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} = μR 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

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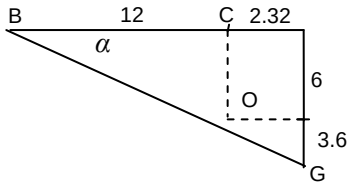
3	(a)	(i)	$300\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = 72\begin{pmatrix}-6\\ 3\end{pmatrix} + 192\begin{pmatrix}4\\ -6\end{pmatrix} + 36\begin{pmatrix}10\\ -4\end{pmatrix}$	B1 M1 B1	Correctly identifying the position of the c.m of triangle EFH (10, –4) A systematic method for at least 1 cpt *Either*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

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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