Question	Scheme	Marks	AOs
1(a)	Use of $P = Fv$: $F = \frac{13000}{20}$	B1	3.3
	Using the model to set up an equation of motion	M1	3.4
	$\frac{13000}{20} - 20\lambda - 750g \times \frac{1}{21} = 0$	A1	1.1b
	$\lambda = 15$ *	A1*	1.1b
		(4)	
(b)	Using the model to set up equation of motion	M1	3.3
	$\frac{11250}{U} - 15U = 750 \times 0.1$	A1	1.1b
	3 term quadratic and solve: $15U^2 + 75U - 11250 = 0$	M1	1.1b
	$U = 25$	A1	2.2a
		(4)	
			(8 marks)

Notes:

(a)
B1: Use of $P = Fv$
M1: Correct number of terms with weight resolved.
A1: Correct equation
A1*: Given answer

(b)
M1: Correct number of terms
A1: Correct equation
M1: This mark can be implied by a correct value of U
A1: $U = 25$

Question	Scheme	Marks	AOs
2(a)	$F_{\max} = \frac{1}{4}mg\cos\alpha = \frac{1}{5}mg$	B1	1.2
	$mg\sin\alpha = \frac{3}{5}mg > \frac{1}{5}mg \Rightarrow$ slides down	B1	2.2a
		(2)	
(b)	Using work-energy principle to solve the problem	M1	3.4
	$\frac{1}{2}m\times(7^2 - V^2) = \frac{1}{5}mg\times 2\times\frac{25}{8}$	A1	1.1b
	OR: $mg\times\frac{25}{8}\times\frac{3}{5} - \frac{1}{2}mV^2 = \frac{1}{5}mg\times\frac{25}{8}$	A1	1.1b
	$V = 4.9$ or 4.95	A1	1.1b
		(4)	
(c)	e.g. Include air resistance in the model.	B1	3.5c
		(1)	
			(7 marks)

Notes:

(a)
B1: Correct expression for max friction
B1: Correct deduction from comparing weight component with Fmax

(b)
M1: Using the work-energy principle with correct no. of terms (either start to finish or descent only)
A1: Correct equation, condone 1 error
A1: Correct equation
A1: 4.9 or 4.95 (m)

(c)
B1: Other refinements e.g. allow for spin of box, dimensions of box, more accurate value of g

Question	Scheme	Marks	AOs
3	Use impulse-momentum principle	M1	3.1a
	$\lambda(2\mathbf{i}-\mathbf{j}) = 0.5(\mathbf{v}-(-\mathbf{i}+2\mathbf{j}))$	A1	1.1b
	$\mathbf{v} = (4\lambda-1)\mathbf{i}+(2-2\lambda)\mathbf{j}$	A1	1.1b
	Use of change in KE to set up quadratic equation in λ only.	M1	2.1
	$12 = \frac{1}{2}\times\frac{1}{2}\left\{(4\lambda-1)^2+(2-2\lambda)^2-((-1)^2+2^2)\right\}$	A1**ft**	1.1b
	Simplifying to $5\lambda^2-4\lambda-12=0$ and solving	M1	1.1b
	$\mathbf{I} = 4\mathbf{i}-2\mathbf{j}$	A1	2.2a
		(7)	
			(7 marks)

Notes: Allow column vectors throughout

M1: Allow **I =** … but must be a *difference* in momenta and dimensionally correct
A1: For LHS (This may be awarded later)
A1: For RHS
M1: All terms present but allow difference reversed
A1ft: Follow through their **v**
M1: Attempt to solve a 3 term quadratic
A1: $4\mathbf{i}-2\mathbf{j}$ only

Question	Scheme	Marks	AOs
4(a)	Using CLM	M1	3.1b
	$2mu = 2mv_A + 3mv_B$	A1	1.1b
	Using NIL	M1	3.4
	$eu = -v_A + v_B$	A1	1.1b
	Overall strategy for setting up two equations and solving for v_A or v_B	M1	3.1b
	Speed of A is $\dfrac{u(3e-2)}{5}$	A1	1.1b
	Speed of B is $\dfrac{2u(1+e)}{5}$	A1	1.1b
		(7)	
(b)	Direction of motion of A is reversed by the collision, since $\dfrac{u(3e-2)}{5}$ is positive when $e > \dfrac{2}{3}$	B1	2.4
		(1)	
(c)	Speed of A = $\dfrac{u}{10}$ Speed of B = $\dfrac{11u}{15}$	B1**ft**	1.1b
	Calculation of KE loss with all terms; condone 'increase'	M1	2.1
	$= \dfrac{1}{2}\times 2mu^2 - \left\{\dfrac{1}{2}\times 2m\left(\dfrac{u}{10}\right)^2 + \dfrac{1}{2}\times 3m\left(\dfrac{11u}{15}\right)^2\right\}$	A1**ft**	1.1b
	$= \dfrac{11mu^2}{60}$	A1	1.1b
		(4)	
			(12 marks)

Notes:

(a)
M1: Correct no.of appropriate terms, condone sign errors
A1: Correct equation
M1: Need e on the correct side of the equation
A1: Correct equation
M1: Solving for either
A1: Correct speed of A
A1: Correct speed of B

(b)
B1: Correct direction with appropriate justification

(c)
B1ft: Follow through their answers for (a)
M1: All terms but condone a negative loss
A1ft: Follow their speeds
A1: cao

Question	Scheme	Marks	AOs
5(a)	CLM parallel to line of centres (loc)	M1	3.1a
	$-4mv_P + 5mv_Q = 4mu\cos\alpha - 5mu\cos\alpha$ $-\ 4v_P + 5v_Q = -u\cos\alpha$	A1	1.1b
	Correct use of NIL	M1	3.4
	$v_P + v_Q = 2ue\cos\alpha$	A1	1.1b
	Solve for v_Q	M1	1.1b
	$v_Q = \dfrac{(8e-1)u\cos\alpha}{9}$	A1	1.1b
	Velocity component of Q perp to loc $= u\sin\alpha$	B1	3.4
	$\tan\theta = \dfrac{u\sin\alpha}{v_Q}$	M1	3.1a
	$\tan\theta = \dfrac{u\sin\alpha}{\dfrac{(8e-1)u\cos\alpha}{9}}$	M1	1.1b
	$\tan\theta = \dfrac{9\tan\alpha}{8e-1}$ *	A1*	2.1
		(10)	
(b) (i)	Perp to loc $\Rightarrow v_Q = 0 \Rightarrow 8e-1=0 \Rightarrow e = \dfrac{1}{8}$	B1	2.2a
(ii)	$v_P = \dfrac{1}{4}u\cos\alpha$	B1	1.1b
	$\tan\phi = \dfrac{u\sin\alpha}{v_P} = \dfrac{u\sin\alpha}{\dfrac{1}{4}u\cos\alpha} = 4\tan\alpha = 4$	M1	3.1a
	$\phi = \tan^{-1}4 = 76^{\circ}$ or better (1.3^{c}) to the line of centres oe	A1	1.1b
		(4)	
(c)	Impulse between spheres acts horizontally i.e. parallel to the plane $\Rightarrow$ momentum conserved horizontally	B1	2.4
		(1)	
		(15 marks)	

Notes:

(a)
M1: Need all four terms

A1: Correct unsimplified equation **M1:** e must be on the correct side of the equation **A1:** Correct unsimplified equation **M1:** Solve for v_Q **A1:** Correct unsimplified equation **B1:** Use the model to find the velocity component perpendicular to loc **M1:** Overall strategy to find $\tan\theta$ **M1:** Sub for v_Q and simplify **A1*:** Given answer
(b)(i) **B1:** Clear explanation. May use $\theta = 90 \Rightarrow 8e - 1 = 0 \Rightarrow e = \frac{1}{8}$ **(b)(ii)** **B1:** Use $v_Q = 0$ to find v_P **M1:** Complete method to solve the problem and find the angle **A1:** Answers in degrees (76°) or rads (1.3) or better, are acceptable.
(c) **B1:** Clear explanation

Question	Scheme	Marks	AOs
6(a)	Overall strategy to set up an equation in one unknown using equilibrium condition and resolving vertically: $2T\times\frac{4}{5}=4mg$	M1	3.1a
	$T=\frac{5mg}{2}$	A1	1.1b
	Use of Hooke's Law	M1	3.1a
	$\frac{5mg}{2}=\frac{5mg}{3}\frac{\left(5a-\frac{1}{2}l\right)}{\frac{1}{2}l}$ **OR** $\frac{5mg}{3}\frac{(10a-l)}{l}$	A1	1.1b
	$l=4a$ *	A1*	1.1b
		(5)	
(b)	Max speed is at equilibrium position	B1	3.1a
	Use of EPE = $\frac{\lambda x^2}{2l}$	M1	3.1a
	Use of conservation of energy principle	M1	3.1a
	$\frac{5mg}{3\times 8a}\left\{(6a)^2-(2a)^2\right\}=4mg\times 4a-\frac{1}{2}4mv^2$	A1	1.1b
		A1	1.1b
	$v=\sqrt{\frac{14ag}{3}}$	A1	1.1b
		(6)	
			(11 marks)

Notes:

(a)
M1: Correct no. of terms with T resolved and correct equation in T only
A1: Correct tension
M1: Use of Hooke's Law
A1: Correct unsimplified equation
A1*: Given answer

(b)
B1: Use of max speed at equilm to solve the problem
M1: Use of EPE formula
M1: Use of Conservation of energy to solve the problem
A1: Correct unsimplified equation with one error
A1: Correct unsimplified equation
A1: cao oe

Question	Scheme	Marks	AOs
7(a)	At A_1: Horiz component = $14\cos\alpha$	B1	3.4
	At A_1: Vert component = $\frac{1}{2}.14\sin\alpha$	B1	3.4
	$\tan\beta = \frac{\text{vert component}}{\text{horiz component}}$ $(=\frac{1}{2}\tan\alpha = \frac{3}{8})$	M1	3.1b
	$\beta = 20.6^\circ$ or 0.359 rad (or better)	A1	1.1b
		(4)	
(b)	Since no air resistance, motion symmetrical so vertical component down at A_1 is equal to vertical component up at O,	B1	2.4
		(1)	
(c)	$(\uparrow): -14\sin\alpha = 14\sin\alpha - gt_1$	M1	3.4
	$t_1 = \frac{2\times 14\sin\alpha}{g}$	A1	1.1b
	$t_2 = \frac{2\times 7\sin\alpha}{g}$	A1	1.1b
	Total time = 2.6 or 2.57 (s)	A1	1.1b
		(4)	
(d)	At A_n: Horiz component = $14\cos\alpha$	B1	3.4
	At A_n: Vert component = $(\frac{1}{2})^n 14\sin\alpha$	B1	3.4
	$\tan\phi = \frac{3}{2^{n+2}}$ oe	B1	3.1b
		(3)	
(e)	Ball continues to bounce with the size of the angle to the ground decreasing	B1	3.2a
		(1)	
(f)	After hitting the ground at A_1, the ball moves along the ground at a constant speed of 11.2 m s^{-1}.	B1 B1	2.4 2.4
		(2)	
			(15 marks)

Notes:

(a)
B1: Using NIL as a model to obtain the horiz component at A_1

B1: Using NIL as a model to obtain the vert component at A_1 **M1:** Using the components found above and tan to solve the problem – allow reciprocal for this mark **A1:** Accept degrees or radians
(b) **B1:** No air resistance means motion is symmetrical
(c) **M1:** Using the model and vert motion to find the time from O to A_1 **A1:** $\sin\alpha$ does not need to be substituted **A1:** $\sin\alpha$ does not need to be substituted **A1:** Either 2 or 3 sf answers only
(d) **B1:** Using NIL as the model to obtain the horiz component at A_n **B1:** Using NIL to obtain the vert component at A_n **B1:** Solving the problem to produce any equivalent form
(e) **B1:** A clear explanation
(f) **B1:** Clear description **B1:** Constant speed and 11.2 (m s^{-1})