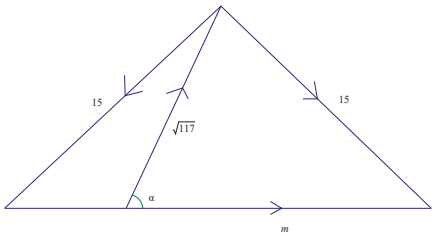
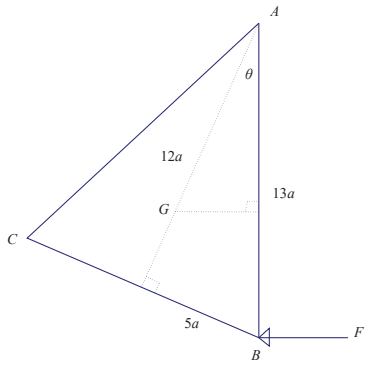
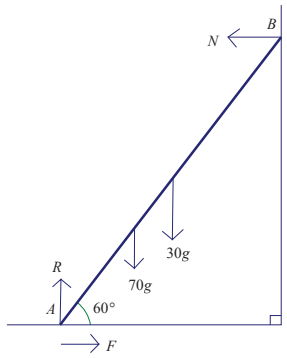
Question Number	Scheme	Marks	
1	$(\mathbf{I}=)1.5\{v\mathbf{i}-(4\mathbf{i}+6\mathbf{j})\}$	M1	Use of $\mathbf{I}=m\mathbf{v}-m\mathbf{u}$. Must be using $v\mathbf{i}$. Condone **u**, **v** confusion. Ignore the left hand side
	$=1.5\{(v-4)\mathbf{i}-6\mathbf{j}\}$	A1	Or equivalent seen or implied Condone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

Question Number	Scheme	Marks	Notes
2.			
	Centre of mass of triangle is at G, where $AG = 8a$	**B1**	Or equivalent. Seen or implied e.g. $\frac{2}{3} \times 5a\cos\theta \left(= \frac{40a}{13} \right)$ from AB
	$\sin\theta = \frac{5}{13}$	**B1**	Or equivalent. Any correct trig ratio for an angle in the triangle. Seen or implied
	M(A): $13aF = W \times 8a \times \frac{5}{13}$	**M1**	Dimensionally correct with resolved component of their $8a$ Condone sin/cos confusion. If g appears, mark as an accuracy error
		A1	Correct substituted equation (any form)
	$F = \frac{40W}{169}\,(\text{N})$	**A1**	$0.24W$ or better
		[5]	

Question Number	Scheme	Marks	Notes
3.	Use of $P = 15F_1$ or $P = 10F_2$	M1	Seen or implied
	$F_1 - R = 600 \times 0.2$	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]	

Question Number	Scheme	Marks	Notes
4	$6m\times 3a+4m\times 4a+5m\times 2a=15m\times y$	M1	Moments about a horizontal axis. Terms dimensionally consistent. Condone slip with a Needs all terms. Condone sign errors
	$\left(44ma=15my\right)$	A1	Correct unsimplified
	$y=\frac{44a}{15}$ from B	A1	Or equivalent. Correct for their axis $\frac{46a}{15}$ from A $\frac{16a}{15}$ from E (CD)
	$5m\times\frac{3a}{2}+4m\times a=15mx$	M1	Moments about a vertical axis Terms dimensionally consistent. Condone slip with a Needs all terms. Condone sign errors
	$\left(\frac{23ma}{2}=15mx\right)$	A1	Correct unsimplified
	$x=\frac{23a}{30}$ from E (AB)	A1	Or equivalent. Correct for their axis $\frac{67a}{30}$ from C
	$\tan\theta=\frac{\frac{23}{30}}{\frac{44}{15}}$	M1	Find a relevant angle using distances measured from B (Allow for $\tan\theta=\frac{88}{23}$)
	$=\frac{23}{88}\left(=0.261...\right)$	A1ft	Correct for their distances from B. $\left(\frac{\text{horizontal}}{\text{vertical}}\right)$
	$\theta=14.64....\simeq 15°$	A1	From correct working. The question asks for the answer to the nearest degree.
		[9]	
	SR1: If a candidate has not used a in their working at all, marks as a misread. Maximum marks available: M1A0A0 M1A1A1 M1A1A1		
	SR2: If a candidate has a in their working, but not as part of their values for $\bar{x}$ and $\bar{y}$ the maximum marks available are M1A1A0 M1A1A0 M1A1A1		

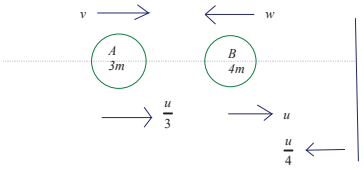
Question Number	Scheme	Marks	Notes
5(a)	$5T^2-12T+15=T^2+8T-10$	M1	Parallel to $\mathbf{i}+\mathbf{j}$
	$\Rightarrow 4T^2-20T+25=0$	A1	Correct quadratic in T
	$\Rightarrow T=\frac{5}{2}$	A1	
		[3]	
5(b)	$\mathbf{a}=(10t-12)\mathbf{i}+(2t+8)\mathbf{j}$	M1	Correct differentiation (at least 2 powers going down by one)
	$=18\mathbf{i}+14\mathbf{j}$	A1	
	$\lvert\mathbf{a}\rvert=\sqrt{18^2+14^2}$	DM1	Use of Pythagoras to find magnitude. Dependent on preceding M1
	$=\sqrt{520}=22.8$ (m s^{-2})	A1	23 or better e.g. $2\sqrt{130}$
		[4]	
5(c)	$\mathbf{s}=\left(\frac{5}{3}t^3-6t^2+15t\right)\mathbf{i}+\left(\frac{1}{3}t^3+4t^2-10t\right)\mathbf{j}$	M1	Integrate (at least 2 powers going up by one)
		A1	At most one error
		A1	All correct
	$=(45-54+45)\mathbf{i}+(9+36-30)\mathbf{j}$		
	$=36\mathbf{i}+15\mathbf{j}$ (m)	A1	
		[4]	
		[11]	

Question Number	Scheme	Marks	Notes
6a			
	M(A): $3\times30g\times\frac{1}{2}+70g\times2\times\frac{1}{2}=N\times\frac{6\sqrt{3}}{2}$	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion and sign errors. Allow with sin/cos 60°
	$\left(45g+70g=3\sqrt{3}N\right)$	A1	Correct unsimplified
	↕: $R=100g$,	B1	B0 if they have $F_B\neq0$
	↔: $F=N=217\,(\text{N})$ $\left(\frac{115g}{3\sqrt{3}}\right)$	B1	Solve for F (216.891… seen or implied)
			NB Either of these B marks could be earned for a second moments equation
	$\sqrt{(100g)^2+217^2}$	DM1	Use of Pythagoras with *their R, F* Dependent on the preceding M mark
	$=1000$ (N)	A1	
Alt6a	M(B): $30g\times3\cos60°+70g\times4\cos60°$ $=R\times6\cos60°-F\times6\sin60°$ M(base wall) $3R=\frac{3}{2}.30g+2.70g+3\sqrt{3}N$	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion and sign errors. Allow with sin/cos 60°
	$\left(45g+140g=3R-3\sqrt{3}F\right)$	A1	
	↕: $R=100g$,	B1	
	$3\sqrt{3}F=115g$, $F=\frac{115g}{3\sqrt{3}}$	B1	Solve for F 216.891……
	$\sqrt{(100g)^2+217^2}$	DM1	Use of Pythagoras with *their R, F*
	$=1000$ (N)	A1	
		[6]	
6b	$F=0.4\times100g\left(=392\right)$	M1	Use of $F=\mu R$ with their value for R
	M(A): $F\times3\sqrt{3}=70g\times\frac{x}{2}+30g\times\frac{3}{2}$	M1	$\left(F\neq217\right)$ Allow for moments about B to find distance from the top
	$40g\times3\sqrt{3}=35gx+45g$	A1	Equation in x (distance from ground) only
	$\left(AD=\right)x=4.65$ (m)	A1	4.7 or better (4.65274….)
		[4]	
6c	e.g. The ladder does not bend The ladder meets the wall/floor at a point The weight acts at a single point	B1	With no incorrect statement(s) seen

		[1]	**[11]**

Question Number	Scheme	Marks	Notes
7a	Equation for conservation of energy.	M1	Need all terms. Condone sign errors
	$\frac{1}{2}\times m\times 144 + m\times g\times 20 = \frac{1}{2}mv^2$	A1 A1	Correct unsimplified equation with at most one error Correct equation (with or without m)
	$v = 23$ or 23.2	A1	Max 3 s.f.
		[4]	
7b	$12\cos\theta\times 5 = 40$	M1	Horizontal motion Condone sine/cosine confusion
	(minimum=) $12\cos\theta = 8$ (m s^{-1})	A1	Final answer : do not ignore subsequent working
		[2]	
7c	Speed = 10 $\Rightarrow$ Vertical component $= 6$ (m s^{-1})	B1ft	Follow their horizontal component
	$(\pm)6 = 12\sin\theta - gt$	M1	Vertical speed
	$= 12\times\frac{\sqrt{5}}{3} - gt$ ($t = 0.30..$ and $t = 1.52..$)	A1	Correct equation for one value of t or for the time interval. Correct trig value seen or implied
	Time = 1.52.. – 0.30.. = 1.22… (s)	A1	Correct interval
	Required time = $5 - 1.22$ (s)	M1	Find required time – follow their 1.22
	$= 3.78$ (s)	A1	Or 3.8. Max 3 s.f.
		[6]	
	Alternatives for M1A1A1		
	Use of $v = u + at$	(M1)	
	$-6 = 6 - gt$	(A1)	Or find time to top and double it
	$t = \frac{12}{g}$	(A1)	
	Vertical speed: $6 = 12\sin\theta - gt_1$	(M1)	
	$-6 = 12\sin\theta - gt_2$	(A1)	
	$12 = g(t_2 - t_1)$, $t_2 - t_1 = \frac{12}{g}$	(A1)	
	Alternatives for B1M1A1A1		
	ht above A $\frac{22}{g}$	(B1)	Using energy 2.24… seen or implied e.g. by 22.24…
	Use of $s = ut + \frac{1}{2}at^2$	(M1)	$20 + \frac{22}{g}$ used with $12\sin\theta$ is M0
	$\frac{22}{g} = 12\sin\theta t - \frac{1}{2}gt^2$	(A1)	
	Time = 1.52.. – 0.30.. = 1.22… (s)	(A1)	Correct interval
	Speed 10, angle to horizontal α $\Rightarrow$ $10\cos\alpha = 8$	(B1)	
	Time to top: $0 = 10\sin\alpha - gt$	(M1)	
	$10\times 0.6 = gt$	(A1)	

	Total time $= \frac{12}{g}$	(A1)	
		[11]	

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]	