1 **(i)**	$16L\cos\theta = 4 \times 2L$ $\theta = 60°$ or $\pi/3^c$ or 1.05^c	M1 A1 [2]	Moments about A, accept L = 1
(ii)	$X = 4\sin60°$ and $Y = 16 - 4\cos60°$ $= \sqrt{[(4\sin60°)^2 + (16 - 4\cos60°)^2]}$ = 14.4 N α = 76.1°	B1 M1 A1ft B1 [4]	 $\tan\alpha = (16 - 4\cos60°)/(4\sin60°)$ ft cv(X,Y). $\alpha = 76.1°$ R = 14.4 N
2 **(i)**	C of M semi-circle = $4 \times 0.2/(3\pi)$ $\frac{\pi 0.2^2}{2} \times 4 \times \frac{0.2}{3\pi} = \frac{0.4h}{2} \times \frac{h}{3}$ = 0.283	B1 M1 A1 A1 [4]	(0.08488…) Moments about a relevant point.
(ii)	$\tan\theta = 0.283/0.2$ $\cos\theta = XD/0.2$ (= 0.5774) XD = 0.115 m **OR** $\tan\alpha = 0.2/0.283$ $\sin\alpha = XD/0.2$ (= 0.5774) XD = 0.115 m	M1 M1 A1 M1 M1 A1 [3]	tanADO = h/0.2 , ADO = 54.75° For candidates ADO tanDAO = 0.2/h, DAO = 35.25 For candidate's DAO
3 **(i)**	$R\cos30° + T\cos60° = 0.5g$ $F = 0.5g/(\cos30° + \cos60°)$ $T\sin60° - R\sin30° = 0.5v^2/0.1$ $v = 0.518$ ms^{-1}	M1 A1 M1 A1 [4]	or with R = T = F F = 3.660… = R = T Newton's Second Law with radial acceleration
(ii)	R = 0 $T\cos60° = 0.5g$ $T\sin60° = 0.5 \times \omega^2 \times 0.1$ $\omega = 13.2$ rads^{-1} **OR** R = 0 $mv^2\sin30°/r$ or $mr\omega^2\sin30°$ $= mg\cos30°$ $\omega = 13.2$ rad s^{-1}	B1 M1 M1 A1 B1 M1 M1 A1 [4]	Could be implied T = 10 N Newton's Second Law with radial acceleration Could be implied

4	**(i)**	$0.24g = 12(x)/0.5$ $x = 0.1$	M1 A1	Finds position for equilibrium
		EITHER $\frac{1}{2} \times 0.24 \times 3^2 + 12 \times (0.8 - 0.5)^2/(2 \times 0.5) =$ $0.24v^2/2 + 12 \times 0.1^2/(2 \times 0.5)$ $+ 0.24g(0.8 - 0.5 - 0.1)$ $v = 3.61 \text{ ms}^{-1}$	M1 A1 A1	Energy balance, initial to equilibrium positions
		OR $0.24vdv/dx = mg - 12x/0.5$ $0.24v^2/2 = 2.4x - 12x^2 \ (+c)$ $v = 3, x = 0.3, \ c = 1.44$ $x = 0.1, v = 3.61 \text{ ms}^{-1}$	M1 A1 A1 [5]	Using Newton's Second Law Or uses limits
	(ii)	$0.24 \times 3^2/2 + 12 \times (0.8 - 0.5)^2/(2 \times 0.5) =$ $0.24g(0.8 + x)$ $x = 0.1\text{m}$ $s = (0.5 + 0.1) = 0.6 \text{ m}$	M1 A1 A1 A1	Initial KE + initial EE = Final PE
		OR $\frac{1}{2} \times 12 \times 0.3^2/0.5 + \frac{1}{2} \times 0.24 \times 3^2$ $= \frac{1}{2} \times 0.24v^2 + 0.24 \times 10 \times 0.3$ $v = \sqrt{12}$ *Either* $0 = 12 - 2 \times 10s$ $s = 0.6$ *Or* $\frac{1}{2} \times 0.24 \times 12 = 0.24 \times 10s$ $s = 0.6$	M1 A1 M1 A1 M1 A1	Initial EE + Initial KE = (KE + PE) at equilibrium position Using $v^2 = u^2 + 2as$ Using KE at equilibrium position = Final PE
		OR $\frac{1}{2} \times 12 \times 0.3^2/0.5 + \frac{1}{2} \times 0.24 \times 3^2$ $= 0.24 \times 10y$ $y = 0.9$ $s = 0.9 - 0.3 = 0.6$	M1 A1 A1 A1 [4]	Initial EE + Initial KE = Final PE where y is the distance above the start

5 **(i)**	$dv/dt = -2.5k\sqrt{v}$	B1	$0.4dv/dt = -k\sqrt{v}$
	$\int v^{-0.5}\,dv = -2.5k\int dt$	M1	
	$v^{0.5}/0.5 = -2.5kt\ (+c)$	A1	LHS $= 0.8\sqrt{v}$
	$t = 0,\ v = 9$ hence $c = 6$ and $t = 2,\ v = 4$ hence $k = 0.4$	M1	$\sqrt{v} = (6-t)/2$ Uses correct limits
	$v = (6-t)^2/4 = (t-6)^2/4$ AG	A1 [5]	
(ii)	$x = \int (t-6)^2/4dt$	M1	$\int (6-t)^2/4dt$
	$x = (t-6)^3/(3\times4)\ (+c)$	A1	$-(6-t)^3/(3\times4)\ (+c)$
	$t = 0,\ x = 0$ hence $c = 18$	M1	Or uses limits 0, 3
	$x(3) = 18-(3-6)^3/12$ $x(3) = 15.75$	A1	Accept 15.7 or 15.8
	OR		
	$\int v^{\frac{1}{2}}\,dv = \int -dx$	M1	From $mvdv/dx = -k\sqrt{v}$
	$\frac{2}{3}v^{\frac{3}{2}} = -x\ (+c)$	A1	
	$x = 18 - \frac{2}{3}v^{\frac{3}{2}}$	M1	Using $v = 9,\ x = 0$ so $c = 18$
	$x = 15.75$	A1 [4]	Put $t = 3$ to find $v = 2.25$
6 **(i)**	$x = (26\cos30^\circ)\times2.3$	B1	$= 51.788..$
	$y = (26\sin30^\circ)\times2.3 + g\times2.3^2/2$	B1	$= 56.35$
	$d^2 = 51.8^2 + 56.35^2$	M1	
	$d = 76.5$ m	A1 [4]	
(ii)	$80 = (26\sin30^\circ)t + 10t^2/2$	M1	or $v^2 = (26\sin30^\circ)^2 + 2\times10\times80$ with $v = 42.06$
	$t = 2.91$s [or $(42.06-13)/10$]	A1	$= 26\sin30^\circ + 10t$ solved for t
	$x = (2.906\times26\cos30^\circ) = 65.4$ m	A1	
	OR		
	$80 = x\tan30^\circ + 10x^2/(2\times26^2\times\cos^2 30^\circ)$	M1 M1	Uses trajectory equation Attempts to solve the quadratic equation
	$x = 65.4$	A1 [3]	
(iii)	$v^2 = (26\sin30^\circ)^2 + 2g\times80$	B1	$v = 42.06$. Accept $v = 26\sin30^\circ + 10\times2.91$ or award correct method to find α
	$V^2 = (26\sin30^\circ)^2 + 2g\times80 + (26\cos30^\circ)^2$	M1	
	$V = 47.7\ ms^{-1}$	A1	
	$\alpha = \tan^{-1}[(42.06)/(26\cos30^\circ)] = 61.8^\circ$	A1 [4]	Below horizontal (1.08)