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	5
	or			
	+ 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