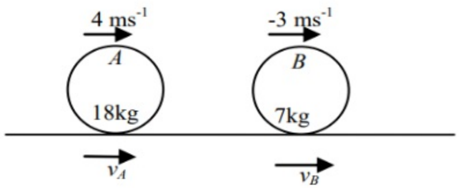
Question 1

		Mark	Notes
1(a)	e = 0.75	B1	
1(b)			



		Mark	Notes
	Conservation of momentum	M1	allow 1 sign error
	$18\times4 + 7\times(-3) = 18v_A + 7v_B$	A1	all correct
	Restitution	M1	allow one sign error
	$v_B - v_A = -\frac{5}{7}(-3-4)$	A1	all correct, any form
	$18v_A + 7v_B = 51$		
	$-7v_A + 7v_B = 35$		
	$25v_A = 16$	m1	one variable eliminated
	$v_A = 0.64$	A1	cao
	$v_B = 5.64$	A1	cao
1(c)	$I = 7[5.64-(-3)]$	M1	oe, ft v_A, v_B
	$I = 60.48$ Ns	A1	ft v_A, v_B

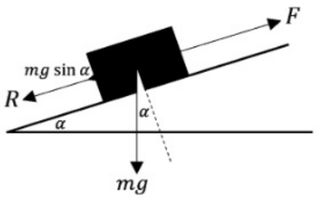
Question 2

Perpendicular to line of centres, momentum of A unchanged, so A has no component of velocity, so A moves parallel to BA Taking L to R as positive NEL along line of centres: $V_A - V_B = e(v + v\cos 60^\circ)$ $V_A - V_B = \frac{3v}{4}$ PCLM $V_A + V_B = -v + v\cos 60^\circ = -\frac{v}{2}$ Solve: $V_A = \frac{1}{8}v$ $(V_B = -\frac{5}{8}v)$ so speed of A is $\frac{1}{8}v$ towards right	B1 M1 A1 M1 A1 A1 [6]	 Use of NEL. Allow sign errors. Must be $\frac{\text{speed of separation}}{\text{speed of approach}}$ Use of PCLM. Allow sign errors	 NEL is Newton's experimental law PCLM is Principle of conservation of linear momentum

Question 3

	Solution	Mark	Notes
(a)	Use of Hooke's Law	M1	
	$21 = \frac{\lambda x}{0{\cdot}15}$	A1	
	$\lambda = 35 \quad (\text{N})$	A1	cao
		[3]	
(b)	Using expression for EE **or** KE	M1	
	Energy at start, $\text{EE} = \frac{\lambda x^2}{2(0{\cdot}15)} \quad \left(\frac{35(0{\cdot}09)^2}{2(0{\cdot}15)} = 0 \cdot 945\right)$	A1	FT λ and x from (a)
	Energy at end, $\text{KE} = \frac{1}{2}(0 \cdot 1)v^2 \quad (= 0 \cdot 05v^2)$	A1	
	Conservation of energy	M1	Used with EE **and** KE
	$0 \cdot 05v^2 = 0 \cdot 945$		
	$v = 4 \cdot 3$ (ms^{-1}) (2 sig. figs)	A1	cao
		[5]	
	Total for Question 1	**8**	

Question 4

		Mark	Notes
(a)			
	At maximum speed $F = R$ (N2L with $a = 0$)	M1	Used
	$F = \frac{P}{v}$	M1	Used, si
	$2000 = \frac{80 \times 1000}{v}$		
	$v = 40 \quad (\text{ms}^{-1})$	A1	cao
		[3]	
(b)			
	$F = \frac{0 \cdot 8 \times 80 \times 1000}{20} \quad (= 3200)$	B1	si
	N2L	M1	All forces, dim. correct F and R opposing
	$F - R - mg \sin \alpha = ma$	A1	Allow one error
	$F - 2000 - 1200g \times \frac{1}{20} = 1200a$	A1	FT candidates F
	$a = 0 \cdot 51 \quad (\text{ms}^{-2})$	A1	cao
		[5]	
(c)	Any valid reason eg. Resistance could vary with speed.	E1	
		[1]	
	Total for Question 4	**9**	

Question 5

	Solution	Mark	Notes
(a)	Conservation of momentum	M1	Allow 1 sign error
	$mu + 0 = mv_A + mv_B$	A1	All correct
	Restitution	M1	Allow one sign error
	$v_B - v_A = -e(-u)$	A1	All correct, any form
	$v_A + v_B = u$ $-v_A + v_B = eu$		
	$2v_A = (1 - e)u$	m1	One variable eliminated
	$v_A = \frac{1}{2}(1 - e)u$	A1	cao, oe
	$v_B = \frac{1}{2}(1 + e)u$	A1	cao, oe
		[7]	
(b)	Loss in KE $= \frac{1}{2}mu^2 - \frac{1}{2}m\left[\left(\frac{1}{4}u\right)^2 + \left(\frac{3}{4}u\right)^2\right]$	M1	
	$= \frac{1}{2}mu^2\left(1 - \frac{5}{8}\right) = \frac{3}{16}mu^2 \quad (\text{J})$	A1	cao
		[2]	

(c)	Velocity of B after 2nd collision = $\frac{1}{2}(1 - e_1) \times \frac{3}{4}u$	M1	FT (a)
	For no further collisions to occur,		
	Vel. of B after 2nd collision $\geq$ Vel. of A after 1st collision		
	$\frac{1}{2}(1 - e_1) \times \frac{3}{4}u \geq \frac{1}{4}u$	M1	FT (a)
	$3 - 3e_1 \geq 2$		
	$e_1 \leq \frac{1}{3}$	A1	Convincing
		[3]	
	<u>Alternative solution</u>		
	Vel. of B after 2nd collision = $\frac{1}{2}(1 - e_1) \times \frac{3}{4}u$	(M1)	FT (a)
	If $e_1 \leq \frac{1}{3}$ then $1 - e_1 \geq \frac{2}{3}$		
	Vel. of B after 2nd collis $\geq \frac{1}{2} \times \frac{2}{3} \times \frac{3}{4}u = \frac{1}{4}u = v_A$	(M1)	FT (a)
	Vel. of B after 2nd collision $\geq$ Vel. of A after 1st collision	(M1)	Convincing
	Total for Question 7	**12**	

Question 6

3	**(i)**		$T\cos\beta = mg\sin\alpha$ $0.8T = (9)(9.8)(0.28)$	M1 A1	Resolving parallel to slope Accept $\cos 36.9°$ etc	α is angle of slope, $\beta = \hat{CAB}$ $\alpha = 16.26°$, $\beta = 53.13 - \alpha = 36.87°$
		OR	$T\sin\gamma + R\cos\alpha = mg$ $T\cos\gamma = R\sin\alpha$ $0.8T + 0.96R = 9\times 9.8$ $0.6T = 0.28R$		M1 Resolving vertically *and* horizontally A1 Both equations correct	γ is between string and horizontal $\gamma = 53.13°$ (R is normal reaction)
			$T = 30.87$ $T = \dfrac{\lambda(4.0-2.2)}{2.2}$ Modulus of elasticity is 37.73 N	A1 B1 E1 **[5]**	Accept anything rounding to 31 Correct equation linking T and λ *Working must lead to 37.73 to 4 sf*	*Dep on M1A1 (May be implied)*
3	**(ii)**	(A)	Resultant force is 18 N (up the slope) Acceleration is 2 ms^{-2} in direction AB	M1 A1 **[2]**	Or $18 + T\cos\beta - mg\sin\alpha$ *Accept positive direction indicated clearly on diagram*	*Just '2' implies M1A0*

Question			Answer	Marks	Guidance	
3	(ii)	(*B*)	At B, tension is $\frac{37.73\times(2.5-2.2)}{2.2}$ $(=5.145)$	B1		
			$18+T_B\sin\alpha-mg\sin\alpha=ma$	M1	Equation of motion	At least two forces required for M1
			$18+5.145\times0.28-9\times9.8\times0.28=9a$	A1	FT for wrong tension	
			Acceleration is 0.584 ms^{-2} in direction BA (3 sf)	A1	CAO	
				[4]		
3	(iii)		WD by force is 18×2.5 $(=45)$	B1		
			EE at A is $\frac{37.73\times1.8^2}{2\times2.2}$ $(=27.783)$ EE at B is $\frac{37.73\times0.3^2}{2\times2.2}$ $(=0.77175)$	B1	For either of these	
			Change in PE is $9\times9.8\times0.7$ $(=61.74)$	B1		
				M1	Equation involving KE and at least two of WD, EE, PE	
			$45+27.783=0.77175+61.74+\frac{1}{2}(9)v^2$	A1	FT from any B0 above, but all 5 terms must be non-zero and all signs correct	
			Speed is 1.51 ms^{-1} (3 sf)	A1	CAO	*Dependent on previous 5 marks*
				[6]		

Question 7

	Solution	Mark	Notes
(a)	Conservation of momentum, $m\mathbf{u}_A + 0 = m\,\mathbf{v}_A + m\,\mathbf{v}_B$	M1	Used
	$m(-\mathbf{i} + 8\mathbf{j}) + 0 = m(2\mathbf{i} + \mathbf{j}) + m\mathbf{v}_B$	A1	
	$\mathbf{v}_B = (-3\mathbf{i} + 7\mathbf{j})$ (ms^{-1})	A1	Convincing
		[3]	
(b)	 		
	Restitution parallel to **j**	M1	Used
	$v = -\frac{5}{7}(7) = -5$	A1	
	$\mathbf{v} = -3\mathbf{i} - 5\mathbf{j}$	A1	Velocity parallel to the cushion remains unchanged, i.e. $-3\mathbf{i}$
		[3]	
(c)	Impulse, $\mathbf{I}$ = change in momentum $\mathbf{I} = m(-3\mathbf{i} - 5\mathbf{j}) - m(-3\mathbf{i} + 7\mathbf{j})$	M1	Used
	$\mathbf{I} = -12m\mathbf{j}$ (Ns)	A1	
	$\|\mathbf{I}\| = 12m$ Ns	A1	**Units must be included,** cao
		[3]	

(d)	(i) $\mathbf{r} = \mathbf{p} + \mathbf{v}t$ $\mathbf{r} = (x\mathbf{i} + 1\cdot 75\mathbf{j}) + (-3\mathbf{i} - 5\mathbf{j})t$ Let $\mathbf{r}_{\text{pocket}} = 1\cdot 75\mathbf{i}$ and compare $\mathbf{j}$ coefficients to get $t = 0\cdot 35 \quad (\text{s})$ (ii) Comparing $\mathbf{i}$ coefficients $x = 2.8\ (\text{m})$ <u>Alternative solution</u> (i) Parallel to y-axis, $\text{time} = \frac{\text{distance}}{\text{speed}} = \frac{1\cdot 75}{5}$ $= 0\cdot 35 \quad (\text{s})$ (ii) Parallel to the x-axis, $\text{dist.} = \text{speed} \times \text{time}$ $= 3 \times 0\cdot 35$ $x = 1\cdot 05 + 1.75$ $x = 2.8\ (\text{m})$	M1 A1 M1 A1 **[4]** (M1) (A1) (M1) (A1) **([4])**	Using $t = 0$ for instant of impact with table cushion and attempt at comparing both coefficients must be made