1	v^2 = 2 x 9.8 x 10 v = 14 m s^{-1} speed = $\sqrt{(7^2 + 14^2)}$ 15.7 or $7\sqrt{5}$ 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)**	(6sin Π/2) ÷ (Π/2) 3.82	M1 A1 **2**	Use of correct formula **AG**
(ii)	8đ = 3(6-3.82) + 5x9.82 or 8x = ±{3(-3.82) + 5x3.82} đ = 6.95 or 6.96 or x = +/-0.955 tanθ = 0.96/6 θ = 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 m s^{-2}	B1 B1 M1 A1 **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° 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 ≠ 0, Y ≠ 0 or 31.2° to left of vertical **10**

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

6 (i)	$2mu = 2mv + 3mv$	M1	Conservation of momentum
		A1	
	$v = 2/5\ u$	A1 **3**	Must be $v =$
(ii)	$e = (3v - v) / u$	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)
	$\frac{1}{2} m (V)^2$ = Final K.E.	M1	
	$V = 3\ u\ /5$	A1 **4**	**AG**
(iv)	$4mu / 5 - 3mu/5 = 2mx + my$	M1	Conservation of momentum
	$u / 5 = 2x + y$	A1 FT	FT on their v from (i); aef
	$e = 4/5 = (y - x) / u$	M1 FT	Using restitution
	$4u = 5y - 5x$	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

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