OCR Maths M2

Mark Scheme Pack

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1	(i)	use of h/4	B1			
		com vert above lowest pt of contact	B1		can be implied	
		r = 5 x tan24°	M1			
		r = 2.2	A1	4	2.226	
	(ii)	No & valid reason (eg 24°☝26.6°)	B1√	1	√Yes if their r ☜ 2.5	**5**

2		$v^2 = 2\text{x}9.8\text{x}10$	M1		energy:$\frac{1}{2}mv^2=\frac{1}{2}mu^2 + mgh$	
		v = 14	A1		$\frac{1}{2}v^2 = \frac{1}{2}.36 + 9.8\text{x}10$	
		speed = $\sqrt{(14^2 + 6^2)}$	M1		(must be 6^2) $v^2 = 36+196=232$	
		speed = 15.2 ms^{-1}	A1			
		$\tan\theta = 14/6$	M1		$\cos^{-1}(6/15.2)$ etc	
		θ=66.8°(below) horiz.	A1	6	or 23.2° to the vertical	**6**

3	(i)	$T\cos\theta = 0.01 \text{ x } 9.8$	M1		resolving vertically	
		8/10T = 0.01 x 9.8	A1		with cosθ = 8/10	
		T = 0.1225 N	A1	3	AG	
	(ii)	$T + T\sin\theta = ma$	M1		resolving horizontally	
		use of $mr\omega^2$	M1			
		ω = 5.72 $rads^{-1}$	A1	3		
	(iii)	K.E.=$\frac{1}{2}\text{x}0.01\text{x}(r\omega)^2$	M1		$\frac{1}{2}mv^2$ with v=rw	
		K.E.= 0.0588	A1√	2	√0.0018 x their ω^2	**8**

4	(i)	5m = mu + 4m	M1		cons. of mom.	
		u = 1	A1			
		e = (2-1)/5	M1			
		e = 🗐	A1	4		
	(ii)	I = 4m	B1			
		→	B1	2	to the right	
	(iii)	4m = 5mv	M1			
		v = ☺	A1			
		☺ < 1	B1	3		**9**

5	(i)	60T = 15x30cosθ	M1		moments about A	
		“	A1			
		60T = 15x30 x 0.6	A1		cosθ = 0.6	
		T = 4.5 N	A1	4	**AG**	
	(ii)	X = Tsinθ	M1		res. horiz. (or moments)	
		X = 3.6 N	A1			
		Y + Tcosθ = 15	M1		res. vert.(3 terms) (or moments)	
		Y = 12.3 N	A1			
		R = 12.8 N	A1√		√(their $X^2 + Y^2$)	
		73.7° to horizontal	A1√	6	or 16.3° to vert.√$\tan^{-1}$their(Y/X)	**10**
		or triangle of forces: Triangle (M1) $R^2 = 15^2+4.5^2-2\text{x}4.5\text{x}15\text{x}0.6$(M1A1)				
		R= 12.8 (A1) sinθ/4.5=sinα/12.8 (M1) θ = 16.3° to vert. (A1)				

6	(i)	½.700.20^2 or ½.700.15^2	B1		either K.E.	
		700x9.8x400sin5°	B1		correct P.E.	
		½.700.15^2+700.9.8.400sin5°= ½.700.20^2 + W.D.	M1		for 4 terms with W.D.	
		W.D. = 178,000 J	A1	4	or 178 kJ	
	(ii)	D=200 + 700.9.8sin5°	M1			
		D = 798 N	A1		may be implied	
		P = Dx15 = 12,000 = 12kW	A1	3	AG **(11,968W)**	
	(iii)	D’ = 11,968÷20 = 598	M1			
		D’-700.9.8sin5°-200 = 700a	M1			
		a = 0.285 ms^{-2} (±)	A1	3	allow 0.283 (from 12kW)	**10**
		Alternative for false assumption			**of constant acceleration**	
	(i)	D-700 x 9.8sin5° = 700a and 15^2 = 20^2 + 2a. 400	M1		(D = 445, a = -0.21875)	
		W.D. = 400xD = 178,000	A1		2 marks (out of 4) maximum	

7	(i)	50x9.8x2 = Rx3.75 +80x9.8x0.25	M1		moments about D.	
		“	A1		SR/no g/ R = 21.3 (M1A1A0)	
		R = 209 N	A1	3		
	(ii)	130$\bar{x}$ = 50 x 2 + 80 x 4.25	M1 A1		moments about BC or FE….. 130$\bar{x}$ =80x0.25 + 50x2.5	
		$\bar{x}$ = 3.385	A1		$\bar{x}$ = 1.115	
		130$\bar{y}$ = 50 x 0.125 + 80 x 0.25	M1 A1		moments about EC	
		$\bar{y}$ = 0.202	A1			
		tanθ = 0.615/0.202	M1			
		θ = 71.8° to the horizontal	A1	8	71.6° to 72.0°	**11**

8	(i)	x = 49cosθ . t	B1			
		y=49sinθ.t - ½.9.8.t^2	B1			
		y=xtanθ - 4.9x^2/49^2.cos^{2}θ	M 1		aef (eliminating t)	
		y=xtanθ – x^2(1+tan^{2}θ)/490	A1	4	AG	
	(ii)	30 = 70tanθ – 10(1+tan^{2}θ)	M 1			
		tanθ=(70±√3300)÷20	M 1		(6.37/0.628)	
		81.1°	A1		θ_1 or θ_2	
		32.1°	A1	4	“	
	(iii)	x^2 (1+tan^2 θ)/490 = xtanθ	M 1		set y = 0	
		x = 490tanθ/(1+tan^2 θ)	A1			
		x = 75.0	A1			

		x = 221 (220.6)	A1			
		d = 146 m	A1 √	5	√	**13**
	(iii)	Alternatively (1st 2 marks)				
		t=49sinθ/4.9 and (9.88/5.31) x=49cosθ.t	M 1		<u>$s=ut+½at^2$ and</u> <u>x=49cosθ.t</u> or $R = u^2 \sin 2\theta/g$ (precise)	
		x = 490sinθcosθ	A1		245sin2θ	

1		$\tan\theta = ⅓$ (θ = 18.4° at B)	B1		71.6° at C	
		3 x T $\sin\theta$ = 20 x 1.5 must have two distances and no g	M1		M(A) (d=3/√10)	
			A1			
		T = 31.6 N	A1	4		**4**

2	(i)	0 = 50 sin25° t – $4.9t^2$	M1		or 0=50sin25° - 9.8t &2t :2x2.16	
			A1			
		t = 4.31 s	A1	3		
	(ii)	d = 50cos25° x 4.31	M1		or $u^2\sin(2x25°)/g$	
		195 m	A1√	2	√ 50cos25° x their t	**5**

3	(i)a	100 J	B1	1		
	b	7500 Nm	B1	1		
	(ii)	400cosα x 25 =7500 + 100	M1		sc N II gets M1A1only.This M1 for total M (a=0.08)&A1for α	
		√ for = a + b	A1√			
		α = 40.5	A1	3	or 0.707 rads	**5**

4	(i)	horiz comps in opp direct	B1		at E & F	
		Right at E + Left at F	B1	2		
	(ii)	1.6x9.8x30 = 20X or	M1		or 10X + 1.6gx30 = 30X M(A)	
		0.5x30g + 0.7x30g + 0.2x60g = 20X	A1		or 10X + (. . . = 470.4) = 30X M mark ok without g but 3 parts	
		X = 23.5 N	A1	3		
	(iii)	1.6 $\bar{y}$ =	M1		must be moments with vert dists	
		20x0.2 + 20x0.2 +40x0.5	A1		or 1.6 $\bar{y}$ =20x0.2x2+40x0.7(22.5)	
		$\bar{y}$ = 17.5 cm	A1	3		**8**

5	(i)	6m = 3mx + 2my	M1		**-** 3mx ok if clear on diagram	
		6 = 3x + 2y	A1		m must have been cancelled	
		e = 1 = (y-x)/2	M1		**or** ½**.**3m.2^2 = ½.3mx^2 + ½.2my^2	
			A1		6 = $3x^2$ /2 + y^2 aef	
		x = 0.4 or 2/5	A1		sc A1A0 if x = 2, y = 0 not rejected	
		y = 2.4 or 12/5	A1	6		
	(ii)	4.8m or 24m/5	B1√		√ 2m x their y or 3m(2-their x)	
		same as original dir. of A	B1	2	use their diagram(or dir. of B)	
	(iii)	e = (2.8 – 1.0)/2.4	M1			
		0.75 watch out for ± fiddles	A1√	2	√(1.8/their y) with $0 \le e \le 1$	**10**

6	(i)	x = 7t	B1			
		y = - 4.9t^2 or -½gt^2	M1		some attempt at vertical motion	
			A1		sc y=xtanθ −gx^2/(2$V^2$$\cos^2$θ)	
		y = - x^2/10 **AG** (no fiddles)	A1	4	with θ=0 M1 then A1 (max = 2)	
	(ii)	-20 = -x^2/10	M1		or t=√(20/4.9) & x=7t	
		14.1 m	A1	2	sc B1 for 14.1 after wrong work	
	(iii)	½mv^2 = ½$m7^2$ + mgx20 n.b. v^2 =u^2	M1		**OR** v_h = 7 (B1)	
		+2as gets M0	A1		v_v = ±19.8 (B1) 14√2,2√98 etc	
		v = 21 ms^{-1}	A1		v = 21 (B1)	
		dy/dx = -2x/10 & tanθ	M1		**OR** tanθ = 19.8/7 or	
			A1		cosθ=7/21 or sinθ=19.8/21	
		70.5° to horizontal	A1	6	or 19.5° to vertical	**12**

7	(i)	F = 300/12	M1			
		R = 25	A1	2		
	(ii)	P=17.5x12 (R_2=17.5 & F_2 = 17.5)	M1		n.b. B1 only for 210 W	
		P = 210 W	A1	2	without working	
	(iii)	500 = Fx12	M1			
		F = 41.67 or 500/12 aef	A1			
		41.67 – 25 – 75x9.8sin1°= 75a	M1			
			A1			
		0.0512 ms^{-2}	A1	5	or 0.051	
	(iv)	PE = 75x9.8x200sin10° (25530)	B1		**OR** 75x9.8sin10° -120= 75a	
		WD = 200x120 (24000)	B1		(M1 + A1)	
		½.75v^2 =	M1		a = 0.102 (A1)	
		½.75.13^2+75x9.8x200sin10°-200.120	A1		v^2 =169+2x0.102x200 (M1)	
		14.5 ms^{-1}	A1	5	v = 14.5	**14**

8	(i)	R cos30° = 0.1 x 9.8	M1		resolving vertically	
			A1			
		R = 1.13 N	A1	3		
	(ii)	r = 0.8cos30° = 0.693 or 2√3/5	B1		may be implied	
		Rcos60° = 0.1 x 0.693 ω^2	M1		or 0.1v^2/r & ω = v/r	
			A1			
		ω = 2.86	A1	4		
	(iii)	T = 1.96 N	B1	1		
	(iv)	Rcos30° = Tcos60° + 0.1x9.8	M1			
			A1			
		R = 2.26 N	A1			
		Rcos60° + Tcos30° = 0.1 x v^2/r	M1		or mrω^2 & use of v = rω	
			A1		with R=1.13 can get M1 only	
		4.43 ms^{-1}	A1	6		**14**
or	(iv)	LHS (or RHS)	M1*		method without finding R	
		T + 0.1x9.8cos60°	A1		i.e. resolving along PA	
		RHS (or LHS)	M1*			
		0.1 x v^2/r x cos30°	A1		r to be 0.8 cos30° for A1	
		solve to find v	M1*		depends on 2* Ms above	
		4.43 ms^{-1}	A1	(6)		

1		mgh = 35 x 9.8 x 4 mgh/t = 1372/10 137 W	M1 A1 M1 A1	 4	 watch out for extras or 0.137 kW	 **4**
2		$v^2 = 2gh$ u=√4g or √39.2 or 6.26 v=√2.8g or √27.44 (5.24) I =? 0.3(6.26 + 5.24) 3.45 Ns	M1 A1 A1 M1 A1✓	 5	kinematics or energy speed of impact (±) speed of rebound (±) must be sum of mags. of vels. ✓ must be positive	**2** **5**
3	(i)	d = 2.25 h = 1.125 or 1.12 or 1.13 or 9/8	B1 B1	 2	3/8x6 *OG* (be generous) horizontal distance	
	(ii)	$T_1 + T_2 = 12$ resolving vertically T_1 x 6cos30° = 12xh (their h) mom(*O*) (their h ok for A1) T_1 = 2.60 N or 3√3/2 T_2 = 9.40 N ✓ (12 – T_1)	M1 M1 A1 A1 A1✓	 5	if not then next M1 ok or mom(*A*)T_2x6cos30°= 12(6cos30° – h) or T_2 = 9.40 or T_1=2.60 or ✓(12–T_2)	 **7**
		above ✓ depends on at least one of the M marks ($T_s > 0$)				
4	(i)	P = 13500 W	B1	1	or 13.5 kW	
	(ii)	500 = 13500/v v = 27 ms^{-1}	M1 A1	 2		
	(iii)	15000/25 – 500 = 950a a = 0.105 or 2/19	M1 A1 A1	 3	2 parts to F A0 for 900a or 100/950	
	(iv)	15000/26–500 – 950.9.8sin5° = 950a a = (–) .773 ms^{-2}	M1 A1 A1	 3	3 parts to F A0 for 900a s.c. accept 0.77	 **9**
5	(i)	$\bar{x}$ = 9 c of m of Δ 4 cm above BD (324 + 108) (m) $\bar{y}$ = 324(m)x9 + 108(m)x(18+4) 432 $\bar{y}$ 324 x 9 (18^2 x 9) 108 x (18 +4) $\bar{y}$ = 12.25	B1 B1 M1 A1 A1 A1 A1	 7	ignore any working 8 cm below C/see their diagram 432 $\bar{y}$ = 108x8 + 18^2 (12 + 9) from C left hand side 1st term on right hand side 2916 2nd term on right hand side 2376 5292÷432 or 49/4	
	(ii)	tanθ = 5.75/9 θ = 32.6° or 147.4°	M1 A1✓	 2	must be …/9 ✓$\tan^{-1}$ ((18-their $\bar{y}$)/9) or 180°..	 **9**

6	(i)	T = 4.9 N $T = 0.3 \times 0.2 \times \omega^2$ $\omega = 9.04$ rads^{-1}	B1 M1 A1 A1	 4	B0 for 0.5g or $0.3v^2/0.2$ and $\omega = v/0.2$	**6**
	(ii)	$\cos\theta = \sqrt{0.6/0.8}$ (0.968) $T\cos\theta = 0.5 \times 9.8$ T = 5.06 N	B1 M1 A1 A1	 4	(θ=14.5°) angle to vert. or equiv. angle consistent with diagram can be their angle	
	(iii)	$T\sin\theta = 0.5 \times v^2/0.2$ v = 0.711 ms^{-1}	M1 A1 A1	 3	must be a component of T ($\sin\theta$ = ¼) can be their angle	**11**
7	(i)	vsin50° $0=v^2\sin^2 50° - 2\text{x}9.8\text{x}13$ (must be 13) v = 20.8 ms^{-1}	B1 M1 A1	 3	initial vertical component or mx9.8x13 = ½m(vsin50°)^2 sin/cos mix ok for above M1	
	(ii)	45 = vcos50°.t t = 3.36 ✓their v (3.13 for v=22.4) s = vsin50° x t - ½ x 9.8 x t^2 s = – 1.6 to – 2.0 inclusive (– 1.68) ht above ground = 0.320 m	M1 A1✓ M1 A1 A1 A1	 6	see alternative below other methods include other t$_s$ ignore ht adjustments can be their v and their t can be implied from next A1	
	(iii)	v_v = vsin50° - 9.8xt v_v = -17.0 ✓their v,t(-13.5 for 22.4) speed=$\sqrt{(v_v^2+(v\cos 50°)^2)}$ speed = 21.6 ms^{-1} ✓ their v and v_v (19.7 for v = 22.4)	M1 A1✓ M1 A1✓	 4	or v_v^2=2g(15-their ans to ii) ✓ above for v_v or ½mv^2 – mgx1.68 = ½mx20.8^2 (4 marks) M1/A1✓ s,v /M1 solve/ A1 ✓	**13**
	(ii)	$y = x\tan\theta - gx^2/2v^2\cos^2\theta$ y=45tan50°-9.8.45^2/2.v^{2}cos^{2}50° calculate y y = – 1.6 to – 2.0 inclusive	B1 M1 A1 M1 A1		**Alternative 1st 5 marks** substitute v and 50° and x=45 can be their v should be – 1.68	

8	(i)	10 = 4 + m.x e = … or rationale for x = 2 m = 3	M1 M1 A1	 3	conservation of momentum	
	(ii)	v = 6 e = 4/5 or 0.8	B1 M1 A1	 3	 allow sign errors for M mark watch out for lost minuses	
	(iii)	10 – 5 = 2x + y (5 = -2a + b) (-5 = 2c + d) e = 0.8 = (y-x)/10 y = x + 8 (a + b = 8) (c – d = 8) x = -1 (a=1) (c=1) y = 7 (b=7) (d=-7) $\frac{1}{2}.2.5^2 + \frac{1}{2}.1.5^2 - \frac{1}{2}.2.1^2 - \frac{1}{2}.1.7^2$ 12 J	M1 A1 M1 A1 A1 A1 M1 A1	 8	 look for consistency or 1 in opp. direction to 1st K.E. lost. Must be 4 parts (37.5 – 25.5)	**14**

±1 in 3rd sig. fig. except where stated

1		com directly above lowest point	B1			
		tan α = 6/10	M1			
		α = 31.0	A1	3	or 0.540 rads	**3**

2		e = 1 = $(y–x)/4$	B1		or ½x0.2x^2 + ½x0.1y^2 =	
		0.8 = 0.2x + 0.1y	B1		½x0.2x4^2(B1/B1 for any 2)	
		solving sim. equ.	M1		not if poor quad. soln.	
		x = 4/3 only	A1	4		**4**

3	(i)	$x^2 = 21^2$ + 2x40x9.8	M1			
		x = 35	A1			
		0 = y^2 – 2x40x9.8	M1			
		y = 28	A1		may be implied	
		e = 28/35	M1			
		e = 0.8	A1	6	aef	
	(ii)	0.2x28 – – 0.2x35	M1		must be double negative	
		I = 12.6	A1	2		**8**

4	(i)	½x80x5^2 or ½x80x2^2 either KE	B1		1000/160	
		70 x 25	B1		1750	
		80x9.8x25sin20°	B1		6703.6	
		WD=½x80x5^2-½x80x2^2+70x25+80x9.8x25sin20°	M1		4 parts	
		9290	A1	5		
	(ii)	Pcos30°x25	B1		or a=0.42	
		Pcos30°.25=9290 / Pcos30°-70-80x9.8sin20°=80a	M1			
		P = 429 /if P found 1st then Pcos30°x25 =9290 ok	A1	3		**8**

5	(i)	D = 3000/5^2 = 120	M1			
			A1	2	**AG**	
	(ii)	120 – 75 = 100a	M1			
		a = 0.45 ms^{-2}	A1	2		
	(iii)	100x9.8x1/98	B1		weight component	
		3000/v^2=3v^2+100x9.8x1/98	M1			
		3000 = 3v^4 + 10v^2	A1		aef	
		solving quad in v^2	M1		(v^2 = 30)	
		v = 5.48 ms^{-1}	A1	5	accept $\sqrt{30}$	**9**

6	(i)	com of Δ 4 cm right of C	B1			
		1.5 x 10 + 7 x 20 = $\bar{x}$ x 30	M1			
			A1			
		$\bar{x}$ = 5.17	A1		5 1/6 31/6	
		com of Δ 6 cm above E	B1		or 3 cm below C	
		4.5 x 10 + 6 x 20 = $\bar{y}$ x 30	M1			
			A1			
		$\bar{y}$ = 5.5	A1	8		
	(ii)	tanθ = 5.17/3.5	M1		right way up and (9 – $\bar{y}$)	
		55.9° or 124°	A1√	2	√ their $\bar{x}$ /(9 – $\bar{y}$)	
	(iii)	d = 15sin45° (10.61)	B1		dist to line of action of T	
		Td = 30 x 5.17	M1		allow Tx15 i.e. T vertical	
		T = 14.6	A1	3		**13**

7	(i)	T sin30°	B1			
		T sin30° = 0.3x0.4x2^2	M1		resolving horizontally	
			A1			
		T = 0.96	A1	4		
	(ii)	R + Tcos30° = 0.3x9.8	M1		resolving vertically	
			A1			
		R = 2.11	A1✓	3	✓ their T (2.94 – Tcos30°)	
	(iii)	T_1sin30° = 0.3 x v^2/0.4	M1		or 0.3x0.4xω^2	
			A1		($T_1 = 1.5v^2$)	
		T_1cos30° = 0.3 x 9.8	B1		($T_1 = 1.96\sqrt{3} = 3.3948$)	
		R = 0	B1		may be implied or stated	
		tan30°=v^2/(0.4 x 9.8)for elim of T_1	M1		and v=0.4ω (ω = 3.76)	
		v = 1.50	A1	6		**13**

8	(i)	v_v = 42sin30° (=21)	B1			
		0 = 21^2 – 2x9.8xh	M1			
		h = 22.5	A1	3		
	(ii)	v_h = 42cos30° (=36.4)	B1			
		v_v = ±v_h x tan10°	M1			
		v_v = ±6.41 or 21√3 tan10°	A1		or 42cos30°.tan10°	
		–6.41 = 42sin30° – 9.8t	M1	**	must be –6.41(also see "or" x 2)	
		t = 2.80	A1	**		
		y=42sin30°x2.8 – 4.9x2.8^2	M1	**		
		y = 20.4	A1✓	**	✓ their t	
		x = 42cos30° x 2.80	M1			
		x = 102	A1✓		✓ their t	
		$\sqrt{(x^2 + y^2)}$	M1			
		d = 104	A1	11		
	or	$6.41^2 = 21^2$ + 2 x -9.8s	M1	**	vert dist first then time	
		s = 20.4	A1	**		
		20.4 = 21t + ½. -9.8t^2	M1	**		
		t = 2.80	A1	**		
	or	22.5 – s and 6.41^2=2x9.8s	M1	**	dist from top (s = 2.096)	
		y = 20.4	A1	**		
		22.5 & 2.1 = ½.9.8t^2	M1	**	2 separate times (2.143, 0.654)	
		t = 2.80	A1	**	2.143 + 0.654	**14**
		alternatively				
	(ii)	$y = x/\sqrt{3} - x^2/270$ aef	B1		y=xtan30°–9.8x^2/2.42^2.$\cos^2$30°	
		d*y*/d*x* = 1/√3 – *x*/135	M1		for differentiating	
			A1		aef	
		d*y*/d*x* = – tan10°	M1		must be –tan10°	
		1/√3 – *x*/135 = – tan10°	A1			
		solve for *x*	M1			
		x = 102	A1✓		✓ on their d*y*/d*x*	
		$y = x/\sqrt{3} - x^2/270$	M1			
		y = 20.4	A1✓		✓ their *x*	
		$\sqrt{(x^2 + y^2)}$	M1			
		d = 104	A1	(11)		

1	40 cos35°	B1	
	WD = 40cos35° x 100	M1	
	3280 J	A1 **3**	ignore units **3**

2	$0 = 12\sin 27°t - 4.9t^2$ any correct.	M1	**or** $R = u^2\sin 2\theta/g$ (B2)
	t = 1.11 …..method for total time	A1	correct formula only
	R = 12cos27° x t	M1	12^2 x sin54° / 9.8 sub in values
	11.9	A1 **4**	11.9 **4**

3 (i)	$WD = ½ x250x150^2 - ½ x250x100^2$	M1	
	1 560 000	A1	1 562 500
	450 000 = 1 560 000/t	M1	
	3.47	A1 **4**	
(ii)	F = 450 000/120	M1	
	3750	A1	
	3750 = 250a	M1	
	15 ms^{-2}	A1 **4**	**8**

4 (i)	$x = 7t$	B1	
	$y = 21t - 4.9t^2$	M1	**or** – g/2
		A1	
	$y = 21.x/7 - 4.9\, x^2/49$	M1	
	$y = 3x - x^2/10$	A1 **5**	**AG**
(ii)	$-25 = 3x - x^2/10$ (must be -25)	M1	**or** method for total time (5.26)
	solving quadratic	M1	**or** 7 x total time
	36.8 m	A1 **3**	**8**

5(i)	$½ . 70 .4^2$	M1	
	560 J	A1 **2**	
(ii)	70 x 9.8 x 6	M1	
	4120	A1 **2**	4116
(iii)	60d	B1	
	8000 = 560 + 4120 + 60d	M1	4 terms
		A1 √	√ their KE and PE
	55.4 m	A1 **4**	**8**

6 (i)	5cos30° = 0.3x9.8 + Scos60°	M1	res. vertically (3 parts with comps)
		A1	
	2.78 N	A1 **3**	
(ii)	r = 0.4sin30° = 0.2	B1	may be on diagram
	5sin30° + Ssin60° =0.3 x 0.2 x ω^2	M1	res. horizontally (3 parts with comps)
	9.04 rads^{-1}	A1 **3**	
(iii)	v = 0.2 x 9.04	M1	**or** previous v via mv^2/r
	KE = ½ x 0.3 x $(0.2 \times 9.04)^2$	M1	
	0.491 J or 0.49	A1√ **3**	√ their ω^2 x 0.006 **9**

7 (i)	1.8 = –0.3 + 3m	M1	
	m = 0.7	A1 **2**	**AG**
(ii)	e = 4/6	M1	accept 2/6 for M1
	2/3	A1 **2**	accept 0.67
(iii)	± 3f	B1	
	1/3 ≤ f (≤ 1)	B1 **2**	
(iv)	I = 3f x 0.7 – – 3 x 0.7	M1	ok for only one minus sign for M1
		A1	
	I = 2.1 (f + 1)	A1 **3**	aef 2 marks only for -2.1(f + 1)
(v)	0.3 + 6.3/4 = 0.3*a* + 0.7*b*	M1	can be – 0.7*b*
	3*a* + 7*b* = 18.75	A1 *	aef
	2/3 = (*a* – *b*)/ 5/4	M1	allow e=3/4 or their e for M1
	3*a* – 3*b* = 5/2	A1 *	aef * means dependent.
	solve	M1	
	a = 2.5	A1	(2.46) allow ± (59/24)
	b = 1.6	A1 **7**	(1.625) allow ± (13/8) **16**

8 (i)	com of hemisphere 0.3 from *O*	B1	**or** 0.5 from base
	com of cylinder *h*/2 from *O*	B1	
	0.6x45 = 40x0.5 + (0.8+*h*/2) x 5 **or**	M1	**or** 40x0.3 – 5xh/2 = 45 x 0.2
	45(h+0.2) = 5h/2 +40(h+0.3)	A1	**or** 5(0.2 + h/2) = 40x0.1
	27 = 20 + (0.8+*h*/2) x 5	M1	solving
	h = 1.2	A1 **6**	**AG**
(ii)	1.2 T	B1	
	0.8 F	B1	
	0.8F = 1.2T	M1	
	F = 3T/2	A1 **4**	aef
(iii)	F + Tcos30°	B1	**or** 45 x 0.8 sin30°
	45sin30° must be involved in res.	B1	T x (1.2 + 0.8cos30°)
	resolving parallel to the slope	M1	mom. about point of contact
	F + Tcos30° = 45sin30° aef	A1	45.0.8sin30°=T(1.2+0.8cos30°)
	T = 9.51	A1	
	F = 14.3	A1 **6**	**16**
or	T + Fcos30° = Rsin30°	B1	res. horizontally
(iii)	Rcos30° + Fsin30° = 45	B1	res. vertically
	tan30°=(T+Fcos30°)/(45-Fsin30°)	M1	eliminating R

4729 Mechanics 2

1 (i)	12 x cos55° 6.88 m s^{-1}	M1 A1 **2**	
(ii)	12 x cos55° x 0.65 (±) 4.47 m s^{-1} ✓	M1 A1 **2**	✓ 0.65 x their (i) **4**

2	F = 0.2 mg cos30° 0.2mgcos30° x d mg x d x sin30° d=½x25/(0.2x9.8cos30°+9.8xsin30°) 1.89 m	M1 A1 B1 B1 M1 A1 **6**	= = (1.6974m) (49√3/50m) a=0.2gcos30°+gsin30° a= (±) 6.60 $0 = 5^2 - 2x6.60d$ **6**

3	direction of R perp. to wall R at 70° to rod 0.8 x 25cos60° = 1.6 x R sin70° 0.8 x 25 cos60° 1.6 x R sin70° R = 6.65 N	B1 B1 M1 A1 A1 A1 **6**	 10° to horiz. moments about A **6**

4 (i)	45 000/v = kv k = 50	M1 A1 **2**	**AG**
(ii)	45 000/20 – 50x20 = 1200a a = 1.04 m s^{-2}	M1 A1 A1 **3**	
(iii)	P/15 = 50x15 + 1200x9.8sin10° 41 900 W	M1 A1 A1 **3**	**8**

5 (i)	2mu – 3kmu = –mu + kmv v = ….. v = 3u(1 – k)/k (0 <) k < 1	M1 M1 A1 A1 **4**	 attempting to make v the subject 3u/k – 3u not ≤ 1
(ii)	I = mu – – 2mu 3mu	M1 A1 **2**	or km(3u/k - 3u + 3u) + only
(iii)	v = ± 3u e = (u/2 + 3u)/4u e = 7/8 or 0.875	B1 M1 A1 **3**	**9**

6 (i)(a)	$T\cos 45° = 2.94$ $T = 4.16$ N	M1 A1 **2**	Resolving vertically **AG**
(b)	$T\cos45° + T = 0.3\text{x}1.96\omega^2$ (res. horiz.) $\omega = 3.47$ rad s^{-1}	M1 A1 A1 **3**	calculates v = 6.81 (Max 2/3)
(ii)(a)	$T\cos30° + T\cos60° = 2.94$ $T = 2.15$ N	M1 A1 A1 **3**	Resolving vertically
(b)	$T\cos30° + T\cos60° = 0.3v^2/1.5$ (res. horiz.) $v = 3.83$ m s^{-1}	M1 A1 A1 **3**	calculates $\omega = 2.56$ (Max 2/3) **11**

7 (i)	$0 = (175\sin\theta)^2 - 2\text{x}9.8\text{x}650$ $\theta = 40.2°$	M1 A1 A1 **3**	
(ii)	Attempt at t_1, t_2, t_{top} or t_{total} 5.61, 23.65, 14.63, 29.26 $t_2 - t_1$ or $2(t_{top} - t_1)$ or $t_{total} - 2t_1$ time difference = 18.0	M1 A1 M1 A1 A1 **5**	$650 = 175\sin55°.t - 4.9t^2$ etc
(iii)	$v_h = 175\cos55°$ (100.4) $v_v = 175\sin55° - 9.8 \text{ x } 5.61$ speed = $\sqrt{(88.4^2 + 100.4^2)}$ 134 m s^{-1}	B1 M1 M1 A1 **4**	or KE ½mv^2 (B1) PE mx9.8x650 $v = \sqrt{(175^2 - 2\text{x}9.8\text{x}650)}$ **12**

8 (i)	$(2\text{x}4\text{x}\sin\Pi/2)/3\text{x}\Pi/2$ 1.70	M1 A1 **2**	or $4r/3\Pi$ **AG**
(ii)(a)	$\bar{x}\,\text{xd}(8\text{x}20 - \Pi\text{x}4^2/2) = 10\text{x}8\text{x}20\text{d} -$ $12\text{x}\Pi\text{x}4^2/2\text{xd}$ $10\text{x}8\text{x}20(\text{d})$ (1600) $(8\text{x}20 - \Pi\text{x}4^2/2)$ (d) (134.9) $(12\text{x}\Pi\text{x}4^2/2)$ (d) (301.6) $\bar{x} = 9.63$ cm	M1 A1 A1 A1 A1 **5**	or $134.9\bar{x} =$ 64x4+38.9x12+32x18 (1298.8) 64x4 38.9x12 32x18 **AG**
(ii)(b)	$\bar{y}\,\text{xd}(8\text{x}20 - \Pi\text{x}4^2/2) = 4\text{x}8\text{x}20\text{d} -$ $1.7\text{x}\Pi\text{x}4^2/2\text{xd}$ 4x8x20 (d) $1.7\text{d x }\Pi\text{ x }4^2/2$ (13.6Π) $\bar{y} = 4.43$ cm	M1 A1 A1M1 A1 **4**	or $64\text{x}4 = 42.7 + 38.9\bar{y}$ $\bar{y} = 5.49$ $135\bar{y} = 32\text{x}4 + 38.9\text{x}5.49 + 64\text{x}4$
(iii)	20cos10° x T 15cos10° x 9.63 15sin10° x 4.43 20cos10°.T=15cos10°x9.63– 15sin10°x4.43 (needs 3 parts) T = 6.64 N	B1 B1 B1 M1 A1 **5**	= or 10.6 (A to com) 34.7° ∠ comAH =15x10.6xcos34.7° **16**

4729 Mechanics 2

1	200cos35°	B1	
	200cos35° x d = 5000	M1	
	d = 30.5 m	A1 **3**	**3**

2	$0.03R = ½x0.009(250^2 – 150^2)$	M1	$150^2 = 250^2 + 2a \times 0.03$
	0.03R	B1	$a = ±2x10^6/3$ or ±666,667 (A1)
	either K.E.	B1	F = 0.009a (M1)
	R = 6000 N	A1✓ **4**	✓ unit errors **4**

3 (i)	D = 12000/20	B1	
	12000/20=k x 20 + 600 x 9.8 x 0.1	M1	
	k = 0.6	A1 **3**	**AG**
(ii)	16000/v = 0.6v + 600 x 9.8 x 0.1	M1	
	$0.6 v^2 + 588v – 16000 = 0$	M1	attempt to solve quad. (3 terms)
	v = 26.5 m s^{-1}	A1 **3**	
(iii)	16000/32 – 0.6 x 32 = 600a	M1	
		A1	
	a = 0.801 m s^{-2}	A1 **3**	0.80 or 0.8 **9**

4 (i)	$0 = 35\sin\theta \times t – 4.9t^2$	M1	$R=u^2\sin2\theta/g$ only ok if proved
	t = 35sinθ/4.9 50sinθ/7	A1	or 70sinθ/g aef
	R = 35cosθ x t aef	B1	their t
	$R = 35^2\sin\theta.\cos\theta/4.9$	M1	eliminate t
	R = 125sin2θ	A1 **5**	**AG**
(ii)	110 = 125sin2θ	M1	
	θ = 30.8° or 59.2°	A1+1	
	t = 3.66 s or 6.13 s	A1+1 **5**	**10**

5 (i)	3/8 x 3 (1.125)	B1	c.o.m. hemisphere
	0.53d = 5x0.02 + (10 + 3/8x3) x 0.5	M1	0.53e=3x5/8x0.5+8x0.02+13x .01
		A1	0.53f=3x3/8x0.5-5x0.02-10x0.01
	d = 10.7	A1 **4**	**AG (**e = 2.316 f = 0.684**)**
(ii)	Attempt to calc a pair relevant to P,G	M1	distance / angle
	OP=0.9 (pair) , p= 73.3° q=16.7° r=76.9° (77.2°) , s=13.1°(12.8°) AC=0.86 , BC=0.67 , AD=10.4 BD=10.2	A1	not a complimentary pair
	r > p , s < q , p + s < 90 , 0.67 < 0.86 , 10.2 < 10.4	M1	make relevant comparison 0.7 < 0.9 (OG < OP) 10.7 < 10.9
	it is in equilibrium	A1 **4**	**8**

6 (i)	$T\cos60° = S\cos60° + 4.9$	M1		Resolving vertically nb for M1:
		A1		(must be components – all 4 cases)
	$T\sin60° + S\sin60° = 0.5 \times 3^2/0.4$	M1		Res. Horiz. $mr\omega^2$ ok if $\omega \neq 3$
		A1		If equal tensions $2T=45/4$ M1 only
	$(S + 9.8)\sin60° + S\sin60° = 45/4$	M1		
	$S = 1.60$ N	A1		
	$T = 11.4$ N	A1	**7**	
(ii)	$T\cos60° = 4.9$	M1		Resolving vertically (component)
	$T = 9.8$	A1		
	$T\sin60° = 0.5 \times 0.4\omega^2$	M1		Resolving horiz. (component)
		A1		
	$\omega = 6.51$ rad s^{-1}	A1	**5**	or 6.5 **12**

7 (i)	$u = 3$ m s^{-1}	B1		
	$6 = 2x + 3y$	M1		
		A1		
	$e = (y - x)/3$	M1		
		A1		($e = ⅔$) (equs must be consistent)
	$y = 2$	A1	**6**	**AG**
(ii)	$v_h = 2$	B1		or (B1) $½m\text{x}2^2$
	$v_v^2 = 2 \times 9.8 \times 4$	M1		(B1) $½m\text{x}v^2$
	$v_v = 8.85$ ($14\sqrt{10}/5$)	A1		
				(B1) mx9.8x4
	speed = $\sqrt{(8.85^2 + 2^2)}$	M1		$v = \sqrt{(2^2 + 2\text{x}9.8\text{x}4)}$
	9.08 m s^{-1}	A1		
	$\tan^{-1}(8.85/2)$	M1		or $\cos^{-1}(2/9.08)$
	77.3° to horizontal	A1	**7**	12.7° to vertical **13**

8 (i)	com of Δ 3 cm right of C	B1		
	$(48+27)\bar{x} = 48\text{x}4 + 27\text{x}11$	M1		
		A1		
	$\bar{x} = 6.52$	A1		
	com of Δ 2 cm above AD	B1		
	$(48+27)\bar{y} = 48\text{x}3 + 27\text{x}2$	M1		
		A1		
	$\bar{y} = 2.64$	A1	**8**	
(ii)	14F	B1		can be implied e.g. 7/sin30°. F
	3gcos30° x 6.52	B1		7.034 (AG) or (6.52-2.64tan30°)
	3gsin30° x 2.64	B1		52.0° (GAH) or (above)xcos30°
				(5.00)xcos30° (4.33)
	14F=3gcos30°x6.52- 3gsin30°x2.64	M1		14F = 3x9.8x7.034xcos52.0°
	F = 9.09 N	A1	**5**	**13**

4729 Mechanics 2

1	$(20 \sin \theta)^2 = 2 \times 9.8 \times 17$	M1	or B2 for
		A1	max ht = $v^2\sin^2\theta/2g$
	$\sin \theta = \sqrt{(2 \times 9.8 \times 17)} \div 20$	M1	subst. values in above
	$\theta = 65.9°$	A1 **4**	**4**

2	$\bar{x} = 8$	B1	
	T sin30° x 12 = 8 x 2 x 9.8	M1	ok if g omitted
		A1 ft	ft their $\bar{x}$
	T = 26.1	A1 **4**	**4**

3 (i)	140 x X = 40 x 70	M1	
	X = 20 N	A1	
	at *F* 20 N to the right	B1	inspect diagram
	at *G* 20 N to the left	B1 **4**	**SR** B1 for correct directions only
(ii)	đ = (2x40sinΠ/2)÷3Π/2	M1	must be radians
		A1	
	đ = 17.0	A1	16.98 160/3Π (8/15Π m)
	$70\,\bar{y} = 100 \times 60 + 217 \times 10$	M1	
		A1 ft	ft 200 + their đ or 2 + their đ (m)
	$\bar{y} = 117$	A1 **6**	116.7 **10**

4 (i)	$P/10 - 800 \times 9.8\sin 12° - 100k = 800 \times 0.25$	M1	$P/10 = D_1$ ok
		A1	D_1 ok
	$P/20 - 400k = 800 \times 0.75$	M1	$P/20 = D_2$ ok
		A1	$D_1 = 2D_2$ needed for this A1
	solving above	M1	
	$k = 0.900$	A1	**AG** 0.9000395
	$P = 19\,200$	A1 **7**	or 19.2 kW (maybe in part (ii))
(ii)	$0.9\,v^2 = 28\,800/v$	M1	ok if $19200/v$
	solving above	M1 *	($v^3 = 32\,000$)
	$v = 31.7$ m s^{-1}	A1 **3**	**10**

5 (i)	$0.8\,S$	B1	vert comp of *S*
	$0.6\,T$	B1	vert comp of *T*
	$S \cos\alpha = T \cos\beta + 0.2 \times 9.8$	M1	
	$0.8\,S = 0.6\,T + 1.96$ aef	A1 **4**	**AG** $4S = 3T + 9.8$
(ii)	$0.6\,S$	B1	
	$0.8\,T$	B1	
	$0.2 \times 0.24 \times 8^2$	B1	3.072 384/125
	$S \sin\alpha + T \sin\beta = 0.2 \times 0.24 \times 8^2$	M1	must be $mr\omega^2$
	$6S + 8T = 30.72$	A1	aef
	eliminate *S* or *T*	M1	
	$S = 3.4$ N	A1	3.411
	$T = 1.3$ N	A1 **8**	1.282 **12**

6 (i)	x = vcosθ t	B1	
	y = vsinθ t – ½ x 9.8 t^2	B1	or g
	substitute t = x/vcosθ	M1	
	y = xtanθ – 4.9x^2 /v^2 $\cos^2$ θ	A1 **4**	**AG**
(ii)	Sub y = -*h* , x = *h* , v = 14 , θ =30	M1	signs must be correct
	–*h* = *h*/√3 – h^2/30	A1	aef
	solving above	M1	
	h = 47.3	A1 **4**	
(iii)	v_v^2 = $(14\sin30°)^2$ – 2x9.8x(-47.3)	M1	14cos30° t=47.3 ft & v_v =14sin30°-9.8t
	(double negative needed) ft their -47.3	A1 ft	t = 3.90 (or dy/dx=1/√3 – x/15 etc ft)
	v_v = ±31.2	A1	v_v = ±31.2 (tanα = 1/√3 – 47.3/15)
	$\tan^{-1}$(31.2/14cos30°)	M1	$\tan^{-1}$(31.2/14cos30°)
	α= 68.8° below horiz/21.2° to d'vert.	A1 **5**	68.8°/…..
(iv)	½mx14^2 + mx9.8x47.3 = ½mv^2	M1	ft (12.1^2 + 31.2^2)
	v = 33.5	A1 **2**	33.5 **15**

7 (i)	p = 4 m s^{-1}	B1	P's first speed
	0.8 = 0.2p_1 + 0.3q_1	M1	
		A1	
	0.5 = (q_1 – p_1)/4	M1	
		A1	
	solving above	M1	
	q_1 = 2.4 12/5	A1	Q's first speed
	p_1 = 0.4 2/5	A1 **8**	may be in (ii). **SR** 1 for both negative
(ii)	0.8 = 0.2p_2 + 0.3q_2	M1	
		A1	
	0.5 = (p_2 – q_2)/2	M1	
		A1	
	solving above	M1	
	p_2 = 2.2 11/5	A1	
	q_2 = 1.2 6/5	A1 **7**	
(iii)	R = 0.3 x 1.2^2 /0.4	M1	
	R = 1.08 N	A1 **2**	**17**

4729 Mechanics 2

1 (i)	½×75×12² or ½×75×3² (either KE) 75×9.8×40 (PE) R×180 (change in energy = 24337) ½×75×12²=½×75×3²+75×9.8×40–R×180 R = 135 N	B1 B1 B1 M1 A1 **5**	M1 $12^2 = 3^2 + 2a \times 180$ A1 $a = 0.375$ (3/8) M1 $75 \times 9.8 \times \sin\theta - R = 75a$ A1 $R = 135$ (max 4 for no energy) **5**

2 (i)	$R = F = P/v = 44\ 000/v = 1400$ $v = 31.4$ m s^{-1}	M1 A1 **2**	
(ii)	$44\ 000/v = 1400 + 1100 \times 9.8 \times 0.05$ $v = 22.7$ m s^{-1}	M1 A1 A1 **3**	must have g
(iii)	22 000/10 + 1100×9.8×0.05 – 1400 = 1100a $a = 1.22$ m s^{-2}	M1 A1 A1 **3**	**8**

3 (i)	$\cos\theta = 5/13$ or $\sin\theta = 12/13$ or $\theta = 67.4°$ 0.5×$F\sin\theta$ = 70×1.4 + 50 × 2.8 F = 516 N	B1 M1 A1 A1 **4**	any one of these moments about A (ok without 70) 0.5sinθ = 0.4615 **SR** 1 for 303 (omission of beam)
(ii)	$F \sin\theta = 120 + Y$ (resolving vertically) Y = 356 ✓ their F × 12/13 – 120 $X = F\cos\theta$ (resolving horizontally) X = 198 ✓ their F × 5/13 Force = √(356² + 198²) 407 or 408 N	M1 A1 ✓ M1 A1 ✓ M1 A1 **6**	M1/A1 for moments (B)Y×2.8+1.4×70=2.3×516✓×12/13 (C) 0.5×Y = 0.9×70 + 2.3×50 (D) 1.2X = 1.4×70 +2.8×50 **10**

4 (i)	$T = 0.4 \times 0.6 \times 2^2$ T = 0.96 N	M1 A1 **2**	
(ii)	$S - T$ $S - T = 0.1 \times 0.3 \times 2^2$ S = 1.08	B1 M1 A1 A1 **4**	may be implied
(iii)	$v = r\omega$ $v_P = 0.6$ $v_B = 1.2$ ½×0.1×0.6² + ½×0.4×1.2² 0.306	M1 A1 A1 M1 A1 **5**	 (0.018 + 0.288) separate speeds **11**

5 (i)	$\bar{r} = (2\times 6\sin\pi/4)/3\pi/4$ $\bar{r} = 3.60$	M1 A1 **2**	must be correct formula with rads AG
(ii)	$\bar{r}\cos45° =$ "2.55" $5\bar{x} = 3\times3 + 2\times$ "2.55" $\bar{x} = 2.82$ $5\bar{y} = 3\times6 + 2\times(12 +$ "2.55") $\bar{y} = 9.42$	B1 M1 A1 A1 M1 A1 A1 **7**	 may be implied moments must not have areas 2kg/3kg misread (swap) gives (2.73,11.13) θ = 21.7° (MR – 2) (max 7 for (ii) + (iii)) SR -1 for $\bar{x}$, $\bar{y}$ swap
(iii)	$\tan\theta = 2.82/8.58$ $\theta = 18.2°$ ✓	M1 A1 **2**	M0 for their $\bar{x}$ / $\bar{y}$ ✓ their $\bar{x}/(18 - \bar{y})$ **11**

6 (i)	$I = 0.9 = 6\times0.2 - v\times0.2$ $v = 1.5$	M1 A1 A1 **3**	needs to be mass 0.2
(ii)	$0.6 = (c - b)/6$ $6\times0.2 = 0.2b + 0.1c$ $b = 2.8$ $0.4\times5 + 0.2\times1.5 = 0.4a + 0.2\times6$ or $I = 0.9 = -0.4a - -\ 0.4\times5$ $a = 2.75$ $2.75 < 2.8$ no further collision	M1 A1 M1 A1 A1 M1 A1 A1 M1 A1 **10**	restitution (allow 1.5 for M1) momentum (allow 1.5 for M1) 1st collision (needs their 1.5 for M1) compare v's of A and B (calculated) **13**

7(i)	$9 = 17\cos25°\times t$ $t = 0.584$ (or 9/17cos25°) $d = 17\sin25°\times0.584 + ½\times9.8\times0.584^2$ ($d = ht$ lost (5.87) $h = 2.13$	M1 A1 M1 A1 A1 **5**	B1 $y = x\tan\theta - 4.9x^2/v^2\cos^2\theta$ M1/A1 $y = 9\tan(-25°) - 4.9\times9^2/17^2\cos^2 25°$ A1 y = -5.87 2.13
(ii)	$v_h = 17\cos25°$ (15.4) $v_v = 17\sin25° + 9.8\times0.584$ or $v_v^{\ 2} = (17\sin25°)^2 + 2\times9.8\times5.87$ $v_v = 12.9$ $\tan\theta = 12.9/15.4$ $\theta = 40.0°$ below horizontal	B1 M1 A1 M1 A1 **5**	M1/A1 dy/dx = $\tan\theta - 9.8x/v^2\cos^2\theta$ A1 dy/dx = -0.838 M1 $\tan^{-1}$(-.838) or 50.0° to vertical
(iii)	speed = $\sqrt{(12.9^2 + 15.4^2)}$ $½mv^2 = ½m\times20.1^2\times0.7$ $v = 16.8$ m s^{-1}	M1 A1 ✓ M1 A1 **4**	(20.1) NB 0.3 instead of 0.7 gives 11.0 (M0) **14**

4729 Mechanics 2

1	75×9.8×40 (75×9.8×40)÷120 245 W	B1 M1 A1 **[3]**	Average Speed = 40÷120 (75×9.8)×(Average speed) **3**
2 (i)	$v^2 = 2\times9.8\times3$ or $2\times9.8\times1.8$ $v_1 = \sqrt{6g}$ or $\sqrt{58.8}$ or $\frac{7}{5}\sqrt{30}$ or 7.67 $v_2 = \sqrt{3.6g}$ or $\sqrt{35.28}$ or $\frac{21}{5}\sqrt{2}$ or 5.94 $I = \pm 0.2(5.94 + 7.67)$ 2.72	M1 A1 A1 M1 A1ft **[5]**	Kinematics or energy Speed of impact (±) Speed of rebound (±) +ve, ft on v_1 and v_2
(ii)	e = 5.94/7.67 0.775 or $\frac{\sqrt{15}}{5}$	M1 A1ft **[2]**	Allow 0.774, ft on v_1 and v_2 **7**
3 (i)	$\bar{u} = 0.2$ (from vertex) or 0.8 or 0.1 $0.5\bar{d} = 0.2\times\bar{u} + 0.3\times0.65$ $\bar{d} = 0.47$	B1 M1 A1 A1 **[4]**	com of conical shell **AG**
(ii)	s = 0.5 Tsin80°× 0.5 = 0.47 × 0.5 × 9.8 T = 4.68 N	B1 M1 A1 A1 **[4]**	slant height, may be implied **8**
4 (i)	D – 400 = 700 × 0.5 D = 750 N	M1 A1 **[2]**	3 terms
(ii)	P = 750 × 12 9 000 W or 9 kW	M1 A1ft **[2]**	
(iii)	P/35 = 400 14 000 W or 14 kW	M1 A1 **[2]**	
(iv)	D = 14000/12 3500/3 = 400 + 700×9.8sinθ θ = 6.42°	B1ft M1 A1 A1 **[4]**	May be implied 3 terms Their P/12 **10**

5	$16 - 12 = 2x + 3y$	M1	
	$4 = 2x + 3y$	A1	aef
	$½.2(8)^2 + ½.3(4)^2$ or $½.2x^2 + ½..3y^2$ or $±½.2(8^2 - x^2)$ or $±½.3(4^2 - y^2)$	B1	
	$½.2(8)^2 + ½.3(4)^2 - ½.2x^2 - ½...3y^2 = 81$	M1	
	$2x^2 + 3y^2 = 14$	A1	aef
	Attempt to eliminate x or y from a linear and a quadratic equation	M1	
	$15y^2 - 24y - 12 = 0$ or $10x^2 - 16x - 26 = 0$	A1	aef
	Attempt to solve a three term quadratic	M1	
	$x = -1$ (or $x = 2.6$)	A1	
	$y = 2$ (or $y = -2/5$)	A1	
	$x = -1$ and $y = 2$ only	A1	
	speeds 1, 2 away from each other	A1 **[12]**	**12**
6 (i)	$30^2 = V_1^2 \sin^2 \theta_1 - 2×9.8×250$	M1	$½m\, V_1^2 = ½m\, 50^2 + m×9.8×250$
	$V_1^2 \sin^2 \theta_1 = 5800$ AEF	A1	
	$V_1 \cos \theta_1 = 40$	B1	
	$V_1 = 86.0$	A1	**AG**
	$\theta_1 = 62.3°$	A1 **[5]**	**AG**
(ii)	$0 = \sqrt{5800}\, t_p - 4.9t_p^2$	M1	$30 = V_1 \sin \theta_1 - 9.8t$
	$t_p = 15.5$	A1	$t = 4.71$
	$-\sqrt{5800} = 30 - 9.8t_q$	M1	
	$t_q = 10.8$	A1 **[4]**	
(iii)	$R = 40×15.5$	M1	
	$R = 621$	A1	(620, 622)
	$V_2 \cos \theta_2 × 10.8 = 621$	B1	$V_2 \cos \theta_2 = 57.4$
	$0 = V_2 \sin \theta_2 × 10.8 - 4.9 × 10.8^2$	M1	
	$V_2 \sin \theta_2 = 53.1$ or 53.0	A1	(52.9,53.1)
	Method to find a value of V_2 or θ_2	M1	
	$\theta_2 = 42.8°$	A1	42.6° to 42.9°
	$V_2 = 78.2$ m s^{-1} or 78.1 m s^{-1}	A1 **[8]**	or 78.1° **17**
7 (i)	$\cos\theta = 3/5$ or $\sin\theta = 4/5$ or $\tan\theta = 4/3$ or $\theta = 53.1°$	B1	θ = angle to vertical
	$R\cos\theta = 0.2×9.8$	M1	
	$R = 3.27$ N or $49/15$	A1 **[3]**	
(ii)	$r = 4$	B1	
	$R\sin\theta = 0.2×4×\omega^2$	M1	
		A1	
	$\omega = 1.81$ rad s^{-1}	A1 **[4]**	

(iii)	φ = 26.6° or $\sin\varphi = \frac{1}{\sqrt{5}}$ or $\cos\varphi = \frac{2}{\sqrt{5}}$ or tan φ = 0.5	B1	φ = angle to horizontal
	T = 0.98 or 0.1g	B1	
	Ncosθ = Tsinφ + 0.2×9.8	M1	Vertically, 3 terms
	N×3/5 = 0.438 + 1.96	A1	
	N = 4.00	A1	may be implied
	Nsinθ + Tcosφ = 0.2×4×ω^2	M1	Horizontally, 3 terms
	4×4/5 + 0.98cos 26.6° = 0.8ω^2	A1	
	ω = 2.26 rad s^{-1}	A1 **[8]**	**15**

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

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

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

4 (i)	4Tcos20° = 5 x g x 2.5	M1	Using moments; allow sin/cos mix
		A1	Allow with omission of g
	T = 32.6 N	A1 **3**	
(ii)	X = Tsin20°	M1	allow sin/cos mix
	X = 11.1 FT	A1	FT their T
	Y + Tcos20° = 5 x g	M1	
	or 2.5Y = 1.5 x Tcos20 or 4Y = 1.5 x 5g		
	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	A1	
	θ = 58.8° above the horizontal	A1 **7**	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
	$\omega = 4.16 \text{ rad s}^{-1}$	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. $= 9mv^2 / 8 = 9mu^2 /50$ $½\ m\ (V)^2$ = Final K.E. $V = 3\ u\ /5$	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) F = 0.1 x 9.8 x cos30° (= 0.849) FT ½ x 0.2 x 11^2 - ½ x 0.2 v^2 = 0.2 x 9.8 x 5sin30 + 5 x 0.849 v = 5.44 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 = ±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 = 5cos30°/5.44cos30° t = 0.919 s u = 5.44sin30° (= 2.72) s = 2.72 x 0.919 – 4.9 x 0.919^2 s = -1.6 (or better) Ht drop to *C* = 5sin30° = 2.5 m Ball does not hit the roof	M1 A1 B1 M1 A1 B1 A1 **7**	time to lateral position over *C* Ht dropped **13**
Or first 5 marks of (ii)	y = xtanθ – $gx^2 \sec^2 \theta/2V^2$ 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 = 5.44sin30° (= 2.72) -2.5 = 5.44sin30t – $4.9t^2$ t = 1.04 x = 5.44cos30 x 1.04 = 4.9 (or better) Horizontal distance from B to C = 5cos30 = 4.3(or better) Ball does not hit the roof	B1 M1 A1 A1 A1 B1 A1 **7**	 aef time to position level with *AC*
OR (ii)	y = xtanθ – $gx^2 \sec^2 \theta/2V^2$ 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 = 5.44sin30° = 2.72 -2.5 = 5.44sin30t – $4.9t^2$ t = 1.0 (or better) T = 5cos30°/5.44cos30° T = 0.92 (or better) Ball does not hit the roof	B1 M1 A1 A1 M1 A1 A1 **7**	 aef time to position level with *AC* time to lateral position over *C*

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

Question			Expected Answer	Mark	Rationale/Additional Guidance
1	**(i)**		$3x_G = 2x0.3 + 1x0.6$ OR $3x_G = 2x0.3 + 0$ OR $3x_G = 4x0.3$ OR $3y_G = 1x0.3 + 1x0.6 + 0$ OR $3y_G = 4x0.3 - 1x0.3$ $x_G = 0.4$ (from AD) OR $x_G = 0.2$ (from BC) $y_G = 0.3$m from AB or CD $AG^2 = 0.4^2 + 0.3^2$ AG = 0.5 m	M1 A1 A1 M1 A1 **[5]**	Table of moments idea. M0 for reducing to 1D problem. Masses/weights may be included. Pythagoras with 2 appropriate distances. This may only be seen in (ii), allow M1A1 in this case.
	(ii)		v = 0.5x3 v = 1.5 ms^{-1}	M1 A1 **[2]**	Allow use of candidate's 0.2, 0.4, 0.3, 0.5
2	**(i)**		 $(k25^{3/2})$ x 25 = 15000 k = 4.8 **AG**	M1 A1 A1 **[3]**	Tractive force x speed = power
	(ii)		R = 4.8 x $16^{3/2}$ T – 4.8x$16^{3/2}$ + 700gx1/15 = 700x0.3 P = 59.9 x 16 P = 958 W	B1 M1 A1 M1 A1 **[5]**	307.2 N2L, 4 terms to find tractive force (T) Allow cv(R), R not 600; (T = 59.866..) 16xTractive force

3	**(i)**		$T_A\cos30 + T_B\cos60 = 0.4g$ $2T\cos30 + T\cos60 = 0.4g$ $T_B = 1.76$ N $T_A = 3.51$ N	M1 A1 A1 A1 **[4]**	Resolves vertically, 3 terms T = 1.756. Watch for MR of Tcos30 + 2Tcos60 = 0.4g Accept 3.52
	(ii)		$r = 0.5\sin30$ (= 0.25) $3.51\sin30 + 1.76\sin60 = 0.4\omega^2 0.5\sin30$ $\omega = 5.72$ rad s^{-1}	B1 M1 A1ft A1 **[4]**	 N2L radial, 3 terms cv(1.76, 3.51, 0.25) Accept 5.73
4	**(i)**		WD = 100cos20 x 30 WD = 2820 J	M1 A1 **[2]**	Product of 3 relevant elements. Angle could be 5, 25 or complements 2819.1...
	(ii)		PE = 25g x 30sin5 PE = 641	M1 A1 **[2]**	Product of weight and vertical height. Allow without g 640.6
	(iii)	 **OR**	 2819.1 = 640.6 + 30x70 + $25v^2/2$ $v = 2.51$ ms^{-1} 25a = 100cos20 -70 -25gsin5 a = 0.105 v^2 = 2 x 30 x ‘a’ v = 2.51	M1 A1ft A1 A1 **[4]** *M1 A1 dep*M1 A1 **[4]**	4 term energy equation ft(cv 2820 and cv 641) cao 4 term equation Allow 0.1 here Or equivalent complete method cao

5	**(i)**		$x_H = 3x0.6/8$ $\pi(0.6^2x0.6)(0.6/2)$ - $(0.6^3x2\pi/3)0.225$ $= \pi x0.6^3(1+2/3)x_G$ $x_G = 0.09$ m **AG**	B1 M1 A1 A1 A1 **[5]**	CoM hemisphere ($x_H = 0.225$), may be implied Use of table of moments idea SC Volume of sphere used, max B1M1A1, moment equation fully correct for A1 (3/5) Accept -0.09
	(ii)	**(a)**	mg(0.09cos45) = 2(0.6+0.6cos45+0.6sin45) m = 4.65kg	M1 A1 A1 A1 **[4]**	Attempt at moments (must resolve), allow without g $2(0.6+\sqrt{[0.6^2+0.6^2]})$ (4.6451...)
	(ii)	**(b)**	2/4.6451g $\mu \geq 0.0439$	M1 A1 A1 **[3]**	Ratio force/weight cv(4.65) Correct inequality sign, accept 0.044
6	**(i)**		$0 = (14\sin30)^2 - 2gh$ h = 2.5 m	M1 A1 **[2]**	$h = (14\sin30)x1/1.4 - g(1/1.4)^2/2$ or use $(u^2\sin^2\theta)/2g$
	(ii)		0.4x15 = 0.4(14cos30) + I I = 1.15	M1 A1 A1 **[3]**	Impulse = change in momentum Not 14 or 0 for horizontal speed before impulse aef
	(iii)		$v^2 = (14\sin30)^2 + 15^2$ $v = 16.6$ ms^{-1} $\tan\theta = 14\sin30/15$ OR $\tan\psi = 15/14\sin30$ $\theta = 25(.0)°$ OR $\psi = 65(.0)°$	M1 A1 M1 A1 **[4]**	Not $(14\sin30)^2 + (14\cos30)^2$ Allow $\sqrt{274}$ Correct trig to find an appropriate angle; not 14cos 30 for 15
	(iv)		t = 14sin30/g (= 1/1.4 = 0.7142..) T = 1.43 s R = 14cos30/1.4 + 15/1.4 R = 19.4 m	M1 A1 M1A1 A1 **[5]**	Rise or fall time (not to be given in (i)) Accept 10/7 $(14^2\sin(2x30) + 16.6^2\sin(2x25))/2g$. 14 resolved, 15 not

7	**(i)**		 $b + a = 1.8e$ $0.7b - 0.2a = 0.2 \times 1.8$ $b = 0.4(1+e)$ $a = 1.4e - 0.4$ $1.4e - 0.4 > 0.4 + 0.4e$ $e > 0.8$	M1 A1 M1 A1 M1 A1 A1 M1 A1 **[9]**	Uses restitution $b - a = 1.8e$ Uses momentum $0.7b + 0.2a = 0.2 \times 1.8$, signs consistent with first eqn Solves 2 simultaneous equations (eliminate a or b) $a = 0.4 - 1.4e$ Using $a>b$, correct signs in a essential
	OR	**Last 5 marks**	Using $a > b$ $a > 0.72$ $b > 0.72$ $1.8e > 0.72 + 0.72$ $e > 0.8$	M1 A1 A1 M1 A1	correct signs in a essential
	OR	**Last 5 marks**	Using $a = b$ to find a or b a (or b) $= 0.9e$ and a (or b) $= 0.72$ $e = 0.8$ Convincing argument for correct inequality $e > 0.8$	M1 A1 A1 M1 A1	
	OR	**Last 5 marks**	 $a = 1.4e - 0.4$ or $b = 0.4(1+e)$ Using $a > b$ $a > 0.9e$ or $b < 0.9e$ $e > 0.8$	M1 A1 M1 A1 A1	Solves 2 simultaneous equations (eliminate a or b) aef or multiples thereof correct signs in a essential aef or multiples thereof

	(ii)		$c - (\pm 0.25) = 1 \times 0.75$ $c = 0.5, 1$ $0.75 \times 0.7 = 0.25 \times 0.7 + m\ (\times 1)$ *OR* $0.75 \times 0.7 = -0.25 \times 0.7 + 0.5m$ m = 0.35 (from first equation) m=1.4 (from second equation)	M1 A1A1 M1 A1 A1 **[6]**	Uses restitution with e = 1, either Or 0.75 ± 0.25 Uses momentum conservation with correct combination of sign and c value *OR* $m \times (0.75 \pm 0.25) \pm 0.7 \times 0.25 = 0.75 \times 0.7$
	OR		$\frac{1}{2} \times 0.7 \times 0.75^2 = \frac{1}{2} \times 0.7 \times 0.25^2 + \frac{1}{2}mc^2$ $0.7 \times 0.75 = 0.7 \times (+/-0.25) + mc$ Solving simultaneous equations m = 0.35 m = 1.4	B1 M1 A1 M1 A1 A1	½ may not be seen At least one momentum equation mc = 0.35 and 0.7
			Total	**[72]**	

[END]

1 i	PE = 70x3g KE change =70x($2.1^2 - 1.4^2$)/2 PE change + KE change 2143.75 J	B1 B1 M1 A1 [4]	2058 85.75 Must include evaluation Accept 2140. Allow all values to be negative.
ii **OR**	 20(90 + T) = 2143.75 T = 17.1875 N 70g.0.15 – 90 – T = 70.(-0.06125) T = 17.1875 N	M1 A1ft A1 [3] M1 A1 A1 [3]	Work done = Energy change used ft(cv(2143.75)) accept 17.2 Use of $v^2=u^2 + 2as$ to find a AND use of N2 law(4 terms) accept 17.2

2 i	21000/25 0 = 21000/25 – 25k – 1250gsin2 k = 16.5	B1 M1 A1 A1 [4]	Use of force = power/speed 3 terms cv(21000/25)
ii	 21000/v= 16.5v v = 35.7 ms^{-1}	M1 A1ft A1 [3]	 ft on cv(k)

3 i	 - (8cos30/3)(8^2sin60/2) + (4)(8^2) = (8^2 +8^2sin60/2)(x_G) x_G = 2.09 cm	M1 A1 A1 A1 A1 [5]	Table of moments idea, may include g and/or density. -2.309 x 27.7
ii	tanθ = (2.09/4) θ = 27.6°	M1 A1ft [2]	 ft cv(x_G)

4 ia b	If reversed 2.9 + 2 = e(3 + 1.5) e > 1 impossible 2.9 - 2 = e(3 + 1.5) e = 0.2	M1 A1 [2] M1 A1 [2]	 Award B1 if no explicit numerical justification May be seen in ia
ii	 3m – 0.2x1.5 = 2m + 0.2x2.9 m = 0.88	M1 A1 A1 [3]	Conservation of momentum Accept with g included consistently Do not award if g used
iii	0.68 = 0.2v + 0.2x2.9 v = 0.5 e = 0.5/2.9 e = 0.172	M1 A1 M1 A1 [4]	Impulse = change in momentum Separation speed not 2.9 Allow 5/29

5 i	$x = (7\cos 30)t$ $y = (7\sin 30)t – gt^2/2$ $y = x\tan 30 - gx^2/(2x7^2\cos^2 30)$	B1 B1 M1 A1 [4]	 Attempt to eliminate t $y = x/\sqrt{3} – 2x^2/15$ or $y = 0.577x – 0.133x^2$ aef
ii	 $2x^2/15 – x/\sqrt{3} + 0.6 = 0$ or $9.8t^2 – 7t + 1.2 = 0$ x = 1.73 m or $\sqrt{3}$ m 2.6(0) m or $3\sqrt{3}/2$ m	M1 M1 A1 A1 [4]	Create a 3 term Q.E. in x or t with y = 0.6 Solve 3 term Q.E. for x or t
iii **OR**	$v^2 = (7\sin 30)^2 – 2x9.8x0.6$ $v = 0.7$ ms^{-1} $\tan\theta = 0.7/(7\cos 30)$ θ = 6.59° to horizontal or 83.4° to vertical Attempt to differentiate equation of trajectory $\tan 30 - gx/(7^2\cos^2 30)$ Substitute $x = \sqrt{3}$ and equate to $\tan\theta$ θ = 6.59° to horizontal or 83.4° to vertical	M1 A1 M1 A1 [4] M1 A1 M1 A1 [4]	Using $v^2 = u^2$ -2gs with u a component of 7; can find t first from their x in (i), and then use v = u + at. Use component of 7 Allow $1/\sqrt{3} – 4x/15$ or y' = 0.577 – 0.267x

6 i	 $R\sin30 = 0.3g$ $R\cos30 = 0.3\omega^2 \times 0.12$ $\omega = 11.9$ rads^{-1}	M1 A1 M1 A1 A1 [5]	 $R = 5.88$ or $0.6g$ accept $v^2/0.12$ for acceleration cao
ii	 $S + R\cos30 = 0.3 \times 2.1^2/0.2$ $R = 5.88$ $S = 1.52$ N	M1 A1 B1ft A1 [4]	Resolve and use N2L on sphere Q, 3 terms needed ft cv(R) from (i)
iii	$v_P = 11.9 \times 0.12$, or $h = 0.2/\tan30$ or $0.12/\tan30$ or $0.08/\tan30$ $+/-(Q - P) =$ $0.5 \times 0.3(2.1^2 - (11.9 \times 0.12)^2)$ $+ (0.2/\tan30 - 0.12/\tan30) \times 0.3g$ $Q-P = +/- 0.763$ J	B1 M1 A2ft A1 [5]	cv(ω) from (i) Attempt to calculate KE or PE for both particles KE difference (ft on cv(ω)) or PE difference $Q - P = +/-(0.3556 + 0.4074)$

7 i	 $F \times 0.8 =$ $0.6\cos60 \times 550$ $F = 206.25$	M1 A1 A1 A1 [4]	Attempt at moments Accept 206, cao
ii	 $T \times 2 \times 0.8/\tan30$ $=$ $550 \times (0.8/\sin30 - 0.6\cos60)$ $T = 258$ $R = 550 - T\cos30$ $Fr = T\sin30$ $\mu = 129/326.6$ $\mu = 0.395$	M1* A1 M1* A1 A1 M1* A1 B1* M1dep* A1 [10]	Moment of T about P $T \times 2.77$ Moment of weight about P $550 \times (1.6 - 0.3)$ Accept to 2sf Resolving vertically, 3 terms needed Value for T not required Value for T not required; accept < or ≤ For correct use of $F = \mu R$, $R \neq 550$

OR	T x 0.8/tan30 + 550 x 0.6cos60 = R x 0.8/cos60 R = 550 – Tcos30 Solve for T or R T = 258 or R=326.5625 Fr = Tsin30 μ = 129/326.6 μ = 0.395	M1* A2 M1* A1 M1 A1 B1* M1dep* A1 [10]	Moments about V, 3 terms needed A1 for two terms correct Resolving vertically, 3 terms needed Accept to 2sf Value for T not required; accept < or ≤ For correct use of F = μR, R ≠ 550
OR	Fr x 1.6cos30 + 550 x (1.6sin30 +0.6sin30) = R x (1.6 + 1.6sin30) R = 550 – Tcos30 Fr = Tsin30 Solving for at least one of R, Fr, or T Either R = 326.5625, or Fr = 129(.0017008), or T=258 μ = 129/326.6 μ = 0.395	M1* A2 M1* A1 B1* M1 A1 M1dep* A1 [10]	Moments about Q, 3 terms needed A1 for two terms correct Resolving vertically, 3 terms needed accept < or ≤ Only one needed. Accept to 2sf. For correct use of F = μR, R ≠ 550

Question			Answer	Marks	Guidance
1			$v_x = 40\cos35$ $v_y = 40\sin35 - 9.8 \times 3$ $v = \sqrt{32.8^2 + 6.46^2}$ or $\tan\theta = 6.46/32.8$ $v = 33.4\ \text{ms}^{-1}$ $\theta = 11.1°$ below horizontal	B1 B1 M1 A1 A1 [5]	Expect 32.8, need not be evaluated. Expect –6.46, need not be evaluated. Use of Pythagoras or relevant trig on cv(v_x) and cv(v_y) AEF; allow 11.2
2	(i)		$h = r\tan\alpha$ $x(\frac{2}{3}\pi r^3 + \frac{1}{3}\pi r^2 h) = \frac{1}{3}\pi r^2 h \times \frac{h}{4} - \frac{2}{3}\pi r^3 \times \frac{3}{8}r$ $x = \dfrac{r(\tan^2\alpha - 3)}{8 + 4\tan\alpha}$	B1 M1 A1 A1 [4]	Seen anywhere and in any form. Table of values idea. **AG** www
2	(ii)		$x < 0$ Solve $\tan^2\alpha - 3 < 0$ $\alpha < 60$	B1 M1 A1 [3]	May be implied. Condone = Condone $\leq$ throughout. SC Use of = or > throughout. Max B0 M1 A0
3	(i)		 $P \times 1.6 = 10g\cos60 \times 1.2$ $P = 36.75$ N	M1 A1 A1 [3]	Moments about A. Allow 36.8
3	(ii)		 $R + 36.75\sin30 = 10g$ $F = 36.75\cos30$ $\mu = 31.8/79.6$ $\mu = 0.4(00)$	M1 A1 FT B1 FT M1 A1 [5]	Attempt at resolving vertically or taking moments. May be implied. $R = 79.6(25)$ Expect 31.8. Or second correct equation involving F or R or both. For use of (their)$F = \mu$(their)R R not $= 10g$ or their P from **(i)**. AWRT www. Allow inequality

Question			Answer	Marks	Guidance
4	(i)	(a)	$\sin\theta = ½$ or $\theta = 30$ $T\cos\theta = 0.2 \times 1.2\cos\theta \times 2.5^2$ $T = 1.5$ N	B1 M1 A1 A1 [4]	θ is angle with horizontal. May have angle with vertical. May be seen later. Attempt at resolving horizontally. cv(r) but not $r = 1.2$ Rounding to 1.5
4	(i)	(b)	 $R + T\sin\theta = 0.2g$ $R = 1.21$ N	M1 A1 FT A1 [3]	Attempt at resolving vertically. FT on cv(T)
4	(ii)		$r = \sqrt{1.2^2 - 0.6^2} = 1.2\cos\theta$ $R = 0$ $T_1\sin\theta = 0.2g$ $T_1\cos\theta = 0.2 \times v^2/_r$ or $0.2 \times r\omega^2$ $v = 4.2$ ms^{-1}	B1 B1 B1 M1 A1 [5]	May been seen in **(i)**, must be used in here. May be implied. Attempt at resolving.
5	(i)		25000/10 1500$g$sin5 2500 – 750 – 1500$g$sin5 = 1500a $a = 0.313$	B1 B1 M1 A1 A1 [5]	 1281.1 Attempt at N2L with 4 terms. cv(1500$g$sin5); cv(2500) not 25000. Allow 0.31
5	(ii)		WD against resistance = 750d WD by engine = 25000×28 (= 700000) Change in PE = 1500g × $d$sin5 Change in KE = ±½ ×1500 × ($20^2 - 10^2$) 25000×28 = ½ ×1500 ×($20^2 - 10^2$) + 750d + 1500g × $d$sin5 $d = 234$	B1 B1 B1 B1 M1 A1 A1 [7]	750h/sin5 1500g × h Use of correct formula for KE. Use conservation of energy, at least 3 used including WD by engine.

Question			Answer	Marks	Guidance
6	(i)		$v^2 = 2 \times 9.8 \times 3.136$ $v = 7.84$ Rebound speed = $7.84e$ $I = \pm 0.5(7.84 + 7.84e) = \pm 3.92(1 + e)$	M1 A1 B1 FT B1 FT [4]	Uses $v^2 = u^2 + 2as$ or energy with $u = 0$. Signs must be consistent. Ignore –ve. AEF seen. FT on cv(v).
6	(ii)		$-7.84e = 7.84e - gt$ $t = 1.6e$ **AG**	M1 A1 [2]	Uses a complete method to find t.
6	(iii)	(a) (b)	$t_2 = 1.6e^2$ $t_3 = 1.6e^3$	B1 B1 [2]	
6	(iv)		Time to first bounce is 0.8 s Identify total time is sum of a GP in e $\frac{1.6e}{1-e} = 4.2$ $e = 0.724$	B1 B1 M1 A1 A1 [5]	 Indication of the sum of at least to term in e^4 Equate 3.4 or 4.2 or 5 or 5.8 with attempt at use of formula for sum to infinity of a GP. Allow 21/29
7	(i)		*For P* $4.9t^2 = 60$ $t = 3.5(0)$ *For Q* $0 = 25\sin\theta \times t - ½ \times 9.8 \times t^2$ $\theta = 43.3$ $PQ = (25\cos\theta - 15) \times t_c$ $= 11.2$	M1 A1 M1 A1 M1 A1 [6]	Signs must be consistent. aef

Question			Answer	Marks	Guidance
7	(ii)		$25\cos\theta(t) = 15(t)$ and solving for θ	M1	Equating horizontal components of velocity (or displacement) and solving for θ.
			$\theta = 53.1$	A1	
			For Q $s_{y1} = 25\sin\theta \times t - ½ \times 9.8 \times t^2$	B1	
			For P $s_{y2} = \pm½ \times 9.8 \times t^2$	B1	
			Using $s_{y1} + s_{y2} = 60$	*M1	
			Solving for t	M1dep*	
			$t = 3$	A1	
			$v = 25\sin\theta - 9.8 \times 3$	M1	Other methods include finding time to max height for Q.
			$v = -9.4$ therefore falling.	A1	
				[9]	
OR	(ii)		$25\cos\theta(t) = 15(t)$ and solving for θ	M1	Equating horizontal components of velocity (or displacement) and solving for θ.
			$\theta = 53.1$	A1	
			For Q $y = x\tan\theta - \dfrac{gx^2}{2\times(25)^2\cos^2\theta}$	B1	
			For P $y = (60-)\dfrac{gx^2}{2\times(15)^2}$	B1	
			Equate y and solve for x	*M1	Must include 60.
			Use $x = u\cos\theta t$ to find t	M1dep*	
			$t = 3$	A1	
			$v = 25\sin\theta - 9.8 \times 3$	M1	Other methods include finding time to max height for Q.
			$v = -9.4$ therefore falling.	A1	
				[9]	

Question			Answer	Marks	Guidance
1	(i)		Speed = 1.2 ms^{-1} Impulse = 0.8 × ± (4 – –1.2) ±4.16 Ns	B1 M1 A1 **[3]**	May be seen anywhere, even in **(ii)**; allow -1.2 Difference between momenta, allow 0.8 × ± (4 – 1.2)
1	(ii)		KE lost = ½ × 0.8 × (4^2 –($\pm1.2)^2$) 5.82(4) J	M1 A1 **[2]**	 Allow -5.82(4)
2	(i)		Driving Force = 20000/20 (= 1000) 20000/20 – 800 = 1600a a = 0.125 ms^{-2}	B1 M1 A1 A1 **[4]**	 Attempt at N2L with 3 terms. Signs may not be correct at this stage. Using their 20000/20, but not 20000 Allow $\frac{1}{8}$
2	(ii)		20000/v DF – 800 – 1600$g$sin4 = 0 v = 10.6 ms^{-1}	B1 M1 A1 A1 **[4]**	 3 terms with attempt at resolving weight; g can be omitted at this stage; if F = ….. then F = 0 somewhere to award M aef
3	(i)		 Tcos30 × 1.5sin 30 = 15g × 2 T = 453	M1 A1 A1 **[3]**	Attempt at moments about A, g can be omitted at this stage
3	(ii)		$X = T_c$sin30 (=226) $Y + T_c$cos30 = 15g $R = \sqrt{(226^2 + 245^2)}$ or tanθ = 245/226 R = 334 θ = 47.3 below horizontal (to the left)	B1ft M1 A1ft M1 A1 A1 **[6]**	Using their value T or taking moments about P Attempt to resolve vertically or taking appropriate moments Using their value T; expect Y = -245 or better Either or both of these equations can be replaced with moments about an appropriate point eg P, Q, B, c of m of beam. Any relevant angle Allow 333 Allow 47.2, 42.7 to the downward vertical SC: If *392* in (i) leading to Y=±*245* only in (ii) max M1A1

Question			Answer	Marks	Guidance
4	(i)		$\frac{1}{2} \times 9.8 \times t^2 = 0.2$ $t = 0.2(02)$ $s = 14.4 \times t_c$ $s = 2.91$ m	M1 A1 M1 A1 **[4]**	Using SUVAT to find t, consistent signs for g and *0.2* aef Using their value of t
		OR	Use equation of trajectory $-0.2 = x\tan 0 - gx^2 \sec^2 0/(2\text{x}14.4^2)$ Solve quadratic for x $x = 2.91$	M1 A1 M1 A1 **[4]**	B1 for correct equation of the trajectory seen anywhere but award in part (ii) unless different method seen; consistent signs for g and *0.2*
4	(ii)		 $U\sin 15 \times t - \frac{1}{2} \times 9.8 \times t^2 = -0.2$ $U\cos 15 \times t = 6$ Eliminate t Attempt to solve to find U $U = 10.2$ ms^{-1}	*M1 A1 B1 Dep*M1 Dep*M1 A1 **[6]**	Using s = $ut + \frac{1}{2} at^2$ with $s = \pm 0.2$ and $a = \pm g$ Eliminate U Attempt to solve to find $t(=0.607)$
		OR	$y = x\tan\theta - gx^2 \sec^2 \theta/2U^2$ Substitute values for y, x, θ $-0.2 = 6\tan 15 - g.6^2 \sec^2 15/2U^2$ Attempt to solve for U $U = 10.2$ ms^{-1}	*B1 Dep*M1 A1 Dep*M2 A1 **[6]**	

Question			Answer	Marks	Guidance
5	(i)		$\sin\theta = 0.8$ or $\cos\theta = 0.6$ or $\tan\theta = 4/3$ or $\theta = 53.1$	B1	θ is angle AP makes with horizontal
				*M1	Attempt to resolve horizontally and use N2L with a version of acceleration, not just a. Allow $T_A = T_B$ for M1 only.
			$T_A\cos\theta + T_B\cos\theta = 2 \times 1.2 \times 4^2$	A1	Use their θ
				*M1	Attempt to resolve vertically
			$T_A\sin\theta = T_B\sin\theta + 2g$	A1	Use their θ
			Solve simultaneously to get at least T_A or T_B	Dep*M1	
			$T_A = 44.25$ and $T_B = 19.75$	A1	For both. Allow 44.2, 44.3, 19.7, 19.8
				[7]	
5	(ii)		$T_B = 0$	B1	May be implied
				*M1	Attempt to resolve horizontally and use N2L with a version of acceleration, not just a
			$T_A\cos\theta = 2v^2/1.2$	A1	Use their θ
			$T_A\sin\theta = 2g$	B1	Use their θ
			Solve for v or ω	Dep*M1	
			$v = 2.97$	A1	
				[6]	
6	(i)			*M1	Attempt at conservation of momentum
			$0.2 \times 1.8 = 0.2v_A + 0.4v_B$	A1	
				*M1	Attempt at restitution
			$v_B - v_A = ⅓ \times 1.8$	A1	aef
			Solve for v_A or v_B	Dep*M1	
			$v_B = 0.8 \text{ m s}^{-1}$ and $v_A = 0.2 \text{ m s}^{-1}$ **AG**	A1	
				[6]	

Question			Answer	Marks	Guidance
6	(ii)		$0.4 \times 0.8 + 0.6 \times 0.2 = 0.4v_{B'} + 0.6v_C$	B1	
			$v_C - v_{B'} = e(0.8 - 0.2)$	B1	aef
			Use two relevant equations to eliminate v_C	*M1	
			State $v_{B'} \geq 0.2$	B1	soi, Allow $v_{B'} > 0.2$
			Set up (in)equality in e and their v_A	dep*M1	Condone incorrect inequality sign for M1 only
			$0.44 - 0.36e \geq 0.2$ or $0.44 - 0.36e = 0.2$	A1	Allow $0.44 - 0.36e > 0.2$
			$e \leq 2/3$ or 0.667	A1	
				[7]	
		OR	$0.4 \times 0.8 + 0.6 \times 0.2 = 0.4v_{B'} + 0.6v_C$	B1	
			$v_C - v_{B'} = e(0.8 - 0.2)$	B1	aef
			State $v_{B'} \geq 0.2$	B1	soi, Allow $v_{B'} > 0.2$
			Sub $v_{B'}$ in momentum equation & solve for v_C	*M1	
			($v_C =$) 0.6	A1	
			Set up (in)equality in e and their v_A	dep*M1	eg $0.6 - e(0.8 - 0.2) \geq 0.2$, Condone incorrect inequality sign for M1 only
			$e \leq 2/3$ or 0.667	A1	
				[7]	

Question			Answer	Marks	Guidance
7	(i)		$\frac{1}{3}a$	B1	Centre of mass of triangle
				M1	Table of values idea, using any fixed axis
			$(25 + 2.5a)x_G$	A1	
			$= 25 \times 2.5 + 2.5a \times (5 + \frac{1}{3}a)$	A1	Relative to the axis they are using
			$x_G = \dfrac{a^2 + 15a + 75}{3(a + 10)}$ **AG**	A1	
				[5]	
7	(ii)		$\dfrac{a^2 + 15a + 75}{3(a + 10)} = 5$	*M1	Substitute x_G as 5
			Solving for a	dep*M1	
			$a = 8.66$ or $5\sqrt{3}$	A1	$a \leq 8.66$
				[3]	
7	(iii)			*M1	Method to find centre of mass from *AB* (or *CD*) with or without a substituted.
			$(25 + 2.5a)y_G = 25 \times 2.5 + 2.5a \times (\frac{2}{3} \text{ x } 5)$	A1ft	
			$y_G = \dfrac{10a + 75}{3(a + 10)}$ or 2.89	A1ft	ft their a from (ii), from CD y_G=2.11
			$\tan\theta = x_G / y_G$	dep*M1	Using trig to find an appropriate angle, eg complement of θ.
			$= 5 / y_G$	A1ft	ft their a from (ii), but not an incorrect y_G
			$\theta = 60$	A1	$\theta \leq 60$ (anything that rounds to 60)
				[6]	

Question			Answer	Marks	Guidance	
1	(i)		 18cos15 x 6 104 J	M1 A1 A1 **[3]**	Force component x distance	
1	(ii)		18cos15 x 6/5 or ans(i)/5 20.9 W	M1 A1 **[2]**	Force component x distance/5 Allow 20.8	
2	(i)		DF = 15000/15 DF – k x $15^{1/2}$ = 1500 x 0.4 k = 103	B1 M1 A1 A1 **[4]**	 N2L, 3 terms and attempt at DF. Numerical DF Allow $^{80\sqrt{15}}/_{3}$	
2	(ii)		 P/30 = $k30^{1/2}$ P = 17000W	M1 A1 A1 **[3]**	 Using cv(k) Allow 17(.0)kW, 16900W, 16.9kW, 12000√2W	
3	(i)		a = gsin30 1+u = 0.4(2+2gsin30) u = 3.72 ms^{-1}	B1 M1 A1 A1 **[4]**	 Using NEL with u_A from cv(a), u_A ≠ 0 cwo	
3	(ii)		Use $v^2 = u^2 - 2(g\sin30)s$ s = 1.41 m	M1 A1 **[2]**	Using v = 0, cv(a) from (i) or correct a SC If a not found in (i), allow a=g for M1A0.	
3	(iii)		Use of conservation of momentum 0.5 x 2gsin30 - 2m = m - 0.5 x 3.72 m = 2.25	M1 A1ft A1 **[3]**	Using cv(a) ft cv(u) from (i) Aef(raction) eg 2 $^{19}/_{75}$ or $^{169}/_{75}$	

Question			Answer	Marks	Guidance	
4	(i)		$(2 \times 3\sin(\pi/2))/(3\pi/2)$ or equivalent 3×6^2 $-(\pi \times 3^2/2) \times (6 - 4/\pi)$ $= (6^2 - \pi \times 3^2/2)x_G$ $x_G = 1.88$ cm	B1 M1 A1 A1 A1 A1 **[6]**	Centre of mass of semicircle; $4/\pi$ Table of moments idea about any axis.	
4	(ii)		$\tan\theta = 1.88/3$ $\theta = 32.1^{o}$	M1 A1ft **[2]**	Attempt at a relevant angle allow 180-θ & radians (0.561 or 0.560)	
5	(i)		Use of moments $2.5R = 3g\cos 60 \times 2$ $R = 11.76$ N	M1 A1 A1 **[3]**	Trig with 3g, no trig with R unless using 2 components. Allow 11.8	
5	(ii)		 $R' + R\cos 60 = 3g$ $F = R\cos 30$ Use $F = \mu R'$ $\mu = 0.433$	M1 A1ft B1ft M1 A1 **[5]**	Resolve vertically, 3 terms, comp (R). Using cv(R) Using cv(R) Not R' = 3g for method Allow 0.435 from use of R = 11.8	
6	(i)		Use $I = mv$ 3.6 ms^{-1}	M1 A1 **[2]**	 -3.6 gets A0	
6	(ii)		$\pm(½ \times 0.5 \times 3.6^2 - ½ \times 0.5 \times v^2)$ $0.5 \times g \times 0.3$ Use of conservation of energy $v = 2.66$ ms^{-1}	B1 B1 M1 A1 **[4]**	 Three terms	

Question			Answer	Marks	Guidance	
	OR		$a = -g\sin\theta$ $s = 0.3/\sin\theta$ Use $v^2 = u^2 + 2as$ $v = 2.66\ \text{ms}^{-1}$	B1 B1 M1 A1	θ angle of plane to horizontal $a \neq -g$, $s \neq 0.3$.	
6	(iii)		Change in energy = $\pm(\frac{1}{2} \times 0.5 \times 3^2 - 0.5 \times g \times 0.2)$ Equate to force x distance 3.175 N	M1 A1 M1 A1 **[4]**	Difference of KE and PE Attempt at 0.2/sin30 for dist, 3 terms Allow 3.18	
	OR		Using $v^2 = u^2 + 2as$ to find a Resolve parallel to plane $0.5g\cos60 + F = 0.5 \times cv(11.25)$ $F = 3.175$	M1 M1 A1 A1	Use v = 0, attempt at s =0.2/sin30 N2L used with cv(11.25), 3 terms Consistent signs Allow 3.18	
7	(i)		$x = u\cos\theta\ t$ $y = u\sin\theta\ t - \frac{1}{2}gt^2$ Eliminate t Get $y = x\tan\theta - gx^2\sec^2\theta/2u^2$ **[AG]**	B1 B1 M1 A1 **[4]**	 www	
7	(ii)		Substitute x = 22, y = -2.1 and u = 14 Use $\sec^2\theta = 1 + \tan^2\theta$ Tidy to $12.1\tan^2\theta - 22\tan\theta + 10 = 0$ **[AG]** Solve QE for $\tan\theta$ $\theta = 42.3$	M1 B1 A1 M1 A1 **[5]**	May start again of course www allow in radians (0.738)	
7	(iii)		$t = 22/14\cos\theta$ $t = 2.12\text{s}$	M1 A1 **[2]**	May work vertically, but must solve for t to get M1	

Question			Answer	Marks	Guidance	
8	(i)	(a)	$0.8F + 0.6R = 0.4g$ $4F + 3R = 19.6$ **[AG]**	M1 A1 **[2]**	Attempt to resolve vertically www	
8	(i)	(b)	 $0.8R – 0.6F = 0.4 \times 4.5^2/3$ Solve for R or F $F = 1.516$ $R = 4.512$ Use $\mu = F/R$ to get $\mu = 0.336$ **[AG]**	M1 A1 M1 A1 A1 B1 **[6]**	Attempt with three terms. aef including cos, sin correct angle Use 2 relevant resolutions.	
8	(ii)		 $0.6R - 0.8F = 0.4g$ $R = 11.8$ or $F = 3.98$ $0.8R + 0.6F = 0.4 \times 3 \times \omega^2$ $\omega = 3.14$ rad s^{-1}	M1 A1 A1 M1 A1 A1 **[6]**	Resolve vertically, three terms N2L, resolve horizontally, three terms	

Question			Answer	Marks	Guidance
1		**(i)**	$0.75 \times g \times 8$ 58.8 J	M1 A1 **[2]**	Weight × distance Allow –58.8
1		**(ii)**	 $+/–(½ \times 0.75 \times v^2 – ½ \times 0.75 \times 2^2)$ $½ \times 0.75 \times v^2 – ½ \times 0.75 \times 2^2 = 58.8$ $v = 12.7$ m s^{-1}	*M1 A1 dep*M1 A1 **[4]**	Attempt at change in KE Equate their change in KE to their PE from **(i)**
	OR	**(ii)**	$a = g\sin\theta$ $s = {}^{8}/_{\sin\theta}$ $v^2 = 2^2 + 2 \times g\sin\theta \times {}^{8}/_{\sin\theta}$ $v = 12.7$ m s^{-1}	B1 B1 M1 A1 **[4]**	θ is angle of slope to horizontal. Not $a = g$, not $s = 8$
2		**(i)**	20000/32 $R = 20000/32$ $R = 625$ N	B1 M1 A1 **[3]**	 cao
2		**(ii)**	 $F + 1500g\sin2 – 625 = 1500 \times 0.1$ Power = $32 \times F$ Power = 8380 W or 8.38 kW	M1 A1ft M1 A1 **[4]**	Using Newton 2, all forces used. ft their R from (i) SC $F – 1500g\sin2 – 625 = 1500 \times 0.1$ Using their F. 8383.27…. SC 41200 W or 41.2 kW (41216.7…)
3		**(i)**	$x_G = (2 \times 2)/\pi$ P(or X) $\times 4 = 0.3g \times x_G$ $Y = 0.3g$ Use $R^2 = X^2 + Y^2$ to find R $R = 3.09$ N	B1 *M1 A1ft B1 dep*M1 A1 **[6]**	$x_G = 1.2732….$ May be seen in **(ii), mark only once.** Take moments about A or B $P = 0.9358…..$ ft their x_G for this mark.

Question			Answer	Marks	Guidance
3		**(ii)**	 $P \times 4 =$ $0.3g \times (2\sin 30 + x_G \sin 60)$ $P = 1.55$	M1 A1 A1 A1 **[4]**	Attempt at moments, force × distance = $0.3g$ × distance $0.3g \times 2.1026$…… 1.545453…….
4		**(i)**	 $4.4x_G = 4 \times ¼ \times 8$ $- 0.4 \times 1/3 \times 10$ $x_G = 1.52$ cm	M1 A1 A1 A1 **[4]**	Table of moments idea. Moments about other axes acceptable Allow $^{50}/_{33}$
4		**(ii)**	 $T_{shell} \times 18 = 4.4g \times (8 - 1.52)$ or $T_{cone} \times 18 = 4.4g \times (10 + 1.52)$ $T_{shell} + T_{cone} = 4.4g$ $T_{shell} = 15.5$ and $T_{cone} = 27.6$	M1 A1ft M1 A1 **[4]**	 Or any other correct moment equation. ft on x_G from **(i)** May use a second moments equation For both
5		**(i)**	Vertical force = mg Horizontal force = $m \times 0.4 \times 7^2$ Uses vertical force = μ × horizontal force $\mu = 0.5$	*B1 *M1A1 dep*M1 A1 **[5]**	 Dependent on B1 and M1 If a value for m used B0M1A0M1A0 max.
5		**(ii)**	$mg = T \times 0.3/0.5$ $m \times 0.4\omega^2 = T \times 0.4/0.5$ Solve for ω or v $\omega = 5.72$ rad s^{-1}	B1 *M1 A1 dep*M1 A1 **[5]**	 Resolve T and equate to mass × ($r\omega^2$ or v^2/r) allow $7\sqrt{6}/3$ If a value for m and/or T used B0M1A0M1A0 max.

Question			Answer	Marks	Guidance
6		(i)		M1	Use of restitution, may have sign errors, must be correct ratio (v/u)
			$4 - 4(1 - e + e^2) = -e(u - 4)$	A1	
			$u = 4e$	A1	oe
				M1	Use of conservation of momentum
			$mu + 0.2 \times 4 = 0.2 \times 4(1 - e + e^2) + 4m$	A1	
			$m = 0.2e$	A1	oe
				[6]	
6		(ii)	Valid method to find e that gives the least speed	M1	Differentiate v_A and equate to 0 or complete the square on v_A
			Get $e = ½$	A1	www
				M1	Difference of KE with 4 terms
			$½ \times 0.2 \times 4^2 + ½ \times 0.1 \times 2^2 - (½ \times 0.2 \times 3^2 + ½ \times 0.1 \times 4^2)$	A1	Must have found the value of e from a legitimate method. www
			(+/–) 0.1 J	A1	SCM1A1 Loss of KE = $8e(1 - e)^3/5$ or $8e(1 - 3e + 3e^2 - e^3)/5$ or $8e/5 - 24e^2/5 + 24e^3/5 - 8e^4/5$
				[5]	
6		(iii)		*M1	Attempt to use impulse = change in momentum on one particle
			$0.2e(4 - 4e) = 0.192$ or $0.2(4 - (4 - 4e + 4e^2)) = 0.192$	A1	
			Solve three term QE in e	dep*M1	method should lead to 2 real values for e
			$e = 0.4$ or 0.6	A1	For both
				[4]	
7		(i)	$u\cos\theta = 14\cos 20$	B1	U_x =13.15... Horizontal component of initial velocity, could use U_x
				M1	Complete method to find vertical component of initial velocity, could use U_y
			$-14\sin 20 = u\sin\theta - 1.4g$	A1	U_y = 8.9317……
			$u^2 = (1.4g - 14\sin 20)^2 + (14\cos 20)^2$	M1	Method to find u
			$u = 15.9$ **AG**	A1	cwo
			$\tan\theta = (1.4g - 14\sin 20)/14\cos 20$	M1	Method to find θ or a relevant angle
			$\theta = 34.2$	A1	SC M1A1 for $-\tan 20 = (u\sin\theta - 1.4g)/u\cos\theta$ **OR** $14^2 = (u\sin\theta - 1.4g)^2 + (u\cos\theta)^2$ B1M1A1 for both.
				[7]	

Question			Answer	Marks	Guidance
7		**(ii)**	 ½ $m(15.9^2 - 14^2) = mgy$ $y = 2.9$ m	M1 A1 A1 **[3]**	Method to find Level of P above A
	OR	**(ii)**	 $(14\sin 20)^2 = (15.9\sin\theta)^2 - 2gs$ or $s = 15.9\sin\theta \times 1.4 - ½g \times 1.4^2$ $s = 2.9$ m	M1 A1ft A1 **[3]**	Use constant acc formulae, a complete method needed. ft their θ from (i). no θ value used then M1A0.
7		**(iii)**	$-2.9 = v\sin 20.t - 9.8t^2/2$ $2.9\tan 20 = v\cos 20.t$ Eliminate t to obtain equation in v only Solve for v $v = 1.37$	B1ft B1ft M1 M1 A1 **[5]**	ft their 2.9 ft their 2.9 Eliminate v to obtain equation in t only and solve for t Substitute t to find v
	OR	**(iii)**	 $-2.9 = (2.9\tan 20) \times \tan 20 - g(2.9\tan 20)^2/2v^2\cos^2 20$ Solve for v $v = 1.37$	M2 A1ft M1 A1 **[5]**	Using equation of trajectory method.
	OR	**(iii)**	$2.9/\cos 20 = ½g\cos 20 \times t^2$ $0 = vt - ½g\sin 20 \times t^2$ Eliminate t Solve for v $v = 1.37$	B1ft B1 M1 M1 A1 **[5]**	 $t = 0.817$
7		**(iv)**	$e = 0.098$	B1ft **[1]**	ft their v from **(iii)**, must be $v/14$.

Question			Answer	Marks	Guidance
1	(i)		$(20\sin\theta)^2 - 2g(2.44) = 0$ $\theta = 20.2$	M1 A1 **[2]**	Use $v^2 = u^2 + 2as$ vertically with $v = 0$ $\theta = 20.22908\ldots$
	(ii)		20 sin cv(θ)t – 1/2gt^2 = 0 AND range = 20 cv(t) cos cv(θ) Range = 26.5 m	M1 A1 **[2]**	Use $s = ut + ½at^2$ vertically with $s = 0$ OR use $v = u + at$ and doubles t AND horizontally with time found from vertical. (t = 1.4113… s or 1.4093…s (from 20.2)) Range = 26.48541… m or 26.45387….m (from 20.2)
		OR	$\dfrac{20^2\sin(2\times \text{cv}(\theta))}{g}$ Range = 26.5 m	M1 A1 **[2]**	Use of range formula Range = 26.48541… m or 26.45387….m (from 20.2)
2	(i)		 $r/6 = \tan 21$ $r = 2.3(0)$	M1 A1 A1 **[3]**	Attempt to use trigonometry to form equation for r $r = 2.30318\ldots$
	(ii)		μ < cv(r)/6 or $\mu mg\cos 21 < mg\sin 21$ μ < 0.384 or tan 21	M1 A1 **[2]**	Attempt comparison between weight comp and max friction. μ < 0.38386… or 0.38333…. (from 2.3); allow ≤
3	(i)		CoM of triangle = $^1/_3$ x cv(12) from BD $(80 + 60)x_G$ = 4(80) + 12(60) x_G = 7.43 cm	B1 M1 A1 A1 A1 **[5]**	OR $^2/_3$ x cv(12) from C. CoM of triangle Table of values idea 7.42857… or $^{52}/_7$ cm
	(ii)		$\tan\theta = (8 - x_G)/5$ $\tan\theta$ = 0.5714…/5 θ = 6.52°	M1 A1ft A1 **[3]**	Using tan to find a relevant angle ft their x_G to target angle with the vertical 6.5198… Allow 6.5(0) from x_G = 7.43

Question			Answer	Marks	Guidance
4	**(i)**		 $18(10) – T(20\sin\theta) + 3(6) = 0$ $T = 16.5$ N	M1 A1 A1 **[3]**	Moments about P Need a value for $\sin\theta$ or θ Exact
	(ii)		$X = T\cos\theta$ $Y + T\sin\theta – 18 – 3 = 0$ $R = \sqrt{(13.2^2 + 11.1^2)} = 17.2$ N	B1ft M1 A1ft A1 **[4]**	ft candidates value of T. Resolve horizontally ($X = 13.2$ N) or moments; Need a value for $\cos\theta$ or θ Resolve vertically or moments ft candidates value of T. $Y = 11.1$ N; Need a value for $\sin\theta$ or θ $R = 17.2467…$
	(iii)		$\mu = \text{cv}(\|Y\|)/\text{cv}(\|X\|) = 11.1/13.2$ $\mu = 0.841$	M1 A1 **[2]**	Use of $Fr = \mu R$ $\mu = 0.8409…$; allow $^{37}/_{44}$
5	**(i)**		Driving Force = 10000/20 (= 500) cv(10000/20) – 1300 + $800g\sin\alpha = 0$ $\sin\alpha = 5/49$	B1 M1 A1 A1 **[4]**	 Attempt at N2L with 3 terms **AG** at least one more line of correct working (at least e.g. $-800+800g\sin\alpha=0$); allow verification (e.g. 500 – 1300 + 800 = 0)
	(ii)		$800(22.1)g\sin\alpha$ $800(22.1)g\sin\alpha + 1300(22.1) + ½(800)(8^2)$ $t = 3.6(0)$ s	B1 M1 A1 M1 A1 **[5]**	Work done against weight; Need a value for $\sin\alpha$ or α Total work done, 3 terms needed Need a value for $\sin\alpha$ or α; (72010 J) Time = work done(from at least one correct energy term)/power 'Exact' is 3.6005
6	**(i)**		 $(2m)(4) – (3m)(2) = 2mv_A + 3mv_B$ $(v_B – v_A)/(4 – -2) = 0.4$ Speed $A = 1.04$ m s$^{–1}$, Speed $B = 1.36$ m s$^{–1}$	*M1 A1 *M1 A1 Dep**M1 A1 **[6]**	Attempt at use of conservation of momentum Attempt at use of coefficient of restitution Solving for v_A and v_B Final answers must be positive

Question			Answer	Marks	Guidance
	(ii)		Energy before = ½(2m)(4^2) + ½(3m)(2^2) Energy after = ½(2m)(1.04^2) + ½(3m)(1.36^2) 22m – 3.856m 18.1m	B1ft B1ft M1 A1 **[4]**	Energy before or Loss in A's KE Energy after or Loss in B's KE Difference of total OR sum of differences (total kinetic energy must decrease) 18.144m (Exact)
		OR	$\frac{1}{2}\frac{m_1m_2}{m_1+m_2}(1-e^2)A^2$ $\frac{1}{2}\frac{(2m)(3m)}{2m+3m}(1-0.4^2)(4+2)^2$ 18.1m	*B1 Dep*M1 A1 A1 **[4]**	Loss of kinetic energy formula, where A = approach speed Substitution of values into quoted formula 18.144m (Exact)
	(iii)		2m(4) – 2m(−1.04) = 2.52 m = 0.25	M1 A1ft A1 **[3]**	Attempt at change in momentum and equate to impulse. Must use 2m or 3m Or 3m(2) – 3m(−1.36) = 2.52 Exact
7	(i)		Tcos30 + Tcos45 = 0.4g T = 2.49 N	M1 A1 A1 **[3]**	Resolve vertically (3 terms); may be different T's at this stage T = 2.4918.…
	(ii)		cv(T)sin30 + cv(T)sin45 = 0.4v^2/0.5 v = 1.94 m s^{-1}	M1 A1 A1 **[3]**	Resolve horizontally (3 terms); may be different T's at this stage Or use acceleration = 0.5ω^2 v = 1.93904…
	(iii)		$(2AP =)\frac{0.5}{\sin 45}+\frac{0.5}{\sin 30}$ AP = 0.854 m	M1 A1 **[2]**	Reasonable attempt to use trigonometry to find total length of string **AG** (AP = 0.85355…m)

Question			Answer	Marks	Guidance
	(iv)		$2T\sin\theta = 0.4(0.854\sin\theta)(3.46^2)$	M1	θ angle with vertical. Resolve horizontally. Allow with T only. r = component of 0.854
			$T = 2.04$ N	A1	$T = 2.04474\ldots$ N using $AP = 0.854$ m, $T = 2.04367\ldots$ N using exact AP
			$2T\cos\theta = 0.4g$	M1	θ angle with vertical. Resolve vertically. Allow with T only
			$\theta = 16.5°$ or $16.6°$	A1	$\theta = 16.55377\ldots°$ using $AP = 0.854$ m, $\theta = 16.4526\ldots°$ using exact AP
				[4]	**SC** M1A0M1A1 for use of T instead of 2T throughout
8	(i)		$v_x = 12\cos 20$	*B1	11.27631…..
			$8 = 12t\cos 20$	B1	Using suvat to find expression in t only. ($t = 0.70945\ldots$)
				*M1	Attempt at use of $v = u + at$
			$v_y = 12\sin 20 - g\text{cv}(t)$	A1	-2.84838……
			$\tan\theta = v_y / v_x$	Dep**M1	Use trig to find a relevant angle
			14.2° below horizontal	A1	14.1763… (75.8° downward vertical)
				[6]	
	(ii)		$8 = Vt\cos 20$	B1	
				*M1	Attempt at use of $s = ut + ½ at^2$
			$1.5 = Vt\sin 20 - gt^2/2$	A1	
			Eliminate t	dep*M1	OR Eliminate V and solve for t
			Attempt to solve a quadratic for V	dep*M1	AND Sub value for t and solve for V
			$V = 15.9$	A1	$V = 15.8606\ldots$
				[6]	
		OR	$y = x\tan\theta - gx^2\sec^2\theta/2u^2$	*B1	Use equation of trajectory
			Substitute values for y, x, θ	dep*M1	
			$1.5 = 8\tan 20 - g8^2\sec^2 20/2V^2$	A1	
			Attempt to solve a quadratic for V	dep*M2	SC M1 for solving for V^2
			$V = 15.9$	A1	$V = 15.8606\ldots$
				[6]	