Q 1		mark		sub
(i)	before $v_2 \text{ m s}^{-1}$ $v_1 \text{ m s}^{-1}$			
	$10 \times 0.5 = 0.5v_2 + 29.5v_1$ $\frac{v_1 - v_2}{0 - 10} = -0.8$ $v_1 = 0.3 \text{ so } V_1 = 0.3$ $v_2 = -7.7 \text{ so } V_2 = 7.7 \text{ m s}^{-1}$ in opposite to original direction	M1 A1 M1 A1 A1 A1 F1	PCLM and two terms on RHS All correct. Any form. NEL Any form Speed. Accept ±. Must be correct interpretation of clear working	7
(ii) (A)	$10 \times 0.5 = 30V$ 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)	before after 2 m s^{-1} 2 m s^{-1} 39.5 kg $0.5 kgu$	B1		
	$2 \times 40 = 0.5u + 39.5V$ u - V = 10 Hence $V = 1.875$	M1 A1 B1 A1 17	PCLM, masses correct Any form May be seen on the diagram. Accept no reference to direction.	5

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(i) $X = R \cos 30$ $Y + R \sin 30 = L$ (2)(i)B1 M1Attempt at resolution3(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 B1Subst their $R = 2L$ into their (1) or (2) E1 Clearly shown4(iii)(Below all are taken as tensions e. g. T_{xn} in ABB1 B1Attempt at all forces (allow one omitted) Correct. Accept internal forces set as tensions or thrusts or a mix2(iv) \downarrow A $T_{xD} \cos 30 (-Y) = 0$ so $T_{x0} = 0$ M1 E1Vert equilibrium at A attempted. $Y = 0$ need not be explicit(iv) \downarrow A $T_{xD} \cos 30 (-Y) = 0$ so $T_{x0} = 0$ M1 E1Vert equilibrium at A attempted. $Y = 0$ need not be explicit(iv) \downarrow A $T_{xD} \cos 30 (-Y) = 0$ so $T_{x0} = 0$ M1 E1At least one relevant equilib attempted(v)Consider the equilibrium at pin-joints A $\rightarrow T_{x0} - S = \sqrt{3}L$ $\sqrt{3} (-2) (-2) (-2) (-2) (-2) (-2) (-2) (-2)$	Q 2		mark	comment	sub
	(i)		M1	Attempt at resolution	3
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	(ii)	ac moments about A $R - 2L = 0$	B1		
$Y + 2L \times \frac{1}{2} = L$ so $Y + L = L$ and $Y = 0$ E1Clearly shown4(iii)(Below all are taken as tensions e. g. T_{AB} in AB)B1Attempt at all forces (allow one omitted) Correct. Accept internal forces set as tensions or thrusts or a mix2(iv) \downarrow A $T_{AD} \cos 30 (-Y) = 0$ so $T_{AD} = 0$ M1Vert equilibrium at A attempted. $Y = 0$ need not be explicit2(iv) \downarrow A $T_{AD} \cos 30 (-Y) = 0$ so $T_{AD} = 0$ M1Vert equilibrium at A attempted. $Y = 0$ need not be explicit(v)Consider the equilibrium at pin-joints A \rightarrow $T_{AB} - X = 0$ so $T_{AB} = \sqrt{3}L$ (T) B1B1(T) not required(v)Consider the equilibrium at $j_{13} = \sqrt{3}L$ (T) B1B1Or equiv from their diagram FT their T_{CR} or equiv but do not condone inconsistent signs even if right answer obtained. (T) not required. Or equivify from their diagram FT their T_{CR} or equiv but do not condone inconsistent signs even if right answer obtained. (T) not required. F1B1(vi) \downarrow B $T_{BD} \cos 30 + T_{BE} \cos 30 = 0$ so $T_{BD} = -T_{BE}$ so mag equal and opp senseM1Resolve vert at B A statement requiredA statement required2			M 1	Subst their $R = 2L$ into their (1) or (2)	
LLHHHHH(iii)(Below all are taken as tensions e. g. T_{AB} in AB)B1 B1Attempt at all forces (allow one omitted) Correct. Accept internal forces set as tensions or thrusts or a mix2(iv) \downarrow A $T_{AD} \cos 30 (-Y) = 0$ so $T_{AD} = 0$ M1 E1Vert equilibrium at A attempted. $Y = 0$ need not be explicit2(iv) \downarrow A $T_{AD} \cos 30 (-Y) = 0$ so $T_{AD} = 0$ M1 E1Vert equilibrium at A attempted. $Y = 0$ need not be explicit2(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) B1B1 B1 B1 C \downarrow $L + T_{CE} \cos 60 = 0$ so $T_{BC} = -\left(-\frac{2\sqrt{3}L}{3} \right) \times \frac{1}{2} = \frac{\sqrt{3}L}{3}$ (T)B1 B1		$X = 2L\frac{\sqrt{3}}{2} \text{ so } X = \sqrt{3}L$	E1	Clearly shown	
		$Y + 2L \times \frac{1}{2} = L$ so $Y + L = L$ and $Y = 0$	E1	Clearly shown	4
$ \begin{array}{ c c c c c } &\downarrow A & T_{AD}\cos 30 & (-Y) = 0 & & M1 \\ & so & T_{AD} = 0 & & E1 & & ed not be explicit & & 2 \\ \hline \\ & so & T_{AD} = 0 & & E1 & & ed not be explicit & & 2 \\ \hline \\ & & ed not be explicit & & E1 & & ed not be explicit & & 2 \\ \hline \\ & & & ed not be explicit & & E1 & & ed not be explicit & & 2 \\ \hline \\ & & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & \\ & & & & & \\ & & & & & & & \\ & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & $	(iii)			Correct. Accept internal forces set as	
$A \rightarrow T_{AB} - X = 0 \text{ so } T_{AB} = \sqrt{3}L (T) \qquad B1 (T) \text{ not required} \\ C \downarrow L + T_{CE} \cos 30 = 0 \\ \text{so } T_{CE} = \frac{-2L}{\sqrt{3}} \text{ so } \frac{2L}{\sqrt{3}} \left(= \frac{2L\sqrt{3}}{3} \right) (C) \\ C \leftarrow T_{BC} + T_{CE} \cos 60 = 0 \\ \text{so } T_{BC} = -\left(-\frac{2\sqrt{3}L}{3} \right) \times \frac{1}{2} = \frac{\sqrt{3}L}{3} (T) \\ B1 \qquad B1 \qquad Accept any form following from their equation. (C) not required. \\ Or equiv from their diagram \\ FT their T_{CE} or equiv but do not condone inconsistent signs even if right answer obtained. (T) not required. \\ T and C consistent with their answers and their diagram \\ F1 \qquad Tand C consistent with their answers and their diagram \\ F1 \qquad B \qquad T_{BD} \cos 30 + T_{BE} \cos 30 = 0 \\ \text{so } T_{BD} = -T_{BE} \text{ so mag equal and opp sense} \\ B1 \qquad A1 \qquad Resolve vert at B \\ E1 \qquad A statement required \\ A \qquad 2 \qquad A \qquad$	(iv)				2
$\begin{bmatrix} C \downarrow L + T_{CE} \cos 30 = 0 \\ \text{so } T_{CE} = \frac{-2L}{\sqrt{3}} \text{ so } \frac{2L}{\sqrt{3}} \left(= \frac{2L\sqrt{3}}{3} \right) \text{ (C)} \\ \text{B1} \\ \text{so } T_{CE} = \frac{-2L}{\sqrt{3}} \text{ so } \frac{2L}{\sqrt{3}} \left(= \frac{2L\sqrt{3}}{3} \right) \text{ (C)} \\ \text{B1} \\ \text{so } T_{BC} + T_{CE} \cos 60 = 0 \\ \text{so } T_{BC} = -\left(-\frac{2\sqrt{3}L}{3} \right) \times \frac{1}{2} = \frac{\sqrt{3}L}{3} \text{ (T)} \\ \text{B1} \\ \text{so } T_{BC} = -\left(-\frac{2\sqrt{3}L}{3} \right) \times \frac{1}{2} = \frac{\sqrt{3}L}{3} \text{ (T)} \\ \text{B1} \\ \text{F1} \\ $	(v)	Consider the equilibrium at pin-joints	M1	At least one relevant equilib attempted	
$so T_{CE} = \frac{-2L}{\sqrt{3}} so \frac{2L}{\sqrt{3}} \left(= \frac{2L\sqrt{3}}{3} \right) (C)$ $C \leftarrow T_{BC} + T_{CE} \cos 60 = 0$ $so T_{BC} = -\left(-\frac{2\sqrt{3}L}{3} \right) \times \frac{1}{2} = \frac{\sqrt{3}L}{3} (T)$ $B1$ $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) $V = B T_{BD} \cos 30 + T_{BE} \cos 30 = 0$ $so T_{BD} = -T_{BE} so mag equal and opp sense$ $M1$ $Resolve vert at B$ $Accept any form following from their equired 7 $		A \rightarrow $T_{AB} - X = 0$ so $T_{AB} = \sqrt{3}L$ (T)	B1	(T) not required	
$\begin{array}{cccc} C &\leftarrow & T_{\rm BC} + T_{\rm CE}\cos 60 = 0 \\ {\rm so} & T_{\rm BC} = -\left(-\frac{2\sqrt{3}L}{3}\right) \times \frac{1}{2} = \frac{\sqrt{3}L}{3} ({\rm T}) \end{array} \begin{array}{c} {\rm B1} & {\rm equation. (C) not required.} \\ {\rm B1} & {\rm Green their diagram} \\ {\rm FT their } & T_{\rm CE} \mbox{ or equiv but do not condone} \\ {\rm B1} & {\rm inconsistent signs even if right answer} \\ {\rm obtained. (T) not required.} \\ {\rm T} & {\rm and C \ consistent with their answers and} \\ {\rm their \ diagram} \end{array} \end{array} \begin{array}{c} 7 \\ 7 \\ \hline \end{array}$			B1	Or equiv from their diagram	
C \leftarrow $T_{BC} + T_{CE} \cos 60 = 0$ soB1Or 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 diagramP1(vi) \downarrow B $T_{BD} \cos 30 + T_{BE} \cos 30 = 0$ soM1Resolve vert at B E17(vi) \downarrow B $T_{BD} \cos 30 + T_{BE} \cos 30 = 0$ soM1Resolve vert at B E12		so $T_{\rm CE} = \frac{-2L}{\sqrt{3}}$ so $\frac{2L}{\sqrt{3}} \left(= \frac{2L\sqrt{3}}{3} \right)$ (C)	B1	Accept any form following from their	
so $T_{BC} = -\left(-\frac{2\sqrt{3}L}{3}\right) \times \frac{1}{2} = \frac{\sqrt{3}L}{3}$ (T) Hand So $T_{BC} = -\left(-\frac{2\sqrt{3}L}{3}\right) \times \frac{1}{2} = \frac{\sqrt{3}L}{3}$ (T) Hand So $T_{BC} = -\left(-\frac{2\sqrt{3}L}{3}\right) \times \frac{1}{2} = \frac{\sqrt{3}L}{3}$ (T) Hand So $T_{B1} = -T_{B2} \cos 30 + T_{B2} \cos 30 = 0$ So $T_{B2} = -T_{B2} \cos 30 + T_{B2} \cos 30 = 0$ SO		$C \leftarrow T_{BC} + T_{CE} \cos 60 = 0$	B1		
(vi) $ \begin{array}{c} F_{1} \\ F_{2} \\ F_{3} \\ F_{4} \\ $			D1	FT their T_{CE} or equiv but do not condone	
(vi) \downarrow B $T_{BD} \cos 30 + T_{BE} \cos 30 = 0$ so $T_{BD} = -T_{BE}$ so mag equal and opp sense E1 Resolve vert at B E1 A statement required 2		$SO T_{BC} = -\left(-\frac{3}{3}\right)^{\frac{1}{2}} = -\frac{3}{3}$ (1)		obtained. (T) not required. T and C consistent with their answers and	
$\begin{array}{c c} \downarrow & B & T_{BD} \cos 30 + T_{BE} \cos 30 = 0 \\ \text{so } T_{BD} = -T_{BE} \text{ so mag equal and opp sense} \end{array} \qquad \begin{array}{c c} M1 & \text{Resolve vert at } B \\ E1 & \text{A statement required} \end{array} \qquad \begin{array}{c c} 2 \end{array}$					7
	(vi)				
			20		2

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Q 3		mark		sub
(i)	(10, 2, 2.5)	B1		1
(ii)	By symmetry $\overline{x} = 10,$ $\overline{y} = 2$ $(240+80)\overline{z} = 80 \times 0 + 240 \times 2.5$ so $\overline{z} = 1.875$	B1 B1 B1 M1 A1	Total mass correct Method for c.m. Clearly shown	5
(iii)	$\overline{x} = 10 \text{ by symmetry}$ $(320 + 80) \begin{pmatrix} \overline{x} \\ \overline{y} \\ \overline{z} \end{pmatrix} = 320 \begin{pmatrix} 10 \\ 2 \\ 1.875 \end{pmatrix} + 80 \begin{pmatrix} 10 \\ 4 \\ 3 \end{pmatrix}$	E1 M1	Could be derived Method for c.m.	
	$\overline{y} = 2.4$ $\overline{z} = 2.1$	B1 B1 E1 E1	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 E1	Award for correct use of dimensions 2.1 and 2.4 or equivalent 1 st term o.e. (allow use of 2.4 and 2.1) 2 nd 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 <i>P</i> = 0 <i>P</i> = 8.22768 so 8.23 (3 s. f.)	M1 A1	Allow use of 5 Allow if cm used consistently	
		18		2

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