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

2 **(i)**	$(6\sin \Pi/2) \div (\Pi/2)$ 3.82	M1 A1 **2**	Use of correct formula **AG**
(ii)	$8đ = 3(6-3.82) + 5x9.82$ or $8x = \pm\{3(-3.82) + 5x3.82\}$ $đ = 6.95$ or 6.96 or $x = +/-0.955$ $\tan\theta = 0.96/6$ $\theta = 9°$	M1 A1 A1 M1 A1 **5**	Method to find centre of mass Attempt to find the required angle **7**

3 **(i)**	D = 128 000/80 (= 1600) $k(80)^2 = 128\ 000/80$ k = ¼ R = 900 N FT	B1 M1 A1 A1 B1 **5**	 Driving force = resistance FT on their k ($R = 3600k$)
(ii)	D = 128 000 / 60 (= 2133⅓) 2000 x 9.8 x sin2° 6400/3-900-2000 x 9.8 x sin2° = 2000a $a = 0.275\ \text{m s}^{-2}$	B1 B1 M1 A1 **4**	 4 terms required **9**

4 **(i)**	$4T\cos20° = 5 \times g \times 2.5$ T = 32.6 N	M1 A1 A1 **3**	Using moments; allow sin/cos mix Allow with omission of g
(ii)	X = Tsin20° X = 11.1 FT Y + Tcos20° = 5 x g or 2.5Y = 1.5 x Tcos20 or 4Y = 1.5 x 5g Y = 18.4 FT $R = \sqrt{(X^2 + Y^2)}$ or $\tan^{-1}(Y/X)$ or $\tan^{-1}(X/Y)$ R = 21.5 N θ = 58.8° above the horizontal	M1 A1 M1 A1 M1 A1 A1 **7**	allow sin/cos mix FT their T FT their T, but not from omission of g $X \neq 0$, $Y \neq 0$ or 31.2° to left of vertical **10**

5 (i)	$T\cos45° + R\sin45° = mg$	*M1 A1	3 terms
	$T\sin45° - R\cos45° = ml\sin45°\omega^2$	*M1 A1	3 terms; $a = r\omega^2$
	$2T = \sqrt{2}mg + ml\omega^2$ $T = m/2(\sqrt{2}g + l\omega^2)$	Dep*M1 A1 **6**	Method to eliminate R **AG** www
(ii)	$R = 0$ $2R = \sqrt{2}mg - ml\omega^2$ or $T\cos45° = mg$ or $T = ml\omega^2$ Solve to find ω	B1 B1 M1	may be implied
	$\omega = 4.16$ rad s^{-1}	A1 **4**	**10**

6 (i)	$2mu = 2mv + 3mv$	M1 A1	Conservation of momentum
	$v = 2/5\ u$	A1 **3**	Must be $v =$
(ii)	$e = (3v - v) / u$ $e = 4/5$	M1 A1 **2**	Using restitution **AG**
(iii)	Initial K.E. $= 9mv^2 / 2 = 18mu^2/25$ Final K.E. $= 9mv^2 / 8 = 9mu^2/50$ $\frac{1}{2} m (V)^2$ = Final K.E. $V = 3u/5$	B1 FT B1 FT M1 A1 **4**	FT on their v from (i) FT on their v from (i) **AG**
(iv)	$4mu / 5 - 3mu/5 = 2mx + my$ $u / 5 = 2x + y$ $e = 4/5 = (y - x) / u$ $4u = 5y - 5x$ solving 2 relevant equations $x = -u/5$ $y = 3u/5$ $y = 3u/5$ away from wall (x) + towards wall (y)	M1 A1 FT M1 FT A1 M1 A1 A1 A1 **8**	Conservation of momentum FT on their v from (i); aef Using restitution FT on their v from (i); aef both **17**

7 (i)	R = 0.2 x 9.8 x cos30° (= 1.70)	B1		
	F = 0.1 x 9.8 x cos30° (= 0.849) FT	B1		FT on their R, but not R =0.2g
		M1		Use of conservation of energy
	½ x 0.2 x 11^2 - ½ x 0.2 v^2 =	A1		
	0.2 x 9.8 x 5sin30 + 5 x 0.849	A1		
	v = 5.44 m s^{-1}	A1	**6**	**AG**
Or	F + 0.2gsin30 = ±0.2a	M1		Use of N2L, 3 terms
last 4	a = ±9.1	A1		
marks	$v^2 = 11^2 + 2$ x a x 5	M1		Complete method to find v
of (i)	v = 5.44 m s^{-1}	A1		
(ii)	t = 5cos30°/5.44cos30°	M1		time to lateral position over *C*
	t = 0.919 s	A1		
	u = 5.44sin30° (= 2.72)	B1		
	s = 2.72 x 0.919 – 4.9 x 0.919^2	M1		
	s = -1.6 (or better)	A1		Ht dropped
	Ht drop to *C* = 5sin30° = 2.5 m	B1		
	Ball does not hit the roof	A1	**7**	**13**
Or	$y = x\tan\theta - gx^2 \sec^2\theta/2V^2$	B1		
first	substitute values	M1		
5	V = 5.44 θ = 30° x = 5cos30°	A1		all 3 correct
marks	y = 2.5 – 9.8x25x3/4x4/3 / (2x5.44^2)	A1		
of (ii)	y = -1.6 (or better)	A1		
OR (ii)	u = 5.44sin30° (= 2.72)	B1		
	-2.5 = 5.44sin30t – $4.9t^2$	M1		
		A1		aef
	t = 1.04	A1		time to position level with *AC*
	x = 5.44cos30 x 1.04 = 4.9 (or better)	A1		
	Horizontal distance from B to C =			
	5cos30 = 4.3(or better)	B1		
	Ball does not hit the roof	A1	**7**	
OR (ii)	$y = x\tan\theta - gx^2 \sec^2\theta/2V^2$	B1		
	substitute values	M1		
	-2.5 = 0.577x – $0.221x^2$	A1		aef
	Attempt to solve quadratic for x	M1		
	x = 4.9 (or better)	A1		
	Horizontal distance from B to C =			
	5cos30 = 4.3 (or better)	B1		
	Ball does not hit the roof	A1	**7**	
OR (ii)	u = 5.44sin30° = 2.72	B1		
	-2.5 = 5.44sin30t – $4.9t^2$	M1		
		A1		aef
	t = 1.0 (or better)	A1		time to position level with *AC*
	T = 5cos30°/5.44cos30°	M1		
	T = 0.92 (or better)	A1		time to lateral position over *C*
	Ball does not hit the roof	A1	**7**	

OR (ii)	Attempt at equation of trajectory $y = 0.577x - 0.221x^2$ $y = -0.577x$ Solving their quadratic and linear equations to get at least x or y x = 5.2 (or better) or y = -3.0 (or better) Horizontal distance from B to C = 5cos30 = 4.3 (or better) Or Ht drop to *C* = 5sin30° = 2.5 Ball does not hit the roof	M1 A1 B1 M1 A1 B1 A1 **7**	 Equation of BC Must be the one needed for comparison
OR (ii)	Attempt at equation of trajectory $y = 0.577x - 0.221x^2$ $y = -0.577x$ Solving their quadratic and linear equations x = 5.2 (or better) and y = -3.0 (or better) Distance = 6.0 (or better) Ball does not hit the roof	M1 A1 B1 M1 A1 B1 A1 **7**	 Distance from B to point of intersection