1	$v^2 = 2 \ge 9.8 \ge 10$		M1	Using $v^2 = u^2 + 2as$ with $u = 0$
	$v = 14 \text{ m s}^{-1}$		A1	
	speed = $\sqrt{7^2 + 14}$ 15.7 or $7\sqrt{5}$ m s ⁻¹	1 ²)	M1	Method to find speed using their "v"
			A1	
	$\tan^{-1}(14/7)$ or $\tan^{-1}(14/7)$	1 ⁻¹ (7/14)	M1	Method to find angle using their "v"
	63.4°	to the horizontal	A1 6	26.6° to vertical
				6

(ii) $8d = 3(6-3.82) + 5x9.82$ or $8x = \pm \{3(-3.82) + 5x3.82\}$ $d = 6.95$ or 6.96 or $x = \pm (-0.955)$ M1 A1 A1 A1	
$\begin{array}{c c} \tan\theta = 0.96/6 \\ \theta = 9^{\circ} \end{array} \qquad \qquad \begin{array}{c c} M1 \\ A1 & 5 \end{array} \qquad \qquad \begin{array}{c c} \text{Attempt to find the required an} \\ 7 \end{array}$	gle

3 (i)	$D = 128\ 000/80\ (= 1600) \\ k(80)^2 = 128\ 000/80$	B1 M1 A1		Driving force = resistance
	$\begin{vmatrix} k = \frac{1}{4} \\ R = 900 \text{ N} \qquad \text{FT}$	A1 B1 5	5	FT on their k ($R = 3600k$)
(ii)	D = 128 000 / 60 (= 2133 ¹ / ₃) 2000 x 9.8 x sin2° 6400/3-900-2000 x 9.8 x sin2° = 2000a $a = 0.275 \text{ m s}^{-2}$		4	4 terms required 9

4	(i)	4Tcos20° = 5 x g x 2.5 T = 32.6 N	M1 A1 A1 3	Using moments; allow sin/cos mix Allow with omission of g
	(ii)	$X = Tsin20^{\circ}$ X = 11.1 FT $Y + Tcos20^{\circ} = 5 x g$ or 2.5Y = 1.5 x Tcos20 or 4Y = 1.5 x 5g	M1 A1 M1	allow sin/cos mix FT their T
		Y = 18.4 FT	A1	FT their T, but not from omission of g
		$R = \sqrt{(X^2 + Y^2)}$ or $tan^{-1}(Y/X)$ or $tan^{-1}(X/Y)$	M1	$X \neq 0, Y \neq 0$
		R = 21.5 N $\theta = 58.8^{\circ}$ above the horizontal	A1 A1 7	or 31.2° to left of vertical 10

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5	(i)	$T\cos 45^\circ + R\sin 45^\circ = mg$	*M1	3 terms
			A1	
		Tsin45° - Rcos45° = mlsin45° ω^2	*M1	3 terms; $a = r \omega^2$
			A1	
		$2T = \sqrt{2mg} + ml\omega^2$	Dep*M1	Method to eliminate R
		$T = m/2(\sqrt{2g} + l\omega^2)$	A1 6	AG www
	(ii)	$\mathbf{R} = 0$	B1	may be implied
	(11)	$2\mathbf{R} = \sqrt{2}$ mg - ml ω^2	B1	indy be implied
		or $T\cos 45^\circ = mg$		
		or $T = ml\omega^2$		
		Solve to find ω	M1	
		$\omega = 4.16 \text{ rad s}^{-1}$	A1 4	10
6	(i)	2mu = 2mv + 3mv	M1	Conservation of momentum
Ŭ	(•)		A1	
		v=2/5 u	A1 3	Must be $v =$
	(ii)	$\mathbf{e} = (3v - v) / u$	M1	Using restitution
		e = 4/5	A1 2	AG
	(iii)	Initial K.E. = $9mv^2 / 2 = 18mu^2 / 25$	B1 FT	FT on their v from (i)
	()	Final K.E. = $9mv^2 / 8 = 9mu^2 / 50$	B1 FT	FT on their v from (i)
		$\frac{1}{2}m(V)^2 = \text{Final K.E.}$	M1	
		V = 3 u / 5	A1 4	AG
	(i w)	$A_{max} = 5$ $\frac{2}{3} m_{max} = 5$ $\frac{2}{3} m_{max} = 1$ m_{max}	M1	Conservation of momentum
	(iv)	4mu / 5 - 3mu / 5 = 2mx + my u / 5 = 2x + y	A1 FT	FT on their v from (i); aef
		$u^{y} = 2x + y$ e = 4/5 = (y - x) / u	M1 FT	Using restitution
		$\begin{aligned} c &= 4/5 = (y - x) / u \\ 4u &= 5y - 5x \end{aligned}$	A1	FT on their v from (i); aef
		solving 2 relevant equations	M1	
		$x = -u/5 \ y = 3u/5$	A1	
		y = 3u/5	A1	
		away from wall (x) + towards wall (y)	A1 8	both
				17

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7 (i)	$R = 0.2 \text{ x } 9.8 \text{ x } \cos 30^{\circ} (= 1.70)$ $F = 0.1 \text{ x } 9.8 \text{ x } \cos 30^{\circ} (= 0.849) \text{ FT}$ $\frac{1}{2} \text{ x } 0.2 \text{ x } 11^{2} - \frac{1}{2} \text{ x } 0.2 \text{ v}^{2} =$ $0.2 \text{ x } 9.8 \text{ x } 5\sin 30 + 5 \text{ x } 0.849$ $v = 5.44 \text{ m s}^{-1}$	B1 B1 M1 A1 A1 A1 6	FT on their R, but not R =0.2g Use of conservation of energy AG
Or last 4 marks of (i)	F + 0.2gsin30 = $\pm 0.2a$ a = ± 9.1 v ² = 11 ² + 2 x a x 5 v = 5.44 m s ⁻¹	M1 A1 M1 A1	Use of N2L, 3 terms Complete method to find v
(ii)	t = $5\cos 30^{\circ}/5.44\cos 30^{\circ}$ t = 0.919 s u = $5.44\sin 30^{\circ}$ (= 2.72) s = $2.72 \times 0.919 - 4.9 \times 0.919^{2}$ s = -1.6 (or better) Ht drop to C = $5\sin 30^{\circ} = 2.5$ m Ball does not hit the roof	M1 A1 B1 M1 A1 B1 A1 7	time to lateral position over <i>C</i> Ht dropped 13
Or first 5 marks of (ii)	y = xtan θ - gx ² sec ² $\theta/2V^2$ substitute values V = 5.44 θ = 30° x = 5cos30° y = 2.5 - 9.8x25x3/4x4/3 / (2x5.44 ²) y = -1.6 (or better)	B1 M1 A1 A1 A1	all 3 correct
OR (ii)	u = $5.44\sin 30^{\circ}$ (= 2.72) -2.5 = $5.44\sin 30t - 4.9t^{2}$ t = 1.04 x = $5.44\cos 30 \times 1.04 = 4.9$ (or better) Horizontal distance from B to C = $5\cos 30 = 4.3$ (or better) Ball does not hit the roof	B1 M1 A1 A1 A1 B1 A1 7	aef time to position level with <i>AC</i>
OR (ii)	y = xtan θ - gx ² sec ² $\theta/2V^2$ substitute values -2.5 = 0.577x - 0.221x ² Attempt to solve quadratic for x x = 4.9 (or better) Horizontal distance from B to C = 5cos30 = 4.3 (or better) Ball does not hit the roof	B1 M1 A1 M1 A1 B1 A1 7	aef
OR (ii)	u = $5.44\sin 30^\circ = 2.72$ -2.5 = $5.44\sin 30t - 4.9t^2$ t = 1.0 (or better) T = $5\cos 30^\circ/5.44\cos 30^\circ$ T = 0.92 (or better) Ball does not hit the roof	B1 M1 A1 A1 M1 A1 A1 A1 7	aef time to position level with <i>AC</i> time to lateral position over <i>C</i>

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OR (ii)	Attempt at equation of trajectory	M1		
	$y = 0.577x - 0.221x^2$	A1		
	y = -0.577x	B1		Equation of BC
	Solving their quadratic and linear			
	equations to get at least x or y	M1		
	x = 5.2 (or better) or $y = -3.0$ (or better)	A1		
	Horizontal distance from B to C =			Must be the one needed for
	$5\cos 30 = 4.3$ (or better)			comparison
	Or Ht drop to $C = 5\sin 30^\circ = 2.5$	B 1		-
	Ball does not hit the roof	A1	7	
OR (ii)	Attempt at equation of trajectory	M1		
	$y = 0.577x - 0.221x^2$	A1		
	y = -0.577x	B 1		
	Solving their quadratic and linear			
	equations	M1		
	x = 5.2 (or better) and $y = -3.0$ (or	A1		
	better)			
	Distance $= 6.0$ (or better)	B 1		Distance from B to point of
				intersection
	Ball does not hit the roof	A1	7	