)	E1		1
(ii)	Distance dropped is $2-2\cos 40$ = 0.467911..	M1	Attempt at distance with resolution used. Accept $\sin \leftrightarrow \cos$	
		E1	Accept seeing $2-2\cos 40$	
	GPE is *mgh* so	M1		
	$0.15\times 9.8\times 0.467911... = 0.687829...$ J	B1	Any reasonable accuracy	4
(iii)	$0.5\times 0.15\times v^2 = 0.687829...$ so *v* = 3.02837… so 3.03 m s^{-1} (3 s. f.)	M1	Using KE + GPE constant	
		F1	FT **their** GPE	2
(iv)	$\frac{1}{2}\times 0.15\left(v^2-2.5^2\right)$	M1	Use of W-E equation (allow 1 KE term or GPE term omitted)	
		B1	KE terms correct	
	$= 0.687829... - 0.6\times\frac{40}{360}\times 2\pi\times 2$	M1	WD against friction	
		A1	WD against friction correct (allow sign error)	
	v = 2.06178… so 2.06 m s^{-1} (3 s. f.)	A1	cao	5
(b)	N2L down slope: $3g\sin 30 - F = 3\times\frac{1}{8}g$	M1	Must have attempt at weight component	
		A1	Allow sign errors.	
	so $F=\frac{9g}{8}$ (= 11.025)	A1		
	$R = 3g\times\frac{\sqrt{3}}{2}$ (= 25.4611…)	B1		
	$\mu = \frac{F}{R} = \frac{\sqrt{3}}{4}$ (= 0.43301…)	M1	Use of $F=\mu R$	
		E1	Must be worked precisely	6
		18		

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Q 1		Mark		Sub
(i)	**either**			
		M1	Use of $I = Ft$	
	$m \times 2u = 5F$	A1		
	so $F = 0.4mu$ in direction of the velocity	A1	Must have reference to direction. Accept diagram.	
	or			
		M1	Use of *suvat* **and** N2L	
	$a = \frac{2u}{5}$	A1	May be implied	
	so $F = 0.4mu$ in direction of the velocity	A1	Must have reference to direction. Accept diagram.	3
(ii)				
		M1	For 2 equns considering PCLM, NEL or Energy	
	PCLM $\rightarrow$ $2um + 3um = mv_P + 3mv_Q$			
	NEL $\rightarrow$ $v_Q - v_P = 2u - u = u$			
	Energy $\frac{1}{2}m \times (2u)^2 + \frac{1}{2}(3m) \times u^2$			
	= $\frac{1}{2}m \times v_P^{\,2} + \frac{1}{2}(3m) \times v_Q^{\,2}$			
		A1	One correct equation	
		A1	Second correct equation	
	Solving to get both velocities	M1	Dep on 1st M1. Solving pair of equations.	
	$v_Q = \frac{3u}{2}$	E1	If Energy equation used, allow 2nd root discarded without comment.	
	$v_P = \frac{u}{2}$	A1		
			[If AG subst in one equation to find other velocity, and no more, max SC3]	6
(iii)	**either**			
	After collision with barrier $v_Q = \frac{3eu}{2}$ $\leftarrow$	B1	Accept no direction indicated	
	so $\rightarrow$ $m\frac{u}{2} - 3m\frac{3eu}{2} = -4m\frac{u}{4}$	M1	PCLM	
		A1	LHS Allow sign errors. Allow use of $3mv_Q$.	
		A1	RHS Allow sign errors	
	so $e = \frac{1}{3}$	A1		
	At the barrier the impulse on Q is given by			
	$\rightarrow$ $3m\left(-\frac{3u}{2} \times \frac{1}{3} - \frac{3u}{2}\right)$	M1	Impulse is $m(v - u)$	
		F1	$\pm\frac{3u}{2} \times \frac{1}{3}$	
	so impulse on Q is $-6mu$ $\rightarrow$	F1	Allow $\pm$ and direction not clear. FT only e.	
	so impulse on the barrier is $6mu$ $\rightarrow$	A1	cao. Direction must be clear. Units not required.	9
		18		

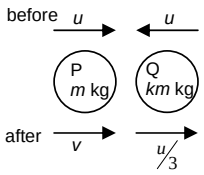
Q 1	continued	mark		sub
(iii)	**or**			
	After collision with barrier $v_Q = \frac{3eu}{2}$ $\leftarrow$	B1		
	Impulse – momentum overall for Q			
	$\rightarrow \quad 2mu + 3mu + I = -4m \times \frac{u}{4}$	M1	All terms present	
		A1	All correct except for sign errors	
	$I = -6mu$	A1		
	so impulse of $6mu$ on the barrier $\rightarrow$	A1	Direction must be clear. Units not required.	
	Consider impact of Q with the barrier to give speed v_Q after impact			
	$\rightarrow \quad \frac{3u}{2} \times 3m - 6mu = 3mv_Q$	M1	Attempt to use I - M	
		F1		
	so $v_Q = -\frac{u}{2}$	F1		
	$e = \frac{u}{2} \div \frac{3u}{2} = \frac{1}{3}$	A1	cao	
				9

Q 2		Mark		Sub
(i)	$R = 80g\cos\theta$ or $784\cos\theta$ $F_{max} = \mu R$ so $32g\cos\theta$ or $313.6\cos\theta$ N	B1 M1 A1	Seen	3
(ii)	Distance is $\frac{1.25}{\sin\theta}$ WD is $F_{max}\,d$ so $32g\cos\theta \times \frac{1.25}{\sin\theta}$ $= \frac{392}{\tan\theta}$	B1 M1 E1	Award for this or equivalent seen	3
(iii)	Δ GPE is mgh so $80\times 9.8\times 1.25 = 980$ J	M1 A1	Accept $100g$ J	2
(iv)	**either** $P = Fv$ so $(80g\sin 35 + 32g\cos 35)\times 1.5$ = 1059.85… so 1060 W (3 s. f.) **or** $P = \frac{\text{WD}}{\Delta t}$ so $\frac{980 + \frac{392}{\tan 35}}{\left(\frac{1.25}{\sin 35}\right)\div 1.5}$ = 1059.85… so 1060 W (3 s. f.)	M1 B1 A1 A1 M1 B1 B1 A1	 Weight term All correct cao Numerator FT **their** GPE Denominator cao	4
(v)	**either** Using the W-E equation $0.5\times 80\times v^2 - 0.5\times 80\times\left(\frac{1}{2}\right)^2 = 980 - \frac{392}{\tan 35}$ v = 3.2793.. so yes **or** N2L down slope a = 2.409973… distance slid, using *uvast* is 1.815372… vertical distance is 1.815372…× sin35 = 1.0412… < 1.25 so yes	M1 B1 B1 A1 A1 M1 A1 A1 M1 A1	Attempt speed at ground or dist to reach required speed. Allow only init KE omitted KE terms. Allow sign errors. FT from (iv). Both WD against friction and GPE terms. Allow sign errors. FT from parts above. All correct CWO All forces present valid comparison CWO	5
		17		

Q 3		Mark		Sub
(i)				
		M1	Correct method for $\bar{y}$ or $\bar{z}$	
		B1	Total mass correct	
		M1	$15\cos\alpha$ or $15\sin\alpha$ attempted either part	
	$\bar{y}$: $250\times 4+125\left(8+\frac{30}{2}\cos\alpha\right)=375\bar{y}$	B1	$\left(8+\frac{30}{2}\cos\alpha\right)$	
		B1	250×4	
	$\bar{y}=\frac{28}{3}=9\frac{1}{3}$	E1	Accept any form	
	$\bar{z}$: $(250\times 0+)\ 125\times\frac{30}{2}\sin\alpha=375\bar{z}$	B1	LHS	
	$\bar{z}=3$	E1		8
(ii)				
	Yes. Take moments about CD. c.w moment from weight; no a.c moment from	E1		
	table	E1	[Award E1 for $9\frac{1}{3}>8$ seen or 'the line of action of the weight is outside the base]	2
(iii)				
	c.m. new part is at (0, 8 + 20, 15)	M1	Either *y* or *z* coordinate correct	
		M1	Attempt to 'add' to (i) or start again. Allow mass error.	
	$375\times\frac{28}{3}+125\times 28=500\bar{y}$ so $\bar{y}=14$	E1		
	$375\times 3+125\times 15=500\bar{z}$ so $\bar{z}=6$	E1		4
(iv)				
	Diagram	B1	Roughly correct diagram	
		B1	Angle identified (may be implied)	
	Angle is $\arctan\frac{6}{14}$	M1	Use of tan. Allow use of 14/6 or equivalent.	
	= 23.1985… so 23.2° (3 s. f.)	A1	cao	4
		18		

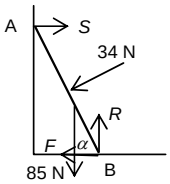
Q 4		mark		sub
(a)	Let the ↑ forces at P and Q be R_P and R_Q			
(i)	c.w. moments about P $2\times600-3R_Q=0$ so force of 400 N ↑ at Q	M1 A1	Moments taken about a named point.	
	a.c. moments about Q or resolve $R_P=200$ so force of 200 N ↑ at P	M1 A1		4
(ii)	$R_P=0$	B1	Clearly recognised or used.	
	c.w. moments about Q	M1	Moments attempted with all forces. Dep on $R_P=0$ or R_P not evaluated.	
	$2L-1\times600=0$ so L = 300	A1		3
(b) (i)	$\cos\alpha=15/17$ or $\sin\alpha=8/17$ or $\tan\alpha=8/15$	B1	Seen here or below or implied by use.	
	c.w moments about A	M1	Moments. All forces must be present and appropriate resolution attempted.	
	$16\times340\cos\alpha-8R=0$	A1		
	so R = 600	E1	Evidence of evaluation.	4
(ii)	Diagram	B1	Must have 600 (or R) and 340 N and reactions at A.	
		B1	All internal forces clearly marked as tension or thrust. Allow mixture. [Max of B1 if extra forces present]	
	(Solution below assumes all internal forces set as tensions)			2
(iii)		M1	Equilibrium at a pin-joint	
	B ↓ $340\cos\alpha+T_{BC}\cos\alpha=0$ so $T_{BC}=-340$ (Thrust of) 340 N in BC	A1		
	C → $T_{BC}\sin\alpha-T_{AC}\sin\alpha=0$ so $T_{AC}=-340$ (Thrust of) 340 N in AC	F1		
	B ← $T_{AB}+T_{BC}\sin\alpha-340\sin\alpha=0$	M1	Method for T_{AB}	
	so $T_{AB}=320$ (Tension of) 320 N in AB	A1		
	Tension/ Thrust all consistent with working	F1		
			[Award a max of 4/6 if working inconsistent with diagram]	6
		19		

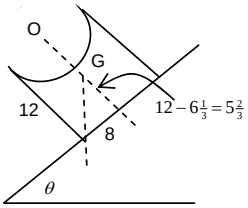
4762 Mechanics 2

Q 1		mark	comment	sub
(a)				
(i)		B1		1
(ii)				
	$mu - kmu = mv + km\frac{u}{3}$	M1	PCLM applied	
		A1	Either side correct (or equiv)	
	$v = \left(1 - \frac{4k}{3}\right)u$	E1	Must at least show terms grouped	
				3
(iii)				
	Need $v < 0$	E1	Accept $\frac{4k}{3} > 1$ without reason	
	so $k > \frac{3}{4}$	B1		
			[SC1: $v = 0$ used and inequality stated without reason]	
				2
(iv)				
	$\frac{\frac{u}{3} - v}{-u - u} = -\frac{1}{2}$	M1	Use of NEL	
		A1		
	so $v = -\frac{2u}{3}$	E1		
	$-\frac{2u}{3} = u\left(1 - \frac{4k}{3}\right)$	M1		
	so $k = 1.25$	A1	cao	
				5
(b)				
(i)	$9\begin{pmatrix}1\\-2\end{pmatrix} + 5\begin{pmatrix}3\\2\end{pmatrix} = 8\mathbf{V}$	M1	Use of PCLM	
		B1	Use of mass 8 in coalescence	
		M1	Use of **I** = **F***t*	
	$\mathbf{V} = \begin{pmatrix}3\\-1\end{pmatrix}$	E1		
				4
(ii)				
	i cpt $3 \rightarrow -3 \times \frac{1}{2}$	M1	Allow wrong sign	

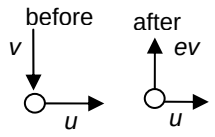
	j cpt unchanged	B1	May be implied	
	new velocity $\begin{pmatrix} -1.5 \\ -1 \end{pmatrix}$ m s^{-1}	A1	cao [Award 2/3 if barrier taken as $\begin{pmatrix} 1 \\ 0 \end{pmatrix}$]	3
		18		

Q 2		mark	comment	sub
(a)				
(i) (A)	Yes. Only WD is against conservative forces.	E1	Accept only WD is against gravity or no work done against friction.	
(B)	Block has no displacement in that direction	E1		2
(ii)				
	$0.5\times 50\times 1.5^2 = 20gx - 5gx$	M1	Use of WE with KE. Allow m = 25.	
		B1	Use of 50	
		M1	At least 1 GPE term	
		A1	GPE terms correct signs	
	x = 0.38265… so 0.383 m (3 s. f.)	A1	cao	5
(iii)				
	$0.5\times 50\times V^2 - 0.5\times 50\times 1.5^2$	M1	WE equation with WD term. Allow GPE terms missing	
		B1	Both KE terms. Accept use of 25.	
	$= 2\times 20g - 2\times 5g - 180$	B1	Either GPE term	
		B1	180 with correct sign	
	V = 2.6095… so 2.61 m s^{-1}	A1	cao	5
(b)				
	Force down the slope is $2000 + 450g\sin 20$	M1	Both terms. Allow mass not weight	
		B1	Weight term correct	
	Using $P = Fv$	M1		
	$P = (2000 + 450g\sin 20)\times 2.5$	F1	FT **their** weight term	
	P = 8770.77… so 8770 W (3 s. f.)	A1	cao	5
		17		

Q 3		mark	comment	sub
(i)				
	c.w. moments about A	M1	Moments equation.	
	$5R_B - 3\times 85 = 0$ so $R_B = 51$ giving 51 N ↑	A1	Accept no direction given	
	Either a.c. moments about B or resolve ↑	M1		
	$R_A = 34$ so 34 N ↑	F1	Accept no direction given	
				4
(ii)				
	c.w. moments about A	M1	Moments with attempt to resolve at least one force. Allow $s \leftrightarrow c$.	
	$85\times 3\cos\alpha - 27.2\times 5\sin\alpha = 0$	B1	Weight term	
		B1	horiz force term	
	so $\tan\alpha = \frac{3\times 85}{27.2\times 5} = \frac{15}{8}$	E1	Must see some arrangement of terms or equiv	
				4
(iii)				
		B1	All forces present and labelled	
	a.c. moments about B	M1	Moments with attempt to resolve forces and all relevant forces present	
	$85\times 2\times\cos\alpha + 34\times 2.5 - 5S\times\sin\alpha = 0$	B1	34×2.5	
		A1	All other terms correct. Allow sign errors.	
	S = 37.4	A1	All correct	
	Resolving horizontally and vertically	M1	Either attempted	
	→ $S - F - 34\sin\alpha = 0$ so F = 7.4	E1		
	↑ $R - 85 - 34\cos\alpha = 0$	A1	R = 101 need not be evaluated here [Allow A1 for the two expressions if correct other than $s \leftrightarrow c$]	
	Using $F = \mu R$	M1		
	$\mu = \frac{7.4}{101}$ = 0.07326… so 0.0733 (3 s. f.)	A1	cao	
				10
		18		

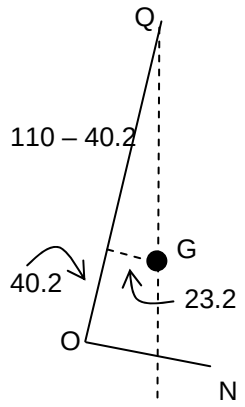
Q 4		mark	comment	sub
(i)				
	Taking a *y*-axis vert downwards from O		Allow areas used as masses	
	$2\pi\sigma\times8^2\times4+2\pi\sigma\times8\times k\times\frac{k}{2}$	M1	Method for c.m.	
		B1	'4' used	
		B1	$16\pi k$	
		B1	*k*/2 used	
	$=\left(2\pi\sigma\times8^2+2\pi\sigma\times8k\right)\bar{y}$	B1	Masses correct	
	so $\bar{y}=\frac{64+k^2}{16+2k}$	E1	Must see some evidence of simplification Need no reference to axis of symmetry	
				6
(ii)				
	k = 12 gives OG as 5.2 and mass as $320\pi\sigma$	B1	Allow for either. Allow $\sigma=1$	
	$320\pi\sigma\times5.2+\pi\sigma\times8^2\times12$	M1	Method for c.m. combining with (i) or starting again	
		B1	One term correct	
		B1	Second term correct	
	$=\left(320\pi\sigma+64\pi\sigma\right)\bar{y}$			
	$\bar{y}=6\frac{1}{3}$	E1	Some simplification shown	
				5
(iii)				
		B1 B1 B1	G above edge of base $12-6\frac{1}{3}=5\frac{2}{3}$ seen here or below 8 seen here or below	
	$\tan\theta=\frac{8}{5\frac{2}{3}}$	M1	Accept $\frac{5\frac{2}{3}}{8}$ or attempts based on $6\frac{1}{3}$ and 8.	
	θ = 54.6887… so 54.7° (3 s. f.)	A1	cao	
				5
(iv)				
	Slips when $\mu=\tan\theta$	M1	Or ….	
	$\frac{8}{5\frac{2}{3}}=1.4117...$	B1		
	< 1.5 so does not slip	A1	There must be a reason	
				3
		19		

4762 Mechanics 2

1 (a) (i)	Let vel of Q be $v \rightarrow$ $6\times1 = 4v + 2\times4$ v = – 0.5 so 0.5 m s^{-1} in opposite direction to R	 M1 A1 A1 A1	 Use of PCLM Any form Direction must be made clear. Accept – 0.5 only if + ve direction clearly shown	4
(ii)	Let velocities after be R: $v_R \rightarrow$; S: $v_S \rightarrow$ PCLM +ve $\rightarrow$ $4\times2 - 1\times3 = 2v_R + 3v_S$ $2v_R + 3v_S = 5$ NEL +ve $\rightarrow$ $\frac{v_S - v_R}{-1-4} = -0.1$ so $v_S - v_R = 0.5$ Solving gives v_R = $0.7\rightarrow$ v_S = $1.2\rightarrow$	 M1 A1 M1 A1 A1 A1	 PCLM Any form NEL Any form Direction not required Direction not required Award cao for 1 vel and FT second	6
(iii)	R and S separate at 0.5 m s^{-1} Time to drop T given by $0.5\times9.8T^2 = 0.4$ so $T = \frac{2}{7}$ (0.28571…) so distance is $\frac{2}{7}\times0.5 = \frac{1}{7}$ m (0.142857…m)	M1 B1 A1	FT **their** result above. Either from NEL or from difference in final velocities cao	3
(b)	 $u \rightarrow u$ $v \rightarrow (-)ev$ KE loss is $\frac{1}{2}m\left(u^2 + v^2\right) - \frac{1}{2}m\left(u^2 + e^2v^2\right)$ $= \frac{1}{2}mu^2 + \frac{1}{2}mv^2 - \frac{1}{2}mu^2 - \frac{1}{2}me^2v^2$ $= \frac{1}{2}mv^2\left(1 - e^2\right)$	 B1 B1 M1 E1	 Accept $v \rightarrow ev$ Attempt at difference of KEs Clear expansion and simplification of correct expression	
				4
				17

2(i)	GPE is 1200 × 9.8 × 60 = 705 600 Power is (705 600 + 1 800 000) ÷ 120 = 20 880 W = 20 900 W (3 s. f.)	B1 M1 B1 A1	Need not be evaluated power is WD ÷ time 120 s cao	4
(ii)	Using $P = Fv$. Let resistance be R N $13500 = 18F$ so $F = 750$ As v const, $a = 0$ so $F - R = 0$ Hence resistance is 750 N We require 750 × 200 = 150 000 J (= 150 kJ)	M1 A1 E1 M1 F1	Use of $P = Fv$. Needs some justification Use of WD = Fd or Pt FT **their** F	5
(iii)	$\frac{1}{2}\times 1200\times\left(9^2-18^2\right)$ $=1200\times 9.8\times x\sin 5-1500x$ Hence 145800 = 475.04846…x so x = 306.91… so 307 m (3 s, f,)	M1 B1 M1 A1 A1 A1	Use of W-E equation with 'x' 2 KE terms present GPE term with resolution GPE term correct All correct cao	6
(iv)	$P = Fv$ and N2L gives $F - R = 1200a$ Substituting gives $P = (R + 1200a)v$ If $a \neq 0$, v is not constant. But P and R are constant so a cannot be constant.	B1 B1 E1 E1	 Shown	4
				19
3 (i) (*A*)	Let force be P a.c. moments about C $P \times 0.125 - 340 \times 0.5 = 0$ P = 1360 so 1360 N	 M1 A1 A1	 Moments about C. All forces present. No extra forces. Distances correct cao	3
(i) (*B*)	Let force be P c.w. moments about E $P \times 2.125 - 340 \times (2 - 0.5) = 0$ P = 240 so 240 N	 M1 A1 A1	 Moments about E. All forces present. No extra forces. Distances correct cao	3

(ii)	$Q\sin\theta \times 2.125 + Q\cos\theta \times 0.9$ $= \frac{25.5Q}{13} + \frac{4.5Q}{13}$ $= \frac{30Q}{13}$ so $\frac{30Q}{13}$ N m	M1 B1 E1	Moments expression. Accept $s \leftrightarrow c$. Correct trig ratios **or** lengths Shown	3
(iii)	We need $\frac{30Q}{13} = 340 \times 1.5$ so Q = 221 Let friction be F and normal reaction R Resolve $\rightarrow$ $221\cos\theta - F = 0$ so F = 85 Resolve $\uparrow$ 221 sin θ + R = 340 so R = 136 $F < \mu R$ as not on point of sliding so $85 < 136\mu$ so $\mu > \frac{5}{8}$	M1 E1 M1 A1 M1 A1 M1 A1 E1	Moments equn with all relevant forces Shown Accept $\leq$ or = Accept $\leq$. FT **their** F and R	
				9
				18
4 (i)	$4000\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = 4800\begin{pmatrix}30\\ 40\end{pmatrix} - 800\begin{pmatrix}50\\ 20\end{pmatrix}$ so $\bar{x} = 26$ $\bar{y} = 44$	M1 A1 E1 A1	Any complete method for c.m. Either one RHS term correct or one component of both RHS terms correct [SC 2 for correct $\bar{y}$ seen if M 0]	4
(ii)	$250\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix}$ $= 110\begin{pmatrix}0\\ 55\end{pmatrix} + 40\begin{pmatrix}20\\ 0\end{pmatrix} + 40\begin{pmatrix}40\\ 20\end{pmatrix} + 20\begin{pmatrix}50\\ 40\end{pmatrix} + 40\begin{pmatrix}60\\ 60\end{pmatrix}$ $\bar{x} = 23.2$ $\bar{y} = 40.2$	M1 B1 B1 E1 A1	Any complete method for c.m. Any 2 edges correct mass and c.m. **or** any 4 edges correct with mass and x or y c.m. coordinate correct. At most one consistent error	5

(iii)		B1	Indicating c.m. vertically below Q	
		B1	Clearly identifying correct angle (may be implied) and lengths	
	Angle is $\arctan\left(\frac{23.2}{110-40.2}\right)$	M1	Award for $\arctan\left(\frac{b}{a}\right)$ where b = 23.2 and a = 69.8 or 40.2 or where b = 69.8 or 40.2 and a = 23.2. Allow use of **their** value for y only.	
	= 18.3856…. so 18.4° (3 s. f.)	A1	cao	4
(iv)	$10\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = 2\times1.5\times\begin{pmatrix}26\\ 44\end{pmatrix}+7\begin{pmatrix}23.2\\ 40.2\end{pmatrix}$	M1	Combining the parts using masses	
		B1	Using both ends	
		A1	All correct	
	$\bar{x} = 24.04$ so 24.0 (3 s.f.)	A1	cao	
	$\bar{y} = 41.34$ so 41.3 (3 s.f.)	F1	FT **their** y values only.	5
				18

OCR
RECOGNISING ACHIEVEMENT

GCE

Mathematics (MEI)

Advanced GCE **4762**

Mechanics 2

Mark Scheme for June 2010

Oxford Cambridge and RSA Examinations

Q 1		mark		sub
(i)	For P $200\times5+250=200v_P$ $v_P=6.25$ so $6.25\mathbf{i}$ m s^{-1} For Q $250\times5-250=250v_Q$ $v_Q=4$ so $4\mathbf{i}$ m s^{-1}	 M1 E1 M1 A1	 Award for I-M Accept no **i** and no units Must have impulse in opposite sense Must indicate direction. Accept no units.	4
(ii)	**i** direction positive PCLM: $2250=200\times4.5+250w_Q$ $w_Q=5.4$ so $5.4\mathbf{i}$ m s^{-1} NEL: $\frac{w_Q-4.5}{4-6.25}=-e$ $e=0.4$	 M1 F1 E1 M1 A1 A1	 PCLM used. Allow error in LHS FT from (i) Any form. FT only from (i) NEL . Allow sign errors Signs correct. FT only from (i) cao	6
(iii)	**i** direction positive Suppose absolute vel of object is $-V\mathbf{i}$ $200\times4.5=-20V+180\times5.5$ $V=4.5$ speed of separation is 5.5 + 4.5 = 10 m s^{-1}	 M1 B1 A1 A1 F1	 Applying PCLM. All terms present. Allow sign errors. Correct masses All correct (including signs) FT **their** V.	5
(iv)	$180\times5.5+250\times5.4=430W$ $W=5.4418\ldots$ so $5.44\ \mathbf{i}$ m s^{-1} (3 s. f.)	M1 A1	Using correct masses and velocities cao	2
				17

Q 2		mark		sub
(i)	$20\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = 15\begin{pmatrix}20\\ 0\end{pmatrix} + 3\begin{pmatrix}0\\ 100\end{pmatrix} + 2\begin{pmatrix}25\\ 200\end{pmatrix}$ $\bar{x} = 17.5$ $\bar{y} = 35$	M1 B1 A1 A1 A1	Method to obtain at least 1 coordinate '100' or '25' correct Either one RHS term correct or one component of two RHS terms correct	5
(ii)	$25\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = \begin{pmatrix}350\\ 700\end{pmatrix} + 5\begin{pmatrix}40\\ 200\end{pmatrix}$ so $\bar{x} = 22$, $\bar{y} = 68$	M1 E1	Using (i) or starting again Clearly shown.	2
(iii)	We need the edge that the $\bar{x}$ position is nearest $\bar{x}$ = 22; distances are 22 to PQ, 18 to SR 15 to QR so edge QR	M1 B1 B1 A1	This may be implied One distance correct All distances correct	4
(iv)	Moments about RS In sense xOy $T\sin 50 \times 200 - T\cos 50 \times 40$ $-20g \times (40 - 17.5) = 0$ T = 34.5889… so 34.6 N (3 s. f.)	M1 B1 M1 A1 B1 A1 A1	Moments about RS attempted Use of weight not mass below. FT mass from here Attempt to find moment of T about RS, including attempt at resolution. May try to find perp dist from G to line of action of the force. 40 – 17.5 All correct allowing sign errors cao (except for use of mass)	7
				18

Q 3		mark		sub
(i)	a.c. moments about A $1 \times T - 2 \times 300 = 0$ so $T = 600$ Resolving $\rightarrow X = 0$ $\uparrow T - Y = 300$ so $Y = 300$	 E1 B1 M1 A1	 Justified 	4
(ii)	Diagram *The working below sets all internal forces as tensions; candidates need not do this.*	B1 B1	All external forces marked consistent with (i) All internal forces with arrows and labels	2
(iii)	Let angle DAB be θ. $\cos\theta = \frac{1}{2}$, $\sin\theta = \frac{\sqrt{3}}{2}$ A $\uparrow$ $-300 - T_{AB}\sin\theta = 0$ so $T_{AB} = -200\sqrt{3}$ so force is $200\sqrt{3}$ (C) A $\rightarrow$ $T_{AD} + T_{AB}\cos\theta = 0$ so $T_{AD} = 100\sqrt{3}$ so force is $100\sqrt{3}$ (T) C $\uparrow$ $T_{CD}\sin\theta - 300 = 0$ so $T_{CD} = 200\sqrt{3}$ so force is $200\sqrt{3}$ (T) C $\leftarrow$ $T_{BC} + T_{CD}\cos\theta = 0$ so $T_{BC} = -100\sqrt{3}$ so force is $100\sqrt{3}$ (C) B $\uparrow$ $T_{AB}\sin\theta + T_{BD} = 0$ so $T_{BD} = 300$ so force is 300 (T)	B1 M1 M1 A1 F1 F1 F1 F1 F1	Or equivalent seen Attempt at equilibrium at pin-joints 1 equilib correct, allowing sign errors All T/C consistent with their calculations and diagrams	9
(iv)	AD, AB, BC, CD 300 N, X and Y not changed. Equilibrium equations at A and C are not altered B $\uparrow$ $T_{AB}\sin\theta + T'_{BD} + 600 = 0$ so $T'_{BD} = -300$ so force is 300 (C)	B1 E1 M1 A1	 C not needed. [If 300 N (C) given WWW, award SC1 (NB it must be made clear that this is a compression)]	4
				19

Q 4		mark		sub
(i)	Let friction be F N and normal reaction R N			
	$F_{\max} = 58\cos 35$	B1	Need not be explicit	
	$R = 16g + 58\sin 35$	M1	Both terms required.	
		A1		
	$F_{\max} = \mu R$	M1		
	so $\mu = 0.249968\ldots$ about 0.25	E1		5
(ii)	WD is $70\cos 35 \times 3 = 210\cos 35$	M1	Use of WD = Fd . Accept $\cos 35$ omitted.	
	so 172.0219… = 172 J (3 s. f.)	A1		
	Average power is WD/time	M1		
	so 34.4043…. = 34.4 W (3 s. f.)	A1	cao	4
(iii)	Using the constant acceleration result			
	$s = \frac{1}{2}(u+v)t$ with $s = 3$, $u = 0$, $v = 1.5$	M1	Attempt to substitute in *suvat* (sequence)	
	and $t = 5$ we see that			
	$3 \neq \frac{1}{2}(0+1.5)\times 5 = 3.75$	E1	Conclusion clear	2
(iv)				
	172.0219…	M1	Using W-E equn, allow 1 missing term	
	$= \frac{1}{2}\times 16 \times 1.5^2$	M1	KE term attempted	
		A1	correct	
	$+0.25\times(16g + 70\sin 35)\times 3$	M1	Attempt at using new F in $F_{\max} = \mu R$	
	+ WD	A1		
		A1	All correct	
	so WD by S is 6.30916…	A1	cao	
	so 6.31 J (3 s. f.)			7
				18

OCR
RECOGNISING ACHIEVEMENT

GCE

Mathematics (MEI)

Advanced GCE

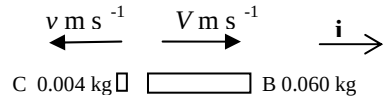
Unit **4762:** Mechanics 2

Mark Scheme for January 2011

Oxford Cambridge and RSA Examinations

Q 1		m a r k	notes
(i)	Let normal reaction be R		
	$\sin\alpha = \sqrt{1-0.8^2} = 0.6$	B1	Accept any form and implied
		M1	Use of $F_{max} = \mu R$
	$R = 2.5\times 9.8\times 0.8$	B1	Expression for R; may be implied
	$F_{max} = 0.85\times R = 16.66$	F1	FT their R
	Wt cpt down slope is $2.5 \times 9.8 \times 0.6 = 14.7$	B1	
	$16.66 > 14.7$ so at rest	E1	FT if their F and weight component show given result If g omitted, allow B1M1B0F1B0E1, so 4/6 [Award as follows for use of $\tan\alpha < \mu$: B1 $\tan\alpha = \frac{3}{4}$ E1 $\tan\alpha < \mu$ shown]
		6	
(ii)	Let the speeds down the plane be v_A and v_B . PCLM down the plane		
	$1.5\times 16 = 2.5v_A + 1.5v_B$	M1	PCLM
	so $5v_A + 3v_B = 48$	A1	Any form
	NEL +ve down the plane		
	$\frac{v_A - v_B}{0-16} = -0.4$	M1	NEL. Allow sign errors
	$v_A - v_B = 6.4$	A1	Any form
	$v_A = 8.4$ so 8.4 m s^{-1} down plane	E1	Condone direction not clear if +8.4 seen
	$v_B = 2$ so 2 m s^{-1} down plane	F1	Condone direction not clear if +2 seen. SC1 if 2 equations obtained and 8.4 substituted into one to obtain answer 2 (instead of E1F1)
		6	
(iii)	$1.5 \times (2 - 16)$ down plane	M1	Use of $m(\mathbf{v} - \mathbf{u})$ If impulse on A found, treat as MR unless final answer relates this to impulse on B
	$= -21$ N s down the plane	A1	± 21 N s
	so 21 Ns up the plane	A1	Direction explicitly commented on
		3	

Q 1		m a r k	notes
(iv)	**either**		
	$(2.5\times 9.8\times 0.6 - F_{max})\times t = 2.5(0-8.4)$	M1	Using Impulse-momentum (must use 8.4) . sufficient to consider one term on LHS
		B1	Either side correct
		A1	Allow only sign errors
	so t = 10.7142… 10.7 s (3 s. f.)	A1	cao
	or		
	Using N2L down the plane	M1	Using N2L ; sufficient to consider one force term
	a = – 0.784	A1	Allow sign errors
		M1	Using appropriate *suvat* must use a or-a found by use of N2L and u = 8.4
	using $v = u + at$, t = 10.7142… 10.7 s (3 s. f.)	A1	cao
	or		
	$0.5\times 2.5\times 8.4^2 + (14.7 - 16.66)x = 0$	M1	Use energy with 8.4, sufficient to consider one non-KE term
	x= 45	A1	
		M1	Using appropriate *suvat*
	T = 10.7142….. 10.7 (3 s. f.)	A1	cao
		4	
		19	

Q 2		mark	notes
(a)			
	Energy: $\frac{1}{2}\times 0.004\times v^2+\frac{1}{2}\times 0.060\times V^2=0.8$	M1	Use of KE in two terms in an equation.
	$v^2+15V^2=400$	A1	Any form
	PCLM in **i** direction: $0.06V-0.004v=0$	M1	PCLM. Accept sign errors.
	$v = 15V$	A1	Any form
	Solving	M1	Valid method for elimination of v or V from a linear and a quadratic
	$(15V)^2+15V^2=400$		
	so $V^2=\frac{400}{240}=\frac{5}{3}$ and $\mathbf{V}=\sqrt{\frac{5}{3}}\mathbf{i}$	A1	Accept 1.29099…**i** Accept no direction
	$\mathbf{v}=-15\sqrt{\frac{5}{3}}\mathbf{i}$ $(=-\sqrt{375}\mathbf{i})$	F1	Accept – 19.3649…**i** Accept no direction Second answer follows from first
		A1	(Relative) directions indicated - accept diagram. Both speeds correct.
		8	
(b) (i)	W is work done by resistances on car		
	$\frac{1}{2}\times 800\times\left(12^2-30^2\right)=-800\times 9.8\times 20+\mathrm{W}$	M1	Use of WE. Must have KE, W and GPE. Allow -*W*
		B1	Both KE terms. Accept sign error
		A1	All correct with *W* or -*W*
	W = – 145 600		
	so 145 600 J done by car against resistances	A1	cao
		4	

Q 2		m a r k	notes
(ii)	**either**		
	The slope is 18 × 25 = 450 m long	B1	
	$\frac{800\times 9.8\times 20+750\times 450}{25}$	M1	Use of P = (Work done) / (elapsed time) used for at least one work done term
		M1	WD is force × distance used for at least one force
		A1	Allow only sign errors both terms
	= 19 772 W	A1	cao.
	or		
	The angle of the slope is arcsin (1/22.5)	B1	
	$\left(800\times 9.8\times \frac{1}{22.5}+750\right)\times 18$	M1	Use of $P = Fv$ used for at least one term
		M1	Attempt at weight component
		A1	Allow only sign errors both terms
	= 19 772 W	A1	cao.
		5	
		17	

Q 3		m a r k	notes
(i)	Horizontal $X - 50 = 0$ Vertical: $R - Y - 45 = 0$	B1 B1 2	Any form Any form
(ii)	a. c. moments about A $1 \times R = 3 \times 45$ so $R = 135$ so $135 - Y - 45 = 0$ and $Y = 90$	 M1 E1 E1 3	 Clearly shown Shown
(iii)	In analysis below all internal forces are taken as tensions	B1 B1 2	Correct arrow pairs for all internal forces Correct labels

Q 3		m a r k	notes
(iv)		M1 M1 M1	Equilibrium attempted at a pin-joint Equilibrium attempted at a 2nd pin-joint Either Equilibrium equation for 2nd direction at a pin-joint or 3rd pin-joint considered
	At C $\uparrow \quad T_{CD}\cos 30 - 45 = 0$ so $T_{CD} = 30\sqrt{3}$ and force in CD is $30\sqrt{3}$ N (T) $\leftarrow \quad T_{BC} + T_{CD}\cos 60 = 0$ so $T_{BC} = -15\sqrt{3}$ and force in BC is $15\sqrt{3}$ N (C)	B1 A1 F1	At least 3 equations of resolution correct or follow through
	At D $\downarrow \quad T_{BD}\cos 30 + T_{CD}\cos 30 = 0$ so $T_{BD} = -30\sqrt{3}$ and force in BD is $30\sqrt{3}$ N (C)	 F1	
	$\leftarrow \quad T_{AD} + T_{BD}\cos 60 - T_{CD}\cos 60 - 50 = 0$ so $T_{AD} = 50 + 30\sqrt{3}$ and the force in AD is $50 + 30\sqrt{3}$ N (T)	 F1	
	At A $\downarrow \quad T_{AB}\cos 30 + 90 = 0$ so $T_{AB} = -60\sqrt{3}$ and the force in AB is $60\sqrt{3}$ N (C)	 F1	
		B1 10	At least 4 T/C correct
(v)	The equilibria at C depend only on the framework geometry and the 45 N. These are not changed so forces in CB and CD are not changed	 E1 E1 2	Resolve in two directions at *C* and obtain same results as in (iv) M1A1
		19	

Q 4		m a r k	notes
(i)	(2, 2.5)	B1 1	Condone writing as a vector
(ii)	By symmetry, $\bar{y} = 2.5$ For $\bar{x}$: $\left(5h + \frac{1}{2}\times 5\times 6\right)\bar{x} = 5h\times\left(-\frac{h}{2}\right) + \frac{1}{2}\times 5\times 6\times 2$ so $(5h+15)\bar{x} = -2.5h^2 + 30$ so $5(h+3)\bar{x} = 2.5(12-h^2)$ and $\bar{x} = \frac{12-h^2}{2(h+3)}$	B1 M1 A1 A1 A1 E1 6	Some justification needed These next 4 marks may be obtained from correct FT of their "2" from (i) 1st term RHS correct (allow sign error) Either other term correct All correct Clearly shown, including signs.
(iii)	Need $\bar{x} > 0$ So $\frac{12-h^2}{2(h+3)} > 0$ Hence $12 - h^2 > 0$ Since $h > 0$, $0 < h < 2\sqrt{3}$	M1 B1 A1 3	Allow $\bar{x} \geq 0$ or = 0 $2\sqrt{3}$ or $-2\sqrt{3}$ oe seen Accept only +ve root mentioned. WWW for signs Accept $h < 2\sqrt{3}$ as answer strict inequality for final A mark

Q 4		m a r k	notes
Q4 (iv)	**continued**		
	When $h = 3$, $\bar{x} = 0.25$	B1	Could be scored in (v)
	Let mag of vert force be T N a.c moments about axis thro' O		
	$T \times 6 - 15 \times 0.25 = 0$	M1	If moments about another point need all relevant forces. Allow sign errors. Condone use of $15g$
	so $T = 0.625$ so 0.625 N	A1 3	cao
(v)	Let magnitude of force be U N a.c. moments about axis thro' D		
	$U\cos30 \times 5 - 15 \times (3 + 0.25) = 0$	M1	Each term must be a moment. If moments about another point need all relevant forces. Condone use of $15g$.
		B1	moment of U ($5U\cos30$ or …) oe
		A1	$(3 + 0.25)$ oe
	$U = 11.25833\ldots$ so 11.3 N (3 s. f.)	A1 4	cao
		17	

OCR
RECOGNISING ACHIEVEMENT

GCE

Mathematics (MEI)

Advanced GCE

Unit **4762:** Mechanics 2

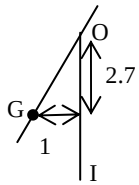
Mark Scheme for June 2011

Q 1		mark	notes
(a) (i)	$13T = 10(4.75 - (-1.75))$ so $T = 5$. So 5 s. OR: $13 = 10a$ $T = \dfrac{4.75-(-1.75)}{1.3} = 5$	M1 A1 A1 B1 M1 A1 3	Use of $I = Ft$. Allow sign errors Signs correct on RHS cao N2L Use of *suvat* cao
(ii)	PCLM: $10\times4.75-15\times0.5=25v_{P+Q}$ $v_{P+Q}=1.6$ so 1.6 m s^{-1} in +ve direction	M1 A1 2	PCLM with combined mass. Allow sign errors No need for reference to direction
(iii)	PCLM: $10\times4.75-15\times0.5=10\times1+15v_Q$ Hence $v_Q = 2$ and Q has velocity 2 m s^{-1} NEL: $\dfrac{v_Q-1}{-0.5-4.75}=-e$ so e = 0.19047… so 0.190 (3 s. f.)	M1 A1 A1 M1 A1 A1 6	PCLM with all correct terms. Allow sign errors Any form Accept no direct reference to direction NEL. Accept **their** v_Q and any sign errors. Fraction must be correct way up Any form. FT **their** v_Q. cao accept 0.19 , 4/21 accept 0.2 only if 0.19 seen earlier

(b)	Initial vert cpt is 14sin30 = 7 1st hits ground at *v* given by	B1	
	$v^2 = 7^2 + 2\times 9.8\times 3.125$	M1	Appropriate *suvat*. Allow ±9.8 etc Condone u =14
	v = 10.5	A1	
	Vert cpt after 2nd bounce		
	10.5×0.6^2	M1	**their** 10.5×0.6^n for n = 1, 2 or 3 Condone use of their initial vertical component. Do not award if horiz component is also multiplied by 0.6
		B1	use of $\times 0.6^2$ or attempt at two bounces with 0.6 used each time
	Horiz cpt is unchanged throughout $(14\cos 30)$	B1	Award even if value wrong or not given
	Angle is $\arctan\left(\frac{10.5\times 0.6^2}{14\cos 30}\right) = 17.31586...$	M1	FT their horiz and vert components. oe. Fraction must be for correct angle.
	so 17.3° (3 s. f.)	A1 8	cao SC answer of 11.7 will usually earn 5/8
		19	

Q 2		mark	notes
			Penalise answers to fewer than 4sf only once
(i)	cw moments about A Let force be S		
	$600\times0.8-S\times2=0$	M1	Moments. All forces. No extras
		A1	
	S = 240 so 240 N vertically upwards	A1	Need statement of direction or diagram
		3	
(ii)	cw moments about A Let tension be T	M1	Moments. All forces. No extras. Attempt at moment of T (need not be resolved) Note that mmts about B needs forces at hinge.
	$600\times0.8-T\sin50\times0.3=0$		
		M1	Correct method for moment of T. Allow length errors and $s \leftrightarrow c$
		A1	Moment of T correct (allow sign error)
		A1	All correct
	T = 2088.65… $(\frac{1600}{\sin 50})$		
	so 2089 N (4 s. f.)	A1	cao
		5	
(iii)	Resolve $\rightarrow$ $X - T\cos50 = 0$	M1	Resolving horiz. Allow sign error. T must be resolved, allow $s \leftrightarrow c$
	so X = 1342.55….		
	= 1343 (4 s. f.)	F1	FT **their** T only. Allow 1600cot50
	Resolve $\downarrow$ $Y - T\sin50 + 600 = 0$	M1	NB other methods possible
	so Y = 1000	F1	FT **their** T only
	Method for either R or α	M1	M dependent on attempts at X and Y using moments/resolution
	$R=\sqrt{1600^2\cot^2 50+1000^2}$ = 1674.05..		
	so 1674 (4 s. f.)	F1	FT **their** X and Y Numerical value only
	$\alpha=\arctan\dfrac{1000}{1600\cot 50}$		
	α = 36.6804… so 36.68° (4 s. f.)	F1	FT **their** X and Y Numerical value only Accept 36.67
		7	
(iv)	Angle GAP is α above so 36.68° (4 s. f.)	B1	
	Weight, T and R are the only forces acting on the beam which is in equilibrium. Hence they are concurrent. Or geometrical calculation	E1	Must be clear
		2	
		17	

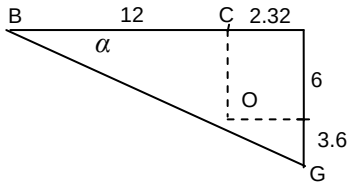
Q 3		mark	notes
(i)	$10\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = 4\begin{pmatrix}-\frac{1}{2}\\ 2\end{pmatrix} + 2\begin{pmatrix}\frac{1}{2}\\ 3\end{pmatrix} + \begin{pmatrix}1\frac{1}{2}\\ 3\frac{1}{2}\end{pmatrix} + 3\begin{pmatrix}2\frac{1}{2}\\ 2\frac{1}{2}\end{pmatrix}$	M1	Correct method clearly indicated for x or y component.
		B1	If 2D method, at least 1 mass + cm correct for a region. If separate cpts, at least 2 mass + cm correct for one of the cpts
	$= \begin{pmatrix}-2+1+1\frac{1}{2}+7\frac{1}{2}\\ 8+6+3\frac{1}{2}+7\frac{1}{2}\end{pmatrix} = \begin{pmatrix}8\\ 25\end{pmatrix}$	E1	Working shown. Either expression shown oe
	so $\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = \begin{pmatrix}0.8\\ 2.5\end{pmatrix}$ and c.m. is (0.8, 2.5)	E1	Both
		4	
(ii)	c.w. moments about J $3.2\times1.8 - T_H \times 4 = 0$	B1	Use of 1.8 oe
		M1	A moments equation with all relevant forces. Allow use of 10 instead of 3.2
	so $T_H = 1.44$ and the force at H is 1.44 N	A1	
	Resolving ↑	M1	Or moments again
	force at J is 3.2 – 1.44 = 1.76 N	F1	Only FT if positive final answer
		5	
(iii)	below		

(iii)	$10\begin{pmatrix}\bar{x}\\ \bar{y}\\ \bar{z}\end{pmatrix} = 4\begin{pmatrix}0\\ 2\\ \frac{1}{2}\end{pmatrix} + 2\begin{pmatrix}\frac{1}{2}\\ 3\\ 0\end{pmatrix} + 2\begin{pmatrix}2\\ 3\frac{1}{2}\\ 0\end{pmatrix} + 2\begin{pmatrix}2\frac{1}{2}\\ 3\\ -1\end{pmatrix}$	M1	Dealing with 3D
		B1	Dealing correctly with one folded part
		B1	Dealing with the other folded part
	$= \begin{pmatrix}0+1+4+5\\ 8+6+7+6\\ 2+0+0-2\end{pmatrix} = \begin{pmatrix}10\\ 27\\ 0\end{pmatrix}$	E1	Working shown. Either expression shown oe
	so $\begin{pmatrix}\bar{x}\\ \bar{y}\\ \bar{z}\end{pmatrix} = \begin{pmatrix}1\\ 2.7\\ 0\end{pmatrix}$ and c.m. is (1, 2.7, 0)	E1	All three components
		5	
(iv)		B1	Recognising that cm is vertically below O (may be implied)
	Let angle IOG be θ	B1	Correctly identifying the angle
	$\tan\theta = \frac{1}{2.7}$	M1	Accept $\tan\theta = \frac{2.7}{1}$ oe
	so angle is 20.323... so 20.3° (3 s. f.)	A1	Do NOT isw
		4	
		18	

Q 4		mark	notes
(a)	$\frac{1}{2}\times 80\times\left(6^2-V^2\right)$	M1	WE equation. Allow GPE OR init KE term omitted or wrong. Allow sign errors. There must be 3 terms one of which is the WD term
	= 80 × 9.8 × 1600 – 1300000	B1	KE terms correct (accept $40 \times (V^2 - 6^2)$)
		B1	GPE term. Allow sign error
		A1	All terms present. Accept only sign errors, but not the 1300000 and 80x9.8x1600 terms with same sign
	so V = 34.29285… so 34.3 m s^{-1}, (3 s. f.)	A1	Cao accept $14\sqrt{6}$
		5	
(b) (i)	N2L up the slope. Driving force is S N		
	S – 1150 – 800 × 9.8 × 0.1 = 800 × 0.25	M1	N2L. Allow either resistance or weight cpt omitted. Allow weight not resolved and sign errors.
		B1	RHS correct
		M1	Attempt at weight cpt ($800g\sin\theta$ is sufficient) Allow missing $\boldsymbol{g}$
		A1	Weight cpt correct (numerical) May be implied
	S = 2134	E1	
	Power is 2134 × 8	M1	Use of $P = Fv$
	= 17072 so 17.1 kW (3 s. f.)	A1	
		7	
(ii)	Let resistance on sledge be F N		
	N2L up slope for sledge		
	900 – F – 300 × 9.8 × 0.1 = 300 × 0.25	M1	Need non-zero accn, correct mass and 900. Allow weight missing or unresolved and allow sign errors. Do not award if 2134 included
	so F = 531	A1	
	normal reaction is $300g\cos\theta$	B1	
	Use $\cos\theta = \sqrt{0.99}$ or cos5.7	B1	In context
	$\mu = \frac{531}{300\times 9.8\times\sqrt{0.99}}$	M1	Use of $F = \mu R$ for any F and R but not F=900
	= 0.181522… so 0.182 (3 s. f.)	A1	cao
		6	
		18	

Question			Answer	Marks	Guidance
1	(a)	(i)	KE change: $\frac{1}{2}\times 0.6\times\left(7.5^2-5.5^2\right)$ = 7.8 J GPE change: 0.6 × 9.8 × 1.5 = 8.82 J	M1 A1 B1 **[3]**	Difference of two KE terms Allow –8.82J
1	(a)	(ii)	*W* is work done against resistance 7.8 = 8.82 – *W* so *W* = 1.02 J	 M1 A1 **[2]**	 W–E all terms. Allow sign errors FT (i) only. Also FT only if mod (their KE) < mod (their PE) –1.02 gets M1A0; 16.62 gets M1A0
1	(a)	(iii)	Average resistance is *F* so *F* × 1.5 = 1.02 so *F* = 0.68 Power is 0.68 × 5.5 = 3.74 so 3.74 W	 M1 A1 M1 A1 **[4]**	 Use of WD = *Fs* OR find *a* = 8.667 and use F = 0.6*g* – 0.6 × 8.667 May be implied. FT (ii) Use of *P* = *Fv* any calculated F cao
1	(b)	(i)	*R* = *mg*cos 40 F_{max} = *mg*sin 40 $F_{max} = \mu R$ so $\mu = \frac{mg\sin 40}{mg\cos 40} = \tan 40$	B1 B1 M1 E1 **[4]**	Seen or implied Seen or implied Use of $F = \mu R$: substitute *F* and *R* This is the minimum amount of working needed to earn the E1 Must see explicit evidence of method Note: *g* omitted, treat as MR
1	(b)	(ii)	**EITHER** tan 40 × 0.8 × 9.8 × cos 20 × 3 (= 18.545) (+)0.8 × 9.8 × 3 sin 20 (= 8.044) = 26.5897… so 26.6 J (3 s.f.)	 B1 M1 B1 M1 A1	 Use of $F_{max} = \mu R$ with tan 40 and cos 20 Use of WD = *Fs* NOTE: This mark may be awarded here or for use in PE term Use of *mgh* Allow sin ↔ cos interchange Two relevant terms added Cao Allow 26.7 Allow 27 Omission of *g* can get B0M1B1M1A0

Question			Answer	Marks	Guidance
			OR		
			tan 40 × 0.8 × 9.8 × cos 20 (= 6.182)	B1	Use of $F_{max} = \mu R$ with tan 40 and cos 20
			(+) 0.8 × 9.8 × sin 20 (= 2.68)	B1	Allow $\sin \leftrightarrow \cos$ interchange
			(= 8.8632444…)	M1	Two relevant forces added
			WD is 3 × 8.8632444…	M1	Use of WD = *Fs* (for at least one of forces)
			= 26.5897… so 26.6 J (3 s.f.)	A1 **[5]**	cao Omission of *g* can get B0B1M1M1A0
2	(i)		a.c. moments about B		
			$10T_C - 15 \times 2 = 0$	M1	Moments with all forces present, no extra forces.
			so $T_C = 3$. Tension at C is 3 N	A1	
			$\uparrow\ T_C + T_B - 15 = 0$	M1	May take moments again
			so $T_B = 12$. Tension at B is 12 N	F1 **[4]**	
2	(ii)		a.c. moments about A		
			$25T\sin 30 - 15 \times 17 = 0$	M1	Attempt at moments with resolution; allow $\cos \leftrightarrow \sin$ error. All forces present, no extra forces
			so $T = 20.4$	A1	cao
			At A Let force $\uparrow$ be Y N		
			$\uparrow\ Y + T\sin 30 - 15 = 0$ so $Y = 4.8$	B1	FT (can take moments about C)
			$\rightarrow X = T\cos 30 = 17.6669\ldots$ N	B1	FT Need not be evaluated
			$\sqrt{4.8^2 + (T\cos 30)^2}$	M1	
			= 18.3073755… so 18.3 N (3 s.f.)	A1 **[6]**	cao
2	(iii)		Let force be *P*.		
			a.c. moments about D.		
			$8 \times 15 - 12 \times P = 0$	M1	Moments about *D* with all forces present, no extra forces
			so $P = 10$ on point of tipping	A1	cao
			Using $F_{max} = \mu R$ on point of slipping	M1	
			with $R = 15$	B1	
			gives $F_{max} = 0.65 \times 15 = 9.75$	A1	cao
			so slips first	E1 **[6]**	cao and WWW

Question			Answer	Marks	Guidance
3	(a)	(i)		B1	Correctly identifying the position of the c.m of triangle EFH (10, –4)
			$300\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = 72\begin{pmatrix}-6\\ 3\end{pmatrix} + 192\begin{pmatrix}4\\ -6\end{pmatrix} + 36\begin{pmatrix}10\\ -4\end{pmatrix}$	M1	A systematic method for at least 1 cpt
				B1	*Either* all x or all y values correct *or* 2 vector terms correct *or* allow one common error in both components, e.g. one wrong mass, misunderstanding of c.m. of triangle
			$\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = \begin{pmatrix}696\\ -1080\end{pmatrix}$		
			so $\bar{x} = 2.32$	A1	
			$\bar{y} = -3.6$	A1	Allow FT for either if only error is common to both
				[5]	
3	(a)	(ii)			
			centre of mass is at G		
				M1*	Identifying correct angle. May be implied
				B1	At least 1 relevant distance found. FT (i)
			tan $\alpha = \frac{9.6}{14.32}$	M1dep*	Use of arctan $\frac{9.6}{14.32}$ or arctan $\frac{14.32}{9.6}$ o.e.
			so $\alpha = 33.8376...$ so 33.8° (3 s.f.)	A1	cao or 180° – 33.8°
				[4]	
3	(b)	(i)	Marking given tension and thrust	B1	Each labelled with magnitude and correct direction
			Marking all other forces internal to rods acting on A, B and C (as T or C)	B1	Need ALL forces at *A*, *B* and *C*. Need pairs of arrows on *AB*, *AC* and *BC*
				[2]	

Question			Answer	Marks	Guidance
3	(b)	(ii)	Equilibrium at A ↑		
			$T_{AB}\cos 30 - 18 = 0$	M1	Equilibrium at one pin-joint
			$T_{AB} = 12\sqrt{3}$. Force in AB: $12\sqrt{3}$ N (T)	A1	20.8 Sign consistent with tension on their diagram
			A ←		
			$T_{AC} + T_{AB}\cos 60 + 5 = 0$	M1	
			$T_{AC} = -(5 + 6\sqrt{3})$.		–15.39
			Force in AC: $(5 + 6\sqrt{3})$ N (C)	F1	FT their T_{AB}
			At B in direction AB		
			$T_{BR}\cos 60 - T_{AB} = 0$		
			so $T_{BR} = 24\sqrt{3}$	M1	Allow FT Other methods are possible, but award this M1 only for a complete method that would lead to T_{BC}
			At B in direction BC		
			$T_{BC} - T_{BR}\cos 30 = 0$		
			$T_{BC} = 36$. Force in BC: 36 N (T)	F1	
				A1	cao WWW T/C all correct
				[7]	
4	(i)		$26t = 3\times 13$	M1	Use of $Ft = m(v - u)$ or N2L to find a (= 26/3) and use $v = u + at$
			t = 1.5 so 1.5 s	A1	cao
				[2]	
4	(ii)		PCLM		
			$10 \times 0 + 3 \times 13 = 10v_Q + 3v_P$	M1	Use of PCLM
			$39 = 10v_Q + 3v_P$	A1	Any form
			NEL		
			$\frac{v_Q - v_P}{0 - 13} = -e$	M1	Use of NEL. Allow sign errors but not inversion
			$v_Q - v_P = 13e$	A1	Any form
				M1	Eliminating one of v_Q or v_P OR allow substitution of given result in one equation and check both answers in other equation
			$v_Q = 3(1 + e)$	B1	cao; aef
			$v_P = 3 - 10e$	E1	Properly shown
				[7]	

Question			Answer	Marks	Guidance
4	(iii)		Need $v_P < 0$ so $3 - 10e < 0$ Hence $\frac{3}{10} < e \leq 1$	M1 A1 **[2]**	Accept $\leq$ cao (Allow $e \leq 1$ omitted) Correct answer www gets 2/2
4	(iv)		When $e > \frac{3}{10}$, its speed is $10e - 3$ We require $(10e - 3) > 3(1 + e)$ so $7e > 6$ and so $\frac{6}{7} < e \leq 1$	M1 M1 A1 A1 **[4]**	 FT their v_Q SC1 for $(3 - 10e) > \pm 3(1 + e)$ FT their v_Q cao. Allow $e > \frac{6}{7}$ (0.857) Correct answer www gets 4/4
4	(v)		**Either** $v_Q = 4.5$ and $v_P = -2$ When they collide the speed of Q is -4.5 and of P is 2 PCLM $10 \times -4.5 + 3 \times 2 = 13V$ so $V = -3$ and velocity is -3 m s^{-1}	M1 M1 M1 A1 **[4]**	Substitute $e = 0.5$; FT their v_Q Change signs of their velocities Use of PCLM Allow sign errors cao; OR 3 m s^{-1} to the right or use argument about final LM is –ve of original LM
			Or $10(-3(1+e)) + 3(10e - 3) = 13V$ $-39 = 13V$ so $V = -3$ and velocity is -3 m s^{-1}	 M1 M1 M1 A1 **[4]**	 Use of PCLM; Allow sign errors ; FT their v_Q Change signs of their velocities Simplify cao; OR 3 m s^{-1} to the right
4	(vi)		$3(-3-2) = -15$ N s	B1 **[1]**	FT $3(\text{their}(v) - 2)$ Using $10(-3 + 4.5) = 15$ gets B0 until it leads to correct answer

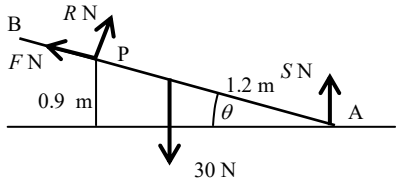
Question			Answer	Marks	Guidance
1	(a)		Take **j** north and **i** east velocity: before $5\mathbf{i} - 5\sqrt{3}\mathbf{j}$ (after $3\mathbf{i}$) $\mathbf{I} = m(\mathbf{v} - \mathbf{u})$ so $\mathbf{I} = 120\,000\,000(-2\mathbf{i} + 5\sqrt{3}\mathbf{j})$ Modulus is $120\,000\,000 \times 8.888194\ldots$ $= 1.0665\ldots \times 10^9$ N s so 1.07×10^9 N s (to 3 s. f.)	B1 M1 A1 A1 **[4]**	Resolving initial velocity (may be implied). Allow $5\mathbf{i} + 5\sqrt{3}\mathbf{j}$ **or** $5\mathbf{i} - 5\sqrt{3}\mathbf{j}$ oe May be implied Allow if only one direction considered or both combined without vectors. Must include an attempt to resolve 10 Accept mass of 120 000 cao Alternative method using a diagram, cos and sine rules
1	(b)	(i)	PCLM $0.4 \times 6 = 0.5\ V$ $V = 4.8$ ms^{-1} direction is opposite to that of P	M1 A1 **[2]**	Implied by 4.8 or -4.8 Allow -4.8 as the speed
1	(b)	(ii)	P travels $6 \times \frac{2}{3} = 4$ m before the collision so Q travels $4 - 2 \times 0.75 = 2.5$ m in $\frac{2}{3}$ s $2.5 = \frac{(4.8 + v_Q)}{2} \times \frac{2}{3}$ Hence $v_Q = 2.7$ ms^{-1}	B1 B1 M1 E1 **[4]**	Or find $t = \frac{13}{24}$ for time from edge to collision AND $d = 3.25$ $3.25 - 0.75 = 2.5$ Using appropriate *suvat* FT their 2.5 Answer given

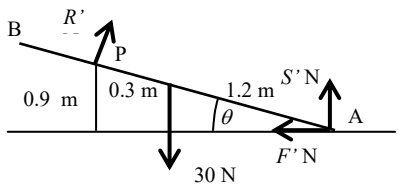
Question			Answer	Marks	Guidance
1	(b)	(iii)	Suppose friction on Q is F $-F \times \frac{2}{3} = 0.5(2.7 - 4.8)$ so $F = 1.575$ $1.575 = \mu \times 0.5 \times 9.8$ $\mu = 0.32142...$ so 0.321 (3 s. f.)	 B1 M1 A1 A1 **[4]**	 Using $Ft = m(v - u)$ or find $a = -3.15$ and use $F = ma$. FT **their** 2.7 $F = \mu R$ R correct (4.9) cao Note: F and R need not be explicit: $F=ma$ and $R=mg$ give $\mu = \frac{a}{g}$ (M1A1). Find $a = -3.15$(B1) gives 0.321 (A1)
1	(b)	(iv)	Let the speeds after be V_P and V_Q. PCLM $0.4 \times 6 + 0.5 \times 2.7 = 0.4\ V_P + 0.5 V_Q$ so $4V_P + 5V_Q = 37.5$ NEL $\frac{V_Q - V_P}{2.7 - 6} = -\frac{1}{8}$ so $V_Q - V_P = 0.4125$ $V_Q = 4.35$ so 4.35 m s^{-1}	 M1 A1 M1 A1 A1 **[5]**	 PCLM. FT **their** 2.7 from (ii). Award M1A0 for use of their 4.8 from (i) instead of 2.7 FT **their** 2.7 from (ii). Accept any form NEL. FT **their** 2.7 from (ii). Award M1A0 for use of their 4.8 from (i) instead of 2.7 FT **their** 2.7 from (ii). Accept any form cao

Question			Answer	Marks	Guidance
2		(i)	$455 = 0.01\times 80 \times 9.8 \times \cos 4 \times 12 + WD$ $WD = 361.149\ldots$ so 361 J (3 s. f.)	M1 B1 A1 A1 **[4]**	Use of Fx rolling friction force correct (7.82) 12 not needed All correct terms in an equation (allow sign errors) cao SC B1B1 for final answer 30.1 seen
2		(ii)	$0.5 \times 80 \times v^2 - 0.5 \times 80 \times 2^2$ $= 80 \times 9.8 \times 12 \times \sin 4 - 455$ $v = 3.0052..$ so 3.01 m s^{-1} (3 s. f.)	M1 B1 B1 A1 A1 **[5]**	Use of W-E equation. Must include GPE, at least one KE and the WD Either KE term GPE term (656.27) All correct terms in an equation (allow sign errors) cao
2		(iii)	Using N2L with driving force S $S - (15 + 0.01 \times 80 \times 9.8 \times \cos 5)$ $- 80 \times 9.8 \times \sin 5$ $= 80 \times 1.5$ $S = 211.1402\ldots$ $405 = Sv$ so $v = 1.918\ldots$ so 1.92 m s^{-1} (3 s. f.)	M1 B1 B1 A1 A1 M1 A1 **[7]**	N2L with at most one force term missing Both resistance terms seen (15 and 7.81) Condone wrong sign (68.33) All correct terms present; allow sign errors May be implicit Use of Power = Sv with any S calculated using N2L FT their S Note: missing out one term in N2L can earn 4/7 (M1B1B0A0A0M1A1)

Question			Answer	Marks	Guidance
3		(i)	$15\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = 2\begin{pmatrix}-1\\ 2.5\end{pmatrix} + 9\begin{pmatrix}1.5\\ 1.5\end{pmatrix} + 2\begin{pmatrix}4\\ 0.5\end{pmatrix} + 2\begin{pmatrix}4.5\\ -1\end{pmatrix}$	M1	A systematic method for at least 1 cpt
				A1	*Either* all x or all y values correct *or* 2 vector terms correct on RHS
				A1	Completely correct expressions seen for all components
			$= \begin{pmatrix}28.5\\ 17.5\end{pmatrix}$		Need not be explicit
			so $\bar{x} = 1.9$	A1	Accept any form
			$\bar{y} = \frac{7}{6}$	A1	Accept any form (1.17, 1.2) but not 1.16
				[5]	
3		(ii)	Referred to Fig 3.1 with c.m. G, G is 2 + 1.9 to the right of K and $3 - \frac{7}{6} = \frac{11}{6}$ below K	B1	FT from (i) May be implied
			When hanging, G is vertically below K	B1	May be implied
			Angle is $\arctan\left(\frac{\frac{11}{6}}{3.9}\right)$	M1	o.e. FT their values but must be attempting to find the appropriate angle
			= 25.1775… so 25.2° (3 s. f.)	A1	cao
				[4]	
3		(iii)	New c.m. is at (1.5, 1.5) & mass of object is 0.3 kg	B1	Do not penalise below if mass of lamina is taken to be 15
			For $\bar{x}$:	M1	Recognising need first to produce an equation in terms of m for the x-component
			$(0.3 + m) \times 1.5 = 0.3 \times 1.9 + m \times 0$	M1	Must be 0 not x
			$m = 0.08$	A1	FT their 1.9 from (i). If 15 used, accept $m = 4$
			For $\bar{y}$: $(0.3 + 0.08) \times 1.5 = 0.3 \times \frac{7}{6} + 0.08y$	M1	
			so particle should be at (0, 2.75)	A1	cao. Condone no reference to x component. Allow obtained using 15. Allow 2.74, 2.7375 (from 1.17), 2.775 (from 1.16), 2.625 (from 1.2)
				[6]	

Question			Answer	Marks	Guidance
3		(iv)	The c.m. must lie inside KFDL as seen in the plan in Fig. 3.2	E1	Some indication of this is what is required. Accept a closed region with KF correct and sides parallel to KL and FD.
				E1	Correct. Accept freehand.
			The c.m. shown to be in this region	M1	Recognition that com is at (1.7, their $\bar{y}$) and is related to their critical region even if region is incorrect or calculation with at least 1 correct equation ($3y + 2x = 9$ and $3y + 4x = 6$) Do NOT award simply for a recalculation of com as (1.7, 7/6)
				E1	Properly established including a statement. (i.e. correct region, correct com marked and statement of stability)
				[4]	

Question			Answer	Marks	Guidance
4		(i)	Let vertical force from support be R N and tension in string T N. moments about A $30 \times 0.5 \times 2.4 - R \times (2.4 - 0.6) = 0$ $R = 20$ so force from block is 20 N $\uparrow\ R + T - 30 = 0$ $T = 10$ so tension is 10 N	 M1 A1 M1 F1 **[4]**	 Use of moments with all relevant moments attempted (FT from T if T found first) FT from R
4	(ii)	(A)	 $\rightarrow\ R\sin\theta - F\cos\theta = 0$ As on the point of slipping $F = 0.6R$ so $R\sin\theta = 0.6R\cos\theta$ so $\sin\theta = 0.6\cos\theta$ and $\tan\theta = 0.6$ OR $F = mg\sin\theta - S\sin\theta$ $R = mg\cos\theta - S\cos\theta$ As on the point of slipping $F = 0.6R$ $\frac{F}{R} = \frac{(mg - S)\sin\theta}{(mg - S)\cos\theta} = \frac{\sin\theta}{\cos\theta}$ $\tan\theta = 0.6$	 M1 A1 M1 M1 E1 **[5]** M1 A1 M1 M1 E1 **[5]**	 Must be consideration of a force at A F and R must be identified, e.g. on a diagram Complete argument Resolve parallel and perpendicular to rod Both correct F and R must be identified, e.g. on a diagram Divide factored expressions with S included

Question			Answer	Marks	Guidance
4	(ii)	(*B*)			
			AP is 1.5 gives sin $\theta = 0.6$ or cos $\theta = 0.8$	B1	oe. or $\theta = 36.9^\circ$
			c. w. moments about A		
			$1.5R' - 30 \times 1.2 \times \cos\theta = 0$	M1	Moments and all terms present. Accept $\cos\theta$ or 0.8
			R' = 19.2 so 19.2 N	A1	cao
			$\uparrow \quad S' + R'\cos\theta - 30 = 0$	M1	An equilibrium equation with all relevant forces, resolved appropriately, e.g. $R' + S'\cos\theta = 30\cos\theta + F'\sin\theta$. Allow $\sin \leftrightarrow \cos$
			(S' = 14.64)	A1	Correct equation involving only S'. Numerical answer not required
			$\rightarrow \quad R'\sin\theta - F' = 0$	M1	Second equilibrium equation with all relevant forces, resolved appropriately. e.g. $F'\cos\theta + S'\sin\theta = 30\sin\theta$. Allow $\sin \leftrightarrow \cos$
			(F' = 11.52)	A1	Correct equation involving only F'. Numerical answer not required
			$\mu = \dfrac{11.52}{14.64}$	M1	Use of $F' = \mu S'$ for a calculated F' and S'
			= 0.78688… so 0.787 (3 s. f.)	A1	cao
				[9]	

Question			Answer	Marks	Guidance
1	(a)	(i)	$3 \times 4 + 21 \times 2 = 4U$ $4U = 54$ so $U = 13.5$ and speed is 13.5 m s^{-1}	M1 A1 **[2]**	Use of PCLM and $I = Ft$
			OR $21 = 4a : a = 5.25$ and $v = 3 + 2 \times 5.25$ speed is 13.5 m s^{-1}	M1 A1 **[2]**	Use of $F = ma$ and *suvat*
1	(a)	(ii)	Let V be the speed of S in direction PQ $54 - 2 \times 3 = (4 + 2)V$ $6V = 48$ so $V = 8$ and velocity is 8 m s^{-1} in direction PQ	 M1 E1 **[2]**	 PCLM for coalescence Answer given. Accept no reference to direction.
1	(a)	(iii)	Let velocities of R be u before and v after, both in the direction SR		
			$6 \times 8 + 4u = 6 \times 5 + 4v$	M1	Use of PCLM. Allow any sign convention. All masses and speeds must be correct.
			$v - u = 4.5$	A1	Any form.
			$\frac{v-5}{u-8} = -\frac{1}{4}$	M1	Use of NEL correct way up; allow sign errors
			$4v + u = 28$	A1	Any form signs consistent with PCLM eqn
			Solving $u = 2$ so 2 m s^{-1} in the direction SR	 A1	 cao **NOTE that a sign error in NEL leads to u =-2; this gets A0**
			$v = 6.5$ so 6.5 m s^{-1} in the direction SR	A1 **[6]**	cao. Withhold only 1 of the final A marks if the directions not clear. Directions can be inferred from a CLEAR diagram

Question			Answer	Marks	Guidance
1	(b)	(i)	Find v, the speed at which particle hits the plane		
			$\frac{1}{2} \times 0.2 \times v^2 - \frac{1}{2} \times 0.2 \times 5^2 = 0.2 \times 10 \times 10$	M1	Use of WE or *suvat* must use distance of 10 allow $g = 9.8$
			so $v^2 = 225$ and $v = 15$	A1	Answer not required ($v = 14.9$ if $g = 9.8$)
			$\cos\alpha = \frac{4}{5}$, $\sin\alpha = \frac{3}{5}$	B1	Use of either expression or use of 36.9°
			Let velocity after be at β to the plane		
			Parallel to the plane		
			$15\cos\alpha = 13\cos\beta$	M1	Attempt to conserve velocity component parallel to plane. Allow use of 5 instead of 15
			So $\cos\beta = \frac{12}{13}$ and $\beta = 22.61..$ so $22.6°$ (3 s. f.)	A1	($\beta = 23.8^\circ$ if g =9.8)
			Perpendicular to the plane: $13\sin\beta = e \times 15\sin\alpha$	M1	Attempt to use NEL perpendicular to plane: Allow use of 5 instead of 15 or use $\tan\beta = e\tan\alpha$
			$\sin\beta = \frac{5}{13}$	A1	o.e. find $\tan\beta = \frac{5}{12}$
			so $13\times\frac{5}{13} = 15\times\frac{3}{5}\times e$ and $e = \frac{5}{9}$	A1	cao Accept 0.56 ($e = 0.589$ if g =9.8)
				[8]	
			OR: First three marks as above	M1A1B1	
			Parallel to plane, $u_x = 15\cos\alpha (= 12)$ and $v_x = u_x (= 12)$	M1	Attempt to conserve velocity component parallel to plane. Allow use of 5 instead of 15
			$\cos\beta = \frac{v_x}{v} = \frac{12}{13}$ $\quad \beta = 22.6^\circ$	A1	
			Perpendicular to plane, $u_y = 15\sin\alpha (= 9)$ and $v_y = eu_y (= 9e)$	M1	Attempt to use NEL perpendicular to plane. Allow use of 5 instead of 15
			$v_x^2 + v_y^2 = 13^2$	A1	Use Pythagoras' theorem for velocities after collision in attempt to find e
			$12^2 + (9e)^2 = 13^2$ so $e^2 = \frac{25}{81}$ $\quad e = \frac{5}{9}$	A1	
				[8]	

Question			Answer	Marks	Guidance
1	(b)	(ii)	Impulse is perp to plane with mod $0.2(13\sin\beta-(-15\sin\alpha))$ = 0.2(5 – (– 9)) = 2.8 N s	M1 A1 **[2]**	For use of $I = m(v - u)$ perp to the plane 0.2(5-9) gets M1A0 cao
2	(i)		WD is 800 × 9.8 × 6 + 400 × 6 J = 49 440 Power is 49440 ÷ 12 = 4120 W	M1 E1 M1 A1 **[4]**	WD as *Fd* Used in TWO terms Power is WD / Δt cao
2	(ii)		Power is (800 × 9.8 + 400) × 0.55 = 4532 W	M1 A1 A1 **[3]**	Power as *Fv* in one term All correct cao
2	(iii)		Let speed be *v* $\frac{1}{2}\times800v^2=800\times9.8\times3-400\times3$ $v^2=55.8$ so *v* = 7.4699… and speed is 7.47 m s^{-1} (3 s.f.)	M1 A1 A1 A1 **[4]**	Use of W-E equation Must include KE and at least one WD term Allow only sign errors All correct SC: Use of N2L and *suvat* : M1 Complete method A1 7.47 cao
2	(iv)		$\frac{1}{2}\times800\times\frac{v^2}{4}-\frac{1}{2}\times800\times v^2$ = (800 × 9.8 – 400) × 0.8 – WD WD is 22 692 so 22 700 J (3 s. f.)	M1 B1 B1 A1 A1 **[5]**	Use of W-E equation Must include 2 KE terms and a WD term Final KE term correct. FT their *v*. One correct WD term All terms present. Allow sign errors and FT their *v*. cao SC Use of N2L and *suvat*: Award maximum of B1 for 'Average force (28365) x 0.8'

Question			Answer	Marks	Guidance
3	(i)		c.w. moments about A		Condone using cm not m in moments in any part if consistent
			$60\cos 40\times 0.3 - 60\sin 40\times 0.1$	M1	oe e.g. $60(0.3-0.1\tan 40)\sin 50$ or $60\times\frac{1}{\sqrt{10}}\cos\left(90^\circ-\arctan 3+40^\circ\right)$ Method of dealing with moment of weight. Allow $\cos\leftrightarrow\sin$
				A1	Both weight terms correct. Allow wrong overall sign but not both terms with the same sign
			= 9.93207… so 9.93 N m (3 s. f.)	E1 **[3]**	
3	(ii)		$P\cos 40\times 0.2 - 9.93207... = 0$	M1	Moments of all relevant forces attempted. No extra terms. Allow $\cos\leftrightarrow\sin$
			P = 64.827… so 64.8 (3 s. f.)	A1 **[2]**	cao (64.813… if 9.93 used)
3	(iii)		a.c. moments about A to find NR, R, at B		
			$R\times 0.8 = 9.93$ or $R\times 0.8 + 60\sin 40\times 0.1 - 60\cos 40\times 0.3 = 0$	M1	Attempt to use moments to find R. Moments of all relevant forces attempted. No extra terms. Allow $\cos\leftrightarrow\sin$ Note that mmts about B can score M1 only if mmt of horiz compt of force at A is included. If R is taken as vertical, M0
			R = 12.4150…	A1	FT their moment of weight from (i) Not a required answer
			Resolve vertically		
			$Y - 60 + R\cos 40 = 0$	depM1	Note that the second M mark awarded in this part must be for a complete method to find Y:
			so Y = 50.489… so 50.5 N (3 s. f.)	A1 **[4]**	FT their calculated R

Question			Answer	Marks	Guidance
3	(iv)		resolve perp to plane		
			$R - 60\cos 40 - 200\sin 40 = 0$	M1	All terms present and no extra terms. Components of 60 and 200; allow cos ↔ sin
				A1	
			R = 174.52…		Not a required answer
			N2L up the plane		
			$200\cos 40 - F - 60\sin 40 = \frac{60}{9.8} \times 1.75$	M1	Use of N2L with all terms present and no extras. Components of 60 and 200; allow cos ↔ sin Allow use of 60 for mass
				B1	Use of mass not weight
				A1	FT use of weight and/or sign errors
			F = 103.927…	A1	All correct. Not a required answer
			As friction limiting $F = \mu R$ so		
			$\mu = \frac{103.927...}{174.520...}$	M1	FT their F and their R
			= 0.59550.. so 0.596 (3 s. f.)	A1	cao
				[8]	

Question			Answer	Marks	Guidance
4	(a)	(i)	Write $d = 0.8$		
			$(2.5+1.2+1.3+2.4)\times d\times\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix}$	M1	Method for c.m (length is 7.4 m, mass is 5.92 kg)
			$=2.5d\begin{pmatrix}1.2\\ -0.35\end{pmatrix}+1.2d\begin{pmatrix}2.4\\ -0.1\end{pmatrix}+1.3d\begin{pmatrix}1.8\\ 0.25\end{pmatrix}+2.4d\begin{pmatrix}1.2\\ 0\end{pmatrix}$	B1	One rod mass and cpts correct or if done by separate x and y equations 2 rod components and masses correct. (Allow length used instead of mass)
			OR: $(2+0.96+1.04+1.92)\times\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix}$		
			$=2\begin{pmatrix}1.2\\ -0.35\end{pmatrix}+0.96\begin{pmatrix}2.4\\ -0.1\end{pmatrix}+1.04\begin{pmatrix}1.8\\ 0.25\end{pmatrix}+1.92\begin{pmatrix}1.2\\ 0\end{pmatrix}$	B1	Another rod dealt with correctly or if done by separate x and y equations, the other equation attempted with 2 rod components and masses correct. (Allow length used instead of mass)
			$7.4\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix}=\begin{pmatrix}3+2.88+2.34+2.88\\ -0.875-0.12+0.325+0\end{pmatrix}=\begin{pmatrix}11.1\\ -0.67\end{pmatrix}$		
			OR:		
			$5.92\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix}=\begin{pmatrix}2.4+2.304+2.304+1.872\\ -0.7-0.096+0.26+0\end{pmatrix}=\begin{pmatrix}8.88\\ -0.536\end{pmatrix}$		
			$\bar{x}=1.5$	E1	Clearly shown, with at least one intermediate step
			$\bar{y}=-0.090540...=-0.0905$ (3 s. f.)	A1	Condone - 0.09
				[5]	

Question			Answer	Marks	Guidance
4	(a)	(ii)	EITHER: New c.m. has $\bar{x} = 1.2$ $(5.92 + m) \times 1.2 = 5.92 \times 1.5 + m \times 0$ $m = 1.48$	M1 M1 A1 **[3]**	Identifying and using a suitable condition. Complete method cao
			OR: Moment about any point is zero e.g. about S: $1.2mg = 0.3 \times 5.92g$ $m = 1.48$	M1 M1 A1 **[3]**	Identifying a suitable condition. Allow g omitted. Correct number of terms must be included cao
4	(b)	(i)	Consider the equilibrium at R Resolving horizontally gives $T_{QR} = 0$ Then resolving vertically gives $T_{OR} = 0$	 E1 E1 **[2]**	
4	(b)	(ii)	c.w. moments about O $120 \times 1 + 60 \times 2 = 3T$ so $T = 80$ Resolve to give $X = 80$ and $Y = 180$	 M1 A1 A1 **[3]**	 May also be argued by first considering internal forces FT $X = T$. Only Y =180 scores 0
4	(b)	(iii)		B1 **[1]**	All correct. Accept T, X and Y labelled but not substituted. Accept mixes of T and C. Require pairs of arrows with label on OQ, OP and PQ.
4	(b)	(iv)	Take angle OPQ as α At P $\downarrow$ $60 + T_{OP} \sin\alpha = 0$ $\sin\alpha = \frac{3}{\sqrt{13}}$: $\alpha = 56.3^\circ$ $T_{OP} = -\frac{60}{\sin\alpha} = -20\sqrt{13}$ so $20\sqrt{13}$ N (C) At P $\leftarrow$ $T_{QP} + T_{OP} \cos\alpha = 0$ so $T_{QP} = 40$ so 40 N (T)	 M1 A1 A1 M1 A1 **[5]**	Forces internal to the rods have been taken to be tensions. Equilibrium at ANY pin-joint (not R) Correct equation(s) that leads directly to finding T_{OP} or T_{QP} o.e. Accept 72.1 N A second equilibrium equation leading to a second internal force cao T/C correct for both rods