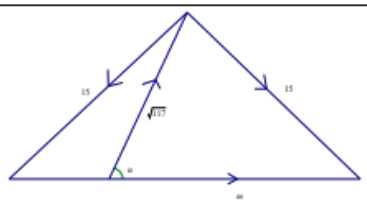
Question Number	Scheme	Marks	
1	$(\mathbf{I}=)1.5\{v\mathbf{i}-(4\mathbf{i}+6\mathbf{j})\}$	M1	Use of $\mathbf{I}=m\mathbf{v}-m\mathbf{u}$. Must be using $v\mathbf{i}$. Condone **u**, **v** confusion. Ignore the left hand side
	$=1.5\{(v-4)\mathbf{i}-6\mathbf{j}\}$	A1	Or equivalent seen or implied Condone subtraction the wrong way round. Ignore the left hand side
	$\Rightarrow 15^2=1.5^2\left\{(v-4)^2+6^2\right\}$	M1	Use of modulus. Allow for $p^2+q^2=100$
	$\left(100=(v-4)^2+36\right)$	A1	Correct unsimplified equation in v
	$\left(v^2-8v-48=0\right)$	A1	Correct simplified equation in v seen or implied.
	$\Rightarrow v=12$	A1	One correct value
	or $v=-4$	A1	Both correct values
		[7]	
1 alt1			
	Initial momentum $=(6\mathbf{i}+9\mathbf{j})$ Ns	M1	Impulse momentum triangle. Accept $\sqrt{117}$ Ns
	$\cos\alpha=\dfrac{6}{\sqrt{117}}\left(=\dfrac{2}{\sqrt{13}}\right)$	A1	Or equivalent
	$m^2+117-2m\sqrt{117}\cos\alpha=225$	M1	Use of cosine formula (final momentum m)
	$m^2-12m-108=0$	A1	Or equivalent
	$\Rightarrow m=-6$ or $m=18$	A1	
	$\Rightarrow v=12$	A1	One correct value
	or $v=-4$	A1	Both correct values
		[7]	
1alt2	Initial momentum $=(6\mathbf{i}+9\mathbf{j})$ Ns	M1	Impulse momentum triangle. Accept $\sqrt{117}$ Ns
	$\sin\alpha=\dfrac{3}{\sqrt{13}}$	A1	Or equivalent
	$\dfrac{15}{\sin\alpha}=\dfrac{\sqrt{117}}{\sin\theta}$	M1	Use of sine formula
	$\Rightarrow \sin\theta=\dfrac{3}{5}$, $\theta=36.9°$ or $\theta=143.1°$	A1	
	$\dfrac{m}{\sin 86.8}=\dfrac{15}{\sin\alpha}$ or $\dfrac{m}{\sin 19.4}=\dfrac{15}{\sin(180-\alpha)}$	A1	Correct equation in m
	$\Rightarrow v=12$	A1	One correct value
	or $v=-4$	A1	Both correct values
		[7]	

2

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
(b)		**(2)**	
	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
	B1: Other refinements e.g. allow for spin of box, dimensions of box, more accurate value of g	B1	
			(8 marks)

Notes:

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

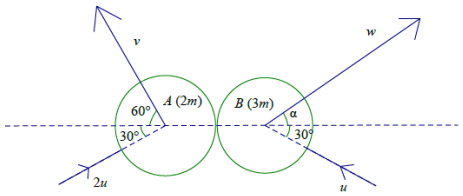
(b)
M1: Using the work-energy principle with correct no. of terms (either start to finish or descent only)
A1: Correct equation, condone 1 error
A1: Correct equation
A1: 4.9 or 4.95 (m)

(c)
B2: One mark for each improvement

3.

Question Number	Scheme	Marks	Notes
3.	Use of $P=15F_1$ or $P=10F_2$	M1	Seen or implied
	$F_1-R=600\times0.2$	M1	Equation of motion. Needs all terms. Condone sign errors. Inclusion of g is an accuracy error
	$\frac{P}{15}-R=120$	A1	Correct equation in P and their R
	Up the slope: $F_2-R-600g\sin\theta=0$	M1	Equation of motion. Needs all terms and $F_2\neq F_1$. Condone sign errors. Condone sin/cos confusion. Omission of g is an accuracy error
		A1	Unsimplified equation in P or F_2 with at most 1 error
	$\frac{P}{10}-R-30g=0$	A1	Correct equation in P and their same R
	$\frac{P}{15}-\frac{P}{10}+30g=120$	DM1	Solve for P. Dependent on the 2 preceding M marks
	$P=5220$ (5200)	A1	Correct max 3 s.f.
		[8]	

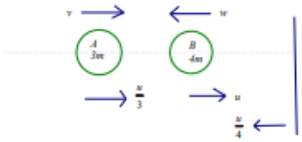
4.

Question Number	Scheme	Marks
6a		
	For A ↕ : $2u\sin 30° = v\sin 60°$	M1
	$v = \frac{2}{\sqrt{3}}u \left(= \frac{2\sqrt{3}}{3}u \right)$	A1
		[2]
6b	CLM : $2m\times 2u\cos 30° - 3m\times u\cos 30° = 3m\times w\cos\alpha - 2m\times v\cos 60°$	M1A1
	$\left(u\cos 30° + v = 3w\cos\alpha\right)$	
	$w\cos\alpha = \frac{1}{3}\left(\frac{\sqrt{3}}{2}u + \frac{2\sqrt{3}}{3}u\right) = \frac{7\sqrt{3}}{18}u$	A1
	For B ↕ : $u\sin 30° = w\sin\alpha = \frac{u}{2}$	M1A1
	$\Rightarrow \tan\alpha = \frac{9}{7\sqrt{3}}$	M1
	$\Rightarrow$ deflected through $\theta = 150° - \alpha = 113.4°$ $(113°)$ (1.98 radians)	M1A1
		[8]
6c	Impact law: $w\cos\alpha + v\cos 60° = e\left(3u\cos 30°\right)$	M1A1
	$\left(\frac{7\sqrt{3}}{18}u + \frac{2\sqrt{3}}{3}u\times\frac{1}{2} = e\times\frac{3\sqrt{3}}{2}u\right)$	
	$e = \frac{13}{27}(= 0.48)$	A1
		[3]

4d

Impulse between spheres acts horizontally i.e. parallel to the plane $\Rightarrow$momentum conserved horizontally	B1	2.4

5.

Question Number	Scheme	Marks	Notes
8a			
	Impulse on A: $8mu = 3mv - 3m \times \frac{u}{3}$	M1	Terms dimensionally correct. Must be subtracting. Condone sign errors. Must be combining correct mass and speed
	$v = 3u$	A1	
	Impulse on B: $8mu = 4mu + 4mw$	M1	Terms dimensionally correct. Condone sign errors Or use CLM: $9mu - 4mw = 3m\frac{u}{3} + 4mu$ Must be combining correct mass and speed
	$w = u$	A1	
	Impact law: $u - \frac{u}{3} = e(3u + u)$	M1	Used the right way round. Condone sign errors
	$e = \frac{1}{6}$	A1	
	Award first 4 marks in order on the scheme. Marks for CLM equation, if used, should be given in place of whichever impulse equation is not used.		
	Watch out for sign errors in the equations If they have $3mv + 4mw$ in the equation for CLM they might combine this with $w = -u$ to obtain a "correct" answer. The sign error in the CLM is due to a misread so the maximum score for this double sign error is 4/6		
		[6]	

8b	Gap when B hits wall $= \frac{2d}{3}$	B1	Or find distances from the first impact: $s_A = \frac{d}{3} + \frac{u}{3}t$ and $s_B = d - \frac{u}{4}t$
	Speed of rebound from wall $= \frac{u}{4}$	B1	Allow + / -
	Time to close gap $= \frac{\frac{2d}{3}}{\frac{u}{3} + \frac{u}{4}}$	M1	
	$= \frac{8d}{7u}$	A1	
	Distance from wall $= \frac{8d}{7u} \times \frac{u}{4}$	DM1	Dependent on the preceding M1
	$= \frac{2d}{7}$	A1 [6]	
8balt	Time for A $\frac{d-x}{u/3}$ $\left(= \frac{3d-3x}{u}\right)$	B1	
	Speed of rebound from wall $= \frac{u}{4}$	B1	
	Time for $B = \frac{d}{u} + \frac{x}{u/4}$	M1	
	$\left(= \frac{d+4x}{u}\right)$	A1	
	$3d - 3x = d + 4x$	DM1	Solve for x Dependent on the preceding M1
	$x = \frac{2d}{7}$	A1 [6]	
		[12]	

6.

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

7.

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	2.4
		B1	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})