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EDEXCEL INTERNATIONAL A LEVEL MATHS: QUESTIONS BY TOPIC

Statics of Rigid Bodies (M2.5)

International A Level Mathematics · M2: Mechanics 2 (WME02)

17 questions · 174 marks · Mark schemes included

Past papers January 2020 - June 2025 · 1 sub-topic

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HOW TO USE THIS BOOKLET

Questions are grouped by sub-topic and run from the lowest to the highest mark tariff, then oldest paper first.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme; < QUESTION brings you back.

A gold bar in the left margin marks exactly where the question sits on the original page.

Diagrams, graphs, grids and tables are printed exactly as they appear in the original papers.

Each question is filed under its main topic; longer questions may also test skills from other topics.

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QUESTIONS

17 questions · 174 marks · 1 sub-topic

SUB-TOPIC M2.5a

RIGID BODIES IN EQUILIBRIUM (LADDERS, RODS & HINGES)

Sub-topic M2.5a · 17 questions · 174 marks · lowest tariff first



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Question 3 continued

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(Total 9 marks)

Q3



Question 5 continued

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Question 5 continued

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Question 5 continued

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(Total 9 marks)

Q5



Question 5 continued

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Question 5 continued

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Question 5 continued

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(Total 9 marks)

Q5



Question 6 continued



Question 6 continued



Question 6 continued

(Total for Question 6 is 9 marks)





Question 6 continued



Question 6 continued

(Total for Question 6 is 9 marks)



Question 5 continued

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Question 5 continued

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Q5

Question 6 continued

Question 6 continued



(Total for Question 6 is 10 marks)



Question 6 continued

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Question 6 continued



Question 6 continued

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(Total for Question 6 is 10 marks)





Question 6 continued



Question 6 continued

(Total for Question 6 is 10 marks)



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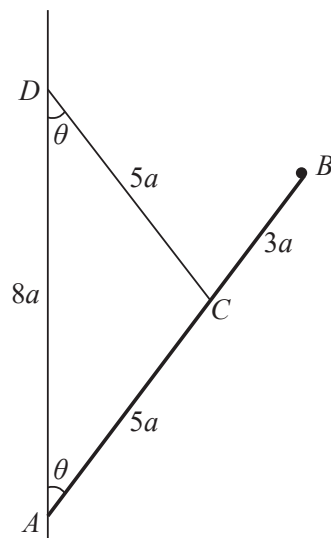


Figure 6

A uniform rod AB has length $8a$ and weight $12W$.

The end A of the rod is freely hinged to a fixed point on a vertical wall.

The rod lies in a vertical plane that is perpendicular to the wall.

A particle of weight W is attached to the rod at B .

A light inextensible string of length $5a$ has one end attached to the rod at the point C , where $AC = 5a$.

The other end of the string is attached to the wall at the point D , where D is above A and $AD = 8a$.

Angle $DAC = \text{Angle } ADC = \theta$, as shown in Figure 6.

The rod and the particle rest in equilibrium.

The tension in the string is T .

(a) Show that $T = 7W$.

(4)

The force exerted on the rod by the hinge at A acts at α° above the rod, where $0 < \alpha < 90$

(b) Find the value of α .

(6)



Question 7 continued



Question 7 continued

(Total for Question 7 is 10 marks)



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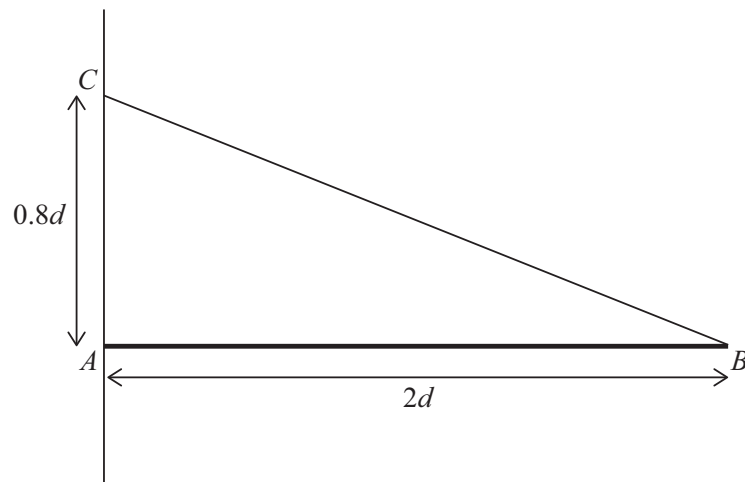


Figure 2

A uniform rod AB has mass m and length $2d$.

The rod is held in equilibrium in a horizontal position, with the end A against a rough vertical wall, by a light inextensible string.

One end of the string is attached to the rod at B .

The other end of the string is attached to the wall at the point C , where $AC = 0.8d$ and C is vertically above A , as shown in Figure 2.

A particle of mass km is attached at B and the rod AB remains in equilibrium in a horizontal position.

The particle, rod and string are in a vertical plane perpendicular to the wall.

(a) Show that the tension in the string is

$$\frac{mg\sqrt{29}}{4}(2k + 1) \quad (4)$$

The resultant force acting on the rod at A makes an angle θ with the horizontal.

(b) Given that $\tan \theta = \frac{1}{8}$, find the exact value of k . (6)

Question 6 continued

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Question 6 continued

(Total for Question 6 is 10 marks)



Question 6 continued

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Question 6 continued

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Question 6 continued

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(Total 11 marks)

Q6



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Question 6 continued

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Question 6 continued

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(Total 11 marks)

Q6



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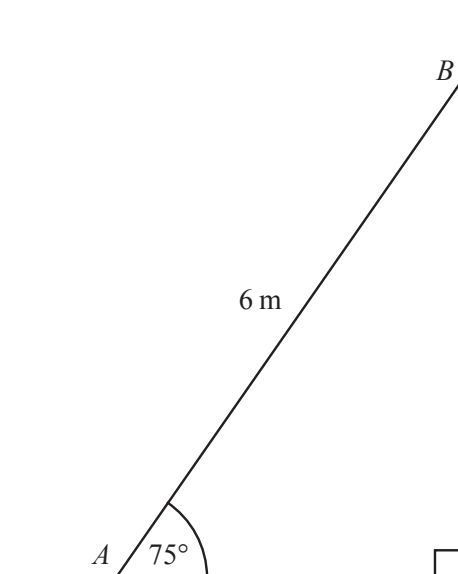


Figure 2

A uniform beam AB , of mass 15 kg and length 6 m, rests with end A on rough horizontal ground. The end B of the beam rests against a rough vertical wall.

The beam is inclined at 75° to the ground, as shown in Figure 2.

The coefficient of friction between the beam and the wall is 0.2

The coefficient of friction between the beam and the ground is μ

The beam is modelled as a uniform rod which lies in a vertical plane perpendicular to the wall.

The beam rests in limiting equilibrium.

(a) Find the magnitude of the normal reaction between the beam and the wall at B .

(5)

(b) Find the value of μ

(6)

Question 5 continued

Lined area for writing the answer to Question 5 continued.



Question 5 continued

Lined area for writing the answer to Question 5 continued.



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Question 5 continued

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Question 5 continued

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Q5



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(Total 12 marks)

Q5



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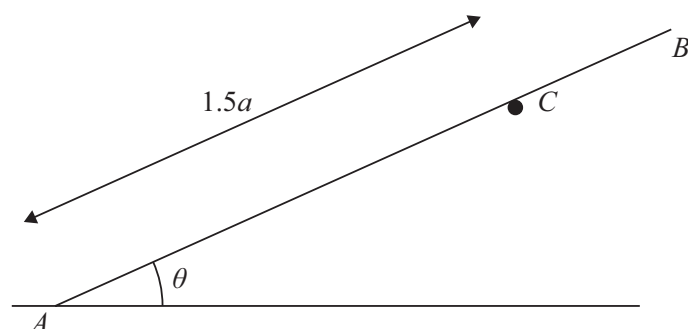


Figure 2

A uniform rod AB , of mass m and length $2a$, has its end A on a rough horizontal floor.

A smooth horizontal rail is fixed above the floor.

The rod rests in equilibrium against the rail at the point C , where $AC = 1.5a$.

The vertical plane containing the rod is at right angles to the rail.

The rod is inclined to the floor at an angle θ , as shown in Figure 2.

The magnitude of the normal reaction exerted on the rod at C is S .

(a) Show that $S = \frac{2mg \cos \theta}{3}$ (3)

The magnitude of the vertical component of the force exerted on the rod at A is V .

(b) Show that $V = \frac{mg}{3} (3 - 2 \cos^2 \theta)$ (3)

Given that the rod is in limiting equilibrium and the coefficient of friction between the rod and the floor is $\frac{4}{7}$

(c) show that

$$p \tan^2 \theta + q \tan \theta + r = 0$$

where p , q and r are integers to be found.

(6)



Question 6 continued

Lined area for writing the answer to Question 6 continued.



Question 6 continued

Lined area for writing the answer to Question 6 continued.



Question 6 continued

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(Total for Question 6 is 12 marks)



MARK SCHEMES

official mark schemes, in the same order as the questions



Question Number	Solution	Marks	Notes
2	Driving force = $\frac{3P}{12}$	B1	Use of $P = Fv$ Allow for $\frac{P}{12}$ in second equation if not awarded here
	Motion up the hill $F - R - W \sin \theta = 0$	M1	Need all terms. Condone sign errors and sin/cos confusion.
	$\frac{3P}{12} - R - \frac{9000}{15} = 0$ $\left(\frac{3P}{12} - R = 600 \right)$	A1	Correct substituted equation Any equivalent form
	Motion down the hill $F + W \sin \theta - R = \frac{9000}{9.8} \times \frac{9.8}{20}$	M1	Need all terms. Condone sign errors and sin/cos confusion.
	$\frac{P}{12} + \frac{9000}{15} - R = 450$ $\left(\frac{P}{12} - R = -150 \right)$	A1 A1	Substituted equation with at most one error. Any equivalent form. Correct substituted equation. Any equivalent form.
	Solve for P or R	DM1	Dependent on both preceding M marks
	$\left(\frac{2P}{12} = 750 \right) \Rightarrow P = 4500$	A1	One correct
	$R = 525$ (530)	A1	Both correct
		(9)	
SC1	Misread mass = 9000kg Gives equations $\frac{P}{4} = R + 5880$ $\frac{P}{12} = R - 1470$ Solutions: $P = 44100, R = 5145$		B1 M1A0 M1A1ftA0 M1A1ftA1ft Total 7/9
SC2	Use of mass = weight = 9000 Gives equations $\frac{P}{4} = R + 600$ $\frac{P}{12} = R + 3810$ Solutions: $P = -19260, R = -5415$		B1 M1A1 M1A1A0 M1A0A0 Total 6/9
		[9]	

Question	Solution	Marks	Notes
3			
	Use of $F = \mu R$	B1	At least once
	Resolve horizontally	M1	Allow with their horizontal friction
	$S = \frac{4}{5} R \quad (S = F_A)$	A1	Correct unsimplified equation
	Resolve vertically	M1	Allow with their vertical friction
	$\frac{3}{5} S + R = 25g \quad F_B + R = 25g$ $\left(\frac{3}{5} S + \frac{5}{4} S = 25g, \quad S = \frac{500}{37} g \right)$	A1	Correct unsimplified equation
	Moments equation	M1	Any moments equation. Need all terms & dimensionally correct
	$M(A): 25g \times 1.5 \cos \theta = S \times 3 \sin \theta + \frac{3}{5} S \times 3 \cos \theta$ $\left(25g \cos \theta - \frac{6}{5} S \cos \theta = 2S \sin \theta \right)$ $M(B): R \times 3 \cos \theta = 25g \times 1.5 \cos \theta + \frac{4}{5} R \times 3 \sin \theta$	A1	Correct unsimplified equation
	M1A1 for first equation, M1A1 for second equation, M1A1 for third equation (i.e. mark in the order in which they appear rather than as listed on the mark scheme). If there are more than 3 equations, mark the 3 used or the best 3 if they go no further. Can also be solved using one resolution and two moments equations. Friction acting in the wrong direction scores A0.		
	$\tan \theta = \left(\frac{25g - \frac{6}{5} S}{2S} \right) = \frac{25 - \frac{600}{37}}{\frac{1000}{37}}$	DM1	Substitute to form equation in $\tan \theta$ only Condone in decimals Dependent on M marks for the equations
	$= \frac{325}{1000} \left(= \frac{13}{40} \right)$	A1	Or exact equivalent (0.325)
		(9)	
SC	It is possible to solve by resolving horizontally or vertically and taking moments about the centre: $1.5 \cos \theta \times R = 1.5 \cos \theta \times \frac{3}{5} S$ $+ 1.5 \sin \theta \times S + 1.5 \sin \theta \times \frac{4}{5} R$		M1A1 for a correct resolution M2A2 for a complete sets of equations to solve
		[9]	

5. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.
6. If a candidate makes more than one attempt at any question:
 - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.
 - If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.
7. Ignore wrong working or incorrect statements following a correct answer.



3			Allow column vectors
	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	Must be subtracting
	$(\mathbf{I} =) \pm 0.5((4 - \lambda)\mathbf{i} + (-\lambda)\mathbf{j})$	A1	Accept $\pm$ correct unsimplified expression on right hand side. (Ignore the left hand side) Allow $2\mathbf{i} - \frac{\lambda}{2}(\mathbf{i} + \mathbf{j})$ or equivalent
	Use of magnitude to form an equation in one variable	M1	Correct use of Pythagoras
	$\frac{5}{2} = \frac{1}{4}((4 - \lambda)^2 + (-\lambda)^2)$	A1ft	Follow their I
	$0 = 2\lambda^2 - 8\lambda + 6 \quad (= (2\lambda - 6)(\lambda - 1))$	DM1	Form a 3 term quadratic (seen or implied). Not necessarily stated “= 0” From $\mathbf{I} = a\mathbf{i} + b\mathbf{j}$ can obtain $4a^2 - 8a + 3 = 0$ or $4b^2 + 8b + 3 = 0$ Dependent on the preceding M1 Solving not required for the M1.
	$\lambda = 3$ and $\lambda = 1$	A1cso	From correct solution only. Do not need to see method of solution.
		[6]	
3alt	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$ to form a vector triangle	M1	
	Triangle with sides of length $\sqrt{\frac{5}{2}}, 2\mathbf{i} $ and $\left \frac{\lambda}{2}(\mathbf{i} + \mathbf{j})\right $	A1	
	Use of cosine rule with $45^\circ \left(\frac{\pi}{4}\right)$	M1	
	$\frac{5}{2} = 2^2 + \left(\frac{\lambda}{2}\right)^2 \times 2 - 2 \times 2 \times \frac{\lambda}{2} \sqrt{2} \cos 45^\circ$	A1ft	Correct unsimplified equation Follow their magnitudes
	$0 = \lambda^2 - 4\lambda + 3 \quad (= (\lambda - 3)(\lambda - 1))$	DM1	Form a 3 term quadratic (seen or implied) Dependent on the preceding M1
	$\lambda = 3$ and $\lambda = 1$	A1	Correct solution only
		[6]	
		(6)	

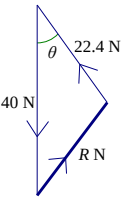
4	Use of $F = \frac{P}{v}$	M1	Formula with a speed substituted correctly At least once.
	Equation for horizontal motion	M1	Dimensionally correct in P or F . Condone sign errors. Need all terms
	$\frac{P}{15} - R = -0.2 \times 900 \quad \left(\frac{P}{15} - R = -180 \right)$	A1	Correct unsimplified equation in P and R
	Equation for motion down hill	M1	Dimensionally correct in P or F_D . Condone sign errors. Condone sin / cos confusion. Need all terms. M0 if using $F(\text{down}) = F(\text{horizontal})$
	$F_D + 900g \times \sin \theta - R = 900 \times 0.4$	A1	Unsimplified equation in F_D or P and R with at most one error.
	$\left(\frac{P}{12} + 30g - R = 360 \right) \quad \left(\frac{P}{12} = R + 66 \right)$	A1	Correct unsimplified equation in (P and) R with trig substituted. e.g. $\frac{5}{4}(R - 180) = 360 - 30g + R$
	Solve for R	DM1	Dependent on the 3 preceding M marks. Condone slips in the algebra.
	$R = 1160 \quad \text{or} \quad R = 1200$	A1	3 sf or 2 sf only NB the answer follows the use of 9.8, so a final answer 1164 is A0. Clear use of 9.81 is a rubric infringement. It gives ($P = 14742$ and) $R = 1162.8$ and scores a maximum of 7/8 (final A0)
		[8]	
		(8)	
	Some candidates work through with the two driving forces. They score M1M1 as above A1 for $4 \times F(\text{down}) = 5 \times F(\text{horizontal})$ or equivalent M1A1 as above A1 for Correct unsimplified equation in R e.g. $\frac{5}{4}(R - 180) = 360 - 30g + R$ M1A1 as above		

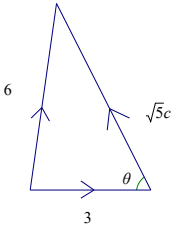
5a			
	Moments about A	M1	Dimensionally correct equation i.e. force x distance = force x distance. Condone sin/cos confusion Mark 50g as an accuracy error
	$4T = 2 \cos \alpha \times 50$ $\left(= 2 \times \frac{4}{5} \times 50 \right)$	A1	Correct unsimplified equation. Need to see $\cos \alpha$ OR $\frac{4}{5}$ Might see LHS = $T \cos \alpha \times 4 \cos \alpha + T \sin \alpha \times 4 \sin \alpha$
	$T = 20$ *	A1*	Obtain given answer from correct working. Must see $\frac{4}{5}$ used correctly.
		[3]	
5b	Resolve horizontally	M1	Condone sin/cos confusion
	$H = T \sin \alpha$	A1	Correct equation
	Resolve vertically	M1	Need all 3 terms. Condone sign error and sin/cos confusion.
	$T \cos \alpha + V = 50$	A1	Correct equation
	Either or both of the above equations could be replaced by a moments equation e.g. $M(B): 4 \cos \alpha \times V = 4 \sin \alpha \times H + 2 \cos \alpha \times 50$ or by resolving perpendicular & parallel to the rod: $T + V \cos \alpha = 50 \cos \alpha + H \sin \alpha$ & $50 \sin \alpha = H \cos \alpha + V \sin \alpha$		
	Use $F = \mu R$ to form an equation in μ	M1	$(H = \mu V)$ Used, not just stated i.e. they must get as far as substituting their values.
	$\mu = \frac{6}{17}$	A1	$\mu = 0.35$ or better Accept $\frac{12}{34}$
		[6]	
		(9)	

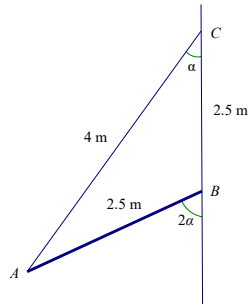
Question	Scheme	Mark	Notes
6a			
	Moments about A: M0 if there is no resolving	M1	Need all terms and no extras. Dimensionally consistent. Condone sign errors and sine/cosine confusion.
	$4a \cos 30^\circ \times W + 8a \cos 30^\circ \times \frac{W}{4} = 5a \cos 30^\circ \times T$	A1	Correct unsimplified equation
	$6W = 5T \Rightarrow T = \frac{6}{5}W \quad *$	A1*	Obtain given answer from correct working, e.g. show cancelling of the common factors or some simplification of the moments equation
		[3]	
6b	They need 2 equations. Award M1A1 for the first correct equation seen and M1A1 for the second correct equation. Common alternatives: $M(B): T \cos 30^\circ \times 3a + V \cos 30^\circ \times 8a = W \cos 30^\circ \times 4a + H \cos 60^\circ \times 8a$ $M(C): W \cos 30^\circ \times a + H \cos 60^\circ \times 5a = \frac{1}{4}W \cos 30^\circ \times 3a + V \cos 30^\circ \times 5a$ Perpendicular to rod: $\frac{1}{4}W \cos 30^\circ + W \cos 30^\circ + H \cos 60^\circ = T \cos 30^\circ + V \cos 30^\circ$ Parallel to rod: $\frac{1}{4}W \cos 60^\circ + T \cos 60^\circ + W \cos 60^\circ = V \cos 60^\circ + H \cos 30^\circ$		
	First equation dimensionally correct. Condone sine/cosine confusion and sign errors	M1	e.g. Resolve horizontally
	Correct unsimplified equation	A1	$H = T \cos 30^\circ \quad \left(H = \frac{3\sqrt{3}}{5}W \right)$
	Second equation dimensionally correct. Condone sine/cosine confusion and sign errors	M1	e.g. resolve vertically
	Correct unsimplified equation	A1	$V + T \cos 60^\circ = W + \frac{W}{4} \quad \left(V = \frac{13}{20}W \right)$
	$ R = \sqrt{V^2 + H^2}$ or $ R ^2 = V^2 + H^2$	DM1	Correct use of Pythagoras Dependent on two preceding M marks.
	$ R = \frac{W}{20} \sqrt{3 \times 144 + 169} = \frac{\sqrt{601}}{20}W$	A1	1.2W or better (1.22576...)
		[6]	
		(9)	

Q	Scheme	Mark	Notes
6a			
	Moments about A:	M1	Dimensionally correct. Condone sine / cosine confusion
	$5P = 40 \times \frac{7}{2} \cos \theta$	A1	Correct unsimplified equation
	$P = 22.4$ *	A1*	Obtain given answer from correct working. Need to see evidence of $\cos \theta = \frac{4}{5}$
		[3]	
6b	Two equations required. M1A1 for the first equation seen, M1A1 for the second equation. If more than 2 equations mark the two equations used to obtain the resultant, or the best 2 if they do not go on to find the resultant.		
	First equation	M1	e.g. Resolve horizontally Condone sine / cosine confusion
	$H = P \sin \theta (=13.44)$	A1	Correct unsimplified equation
	Second equation	M1	e.g. Resolve vertically Condone sine / cosine confusion
	$V + P \cos \theta = 40$ ($V = 22.08$)	A1	Correct unsimplified equation
	$ R = \sqrt{H^2 + V^2}$	DM1	solve for $ R $ Dependent on the 2 preceding Ms
	$ R = 26$ (N)	A1	Or better (25.84879.....) Accept $\frac{24\sqrt{29}}{5}$
		[6]	

Two alternatives on following page

6balt	First equation	M1	e.g. Resolve parallel Condone sine / cosine confusion
	$X = 40 \sin \theta (= 24)$	A1	Correct unsimplified equation
	Second equation	M1	e.g. Resolve perpendicular Condone sine / cosine confusion
	$Y + P = 40 \cos \theta (Y = 9.6)$	A1	Correct unsimplified equation
	$ R = \sqrt{X^2 + Y^2}$	DM1	solve for $ R $ Dependent on the 2 preceding Ms
	$ R = 26 \text{ (N)}$	A1	Or better (25.84879.....) Accept $\frac{24\sqrt{29}}{5}$
		[6]	
	Alternative equations: $M(C) \quad 40 \times 1.5 \cos \theta + H \times 5 \sin \theta = V \times 5 \cos \theta$ $M(B) \quad 2P + 7 \cos \theta \times V = 7 \sin \theta \times H + 3.5 \times 40 \cos \theta$ $M(G) \quad 1.5P + 3.5 \sin \theta \times H = 3.5 \cos \theta \times V$		
6balt		M1 A1	3 force diagram seen or implied Forces and angle in correct positions
	Use Cosine Rule	M1	Correct formula used
	$(R)^2 = 40^2 + 22.4^2 - 2 \times 40 \times 22.4 \cos \theta$	A1	Correct unsimplified equation
	Substitute for trig and solve for $ R $	DM1	Dependent on the 2 preceding Ms
	$ R = 26 \text{ (N)}$	A1	Or better (25.84879.....) Accept $\frac{24\sqrt{29}}{5}$
		[6]	
		(9)	

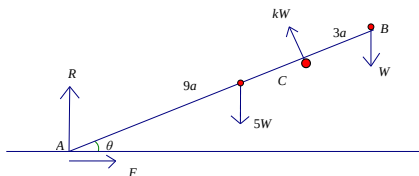
4	Use of $\mathbf{I} = m(\mathbf{v} - \mathbf{u})$	M1	As a single vector equation or two separate equations.
	$c \begin{pmatrix} -1 \\ 2 \end{pmatrix} = \frac{3}{4} \mathbf{v} - \begin{pmatrix} 3 \\ 0 \end{pmatrix}$ $\left(\mathbf{v} = \frac{4}{3} \begin{pmatrix} 3-c \\ 2c \end{pmatrix} \right)$	A1	Any equivalent substituted form
	Use of Pythagoras	M1	
	$64 = \frac{16}{9} \left((3-c)^2 + 4c^2 \right)$	A1	Correct unsimplified equation in c or a component of $\mathbf{v}$. ($5a^2 - 32a = 0$ or $5b^2 - 16b - 192 = 0$)
	Simplify to 3 term quadratic and solve for c	M1	$5c^2 - 6c - 27 = 0$
	$c = 3$ or $c = -\frac{9}{5}(-1.8)$	A1	Correct only
		(6)	
4 Alt		M1	Form vector triangle. Dimensionally correct
		A1	Three correct lengths and $ \cos \theta = \frac{1}{\sqrt{5}}$ seen or implied
	Use of cosine rule	M1	
	$36 = 9 + 5c^2 - 2 \times 3\sqrt{5}c \cos \theta$	A1	Correct unsimplified equation in c with $\cos \theta$ or their $\cos \theta$
	Rearrange as 3 term quadratic and solve for c .	M1	$5c^2 - 6c - 27 = 0$
	$c = 3$ or $c = -\frac{9}{5}(-1.8)$	A1	Correct only
		(6)	
		[6]	

5a			
	Moments about B:	M1	Dimensionally correct Condone sin/cos confusion and errors in angles OR: Correct moments equation and resolution Resolving where required
	$T \times 2.5 \sin \alpha = 70 \times 1.25 \sin 2\alpha$ Or $T \times 2.5 \sin \alpha = 70 \times 2 \sin \alpha$ Or use similar triangles $T \times \frac{3}{2} = 70 \times \frac{6}{5}$	A1 A1	Unsimplified equation in α with at most one error Correct unsimplified equation in α
	$T = 70 \times \frac{4}{5} = 56(\text{N})$ *	A1*	Obtain given answer from correct exact working and no errors seen
		(4)	
5b	Resolve horizontally:	M1	First equation
	$H = T \sin \alpha (= 33.6(\text{N}))$	A1ft	Correct unsimplified equation
	Resolve vertically	M1	Second equation
	$V + T \cos \alpha = 70$ ($V = 25.2(\text{N})$)	A1ft	Correct unsimplified equation
	$V = \mu H$	M1	Use of $F = \mu R$ with their V, H
	$\mu = \frac{3}{4}$	A1	Correct only (no subst for g required)
		(6)	
5balt	Resolve parallel to the rod:	M1	
	$H \sin 2\alpha + 70 \cos 2\alpha = 56 \cos \alpha + V \cos 2\alpha$	A1ft	$(24H - 7V = 630)$
	Resolve perpendicular to the rod:	M1	
	$70 \sin 2\alpha = 56 \sin \alpha + V \sin 2\alpha + H \cos 2\alpha$	A1ft	$(24V + 7H = 840)$
	$V = \mu H$	M1	Use of $F = \mu R$ with their V, H
	$\mu = \frac{3}{4}$	A1	Correct only (no subst for g required)
		(6)	
		[10]	

6a			
	M(A)	M1	Or equivalent method to form an equation in W only. Equation(s) must be dimensionally correct and contain all relevant terms. Condone sin / cos confusion and sign error(s)
	$50 \times 3 \cos 30^\circ + W \times 6 \cos 30^\circ = 60\sqrt{3} \times 4 \sin 30^\circ$	A1	Unsimplified equation with at most one error.
		A1	Correct unsimplified equation
	$W = 15$ *	A1*	Correct answer only
		4	
6b	First equation e.g. Resolve vertically	M1	Or resolve parallel to pole
	$(\pm)V + 50 + 15 = T \cos 30^\circ$ ($V = 25$)	A1	Or: $P + 50 \cos 60^\circ + 15 \cos 60^\circ = 60\sqrt{3} \times \frac{\sqrt{3}}{2}$
	Second equation e.g. Resolve horizontally	M1	Or resolve perpendicular to the pole
	$(\pm)H = T \cos 60^\circ$ ($= 30\sqrt{3} = 51.96 \dots$)	A1	Or: $50 \cos 30^\circ + 15 \cos 30^\circ = 60\sqrt{3} \cos 60^\circ + Q$
	NB: One of the equations could be a second moments equation		
	$ R = \sqrt{25^2 + (30\sqrt{3})^2}$	DM 1	Dependent on the 2 preceding M marks
	$= 5\sqrt{133} (57.662 \dots)$ (N)	A1	$(\sqrt{57.5^2 + 3 \times 6.25})$
		6	Full marks available using $\pm V, \pm H, \pm P, \pm Q$
6b alt	Form vector triangle for the vertical forces, the thrust and the resultant Correct triangle	M1 A1	
	Use cosine rule	M1	
	$R^2 = T^2 + (50 + W)^2 - 2T(50 + W) \cos 30^\circ$	A1	Correct unsimplified equation
	$R^2 = (60\sqrt{3})^2 + (65)^2 - 2 \times 60\sqrt{3} \times 65 \cos 30^\circ$	DM 1	Substitute values and solve for $ R $
	$ R = 5\sqrt{133} (57.662 \dots)$ (N)	A1	58 N or better
		6	
		(10)	

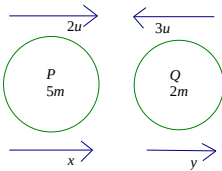
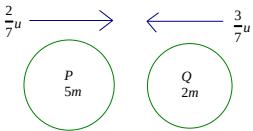
Q	Scheme	Marks	Notes
6(a)			
	$F = \frac{1}{3} R$	B1	For a correct statement seen anywhere e.g. on a diagram
either	Horizontal forces: $S = F (= \frac{1}{3} mg)$	B1	
	Equation for M(A)	M1	need correct terms, condone sign errors and sin/cos confusion. Condone a missing throughout.
	$S \times 2a \cos \alpha = mga \sin \alpha$	A1	Correct unsimplified
or	$R = mg$	B1	
	Equation for M(B)	M1	need correct terms, condone sign errors and sin/cos confusion. Condone a missing throughout.
	$F \times 2a \cos \alpha + mga \sin \alpha = R \times 2a \sin \alpha$	A1	Correct unsimplified
or	$S = F (= \frac{1}{3} mg)$	B1	
	Equation for M(G)	M1	need correct terms, condone sign errors and sin/cos confusion. Condone a missing throughout.
	$Fa \cos \alpha + Sa \cos \alpha = mga \sin \alpha$	A1	Correct unsimplified
SC	$S = F (= \frac{1}{3} mg)$ or $R = mg$ and no moments equation	B1	And no further marks
	Solve for $\tan \alpha$	M1	
	$\tan \alpha = \frac{2}{3} *$	A1*	Obtain given answer from correct working
SC	A candidate who never uses g can score B1B0M1A0M1A0		
		(6)	

Q	Scheme	Marks	Notes
6(b)			
	A good starting point for marking part (b) is to count the number of terms in the moments equation		
either	Use of $R = mg$ and $M(A)$	M1	
	$N = S = \frac{1}{3}mg$	A1	Correct only
	Resolve horizontally: $kmg = \frac{1}{3}R + N$ and solve for k	DM1	Dependent on the moments equation need correct terms, condone sign errors
	$k = \frac{2}{3}$	A1	correct equation
		(4)	
or	$M(A)$ and	M1	need correct terms, condone sign errors and sin/cos confusion. Condone a missing throughout.
	$mg \sin \alpha = N \times 2a \cos \alpha$	A1	Correct unsimplified equation
	Resolve horizontally : $kmg = \frac{1}{3}R + N$ and use $R = mg$ and $\tan \alpha = \frac{2}{3}$ to solve for k	DM1	Dependent on the moments equation need correct terms, condone sign errors OR could use a second moments equation
	$k = \frac{2}{3}$	A1	Correct only
or	$M(B)$,	M1	need correct terms, condone sign errors and sin/cos confusion. Condone a missing throughout.
	$mg \sin \alpha + kmg \times 2a \cos \alpha$ $= R \times 2a \sin \alpha + \frac{1}{3}R \times 2a \cos \alpha$	A1	
	Use of $R = mg$ and $\tan \alpha = \frac{2}{3}$ to solve for k	DM1	Dependent on the moments equation OR could use a second moments equation
	$k = \frac{2}{3}$	A1	Correct only
		(4)	
or	$M(G)$,	M1	need correct terms, condone sign errors and sin/cos confusion
	$Na \cos \alpha + kmg a \cos \alpha = Ra \sin \alpha + Fa \cos \alpha$	A1	Correct unsimplified equation
	Resolve horizontally : $kmg = \frac{1}{3}R + N$ and use $R = mg$ and $\tan \alpha = \frac{2}{3}$ to solve for k	DM1	Dependent on the moments equation need correct terms, condone sign errors OR could use a second moments equation
	$k = \frac{2}{3}$	A1	Correct only
		(10)	

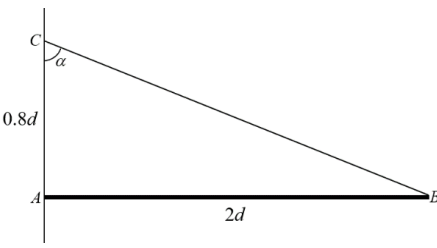
Question	Scheme	Marks
6(a)		
	Moments about A	M1
	$5W \times 6a \cos \theta + W \times 12a \cos \theta = 9akW$ $\left(30 \times \frac{12}{13} + 12 \times \frac{12}{13} = 9k \right)$	A1 A1
	$\Rightarrow k = \frac{56}{13} *$	A1*
		(4)
6(b)	First relevant equation	M1
	Correct unsimplified equation	A1
	Relevant equations:	
	- Vert: $R + kW \cos \theta = 6W \left(R = \frac{342}{169} W \right)$ - Horiz: $F = kW \sin \theta \left(F = \frac{280}{169} W \right)$ // to AB: $F \cos \theta + R \sin \theta = 6W \sin \theta$ - Perp to AB: $kW + R \cos \theta = 6W \cos \theta + F \sin \theta$ - M(G): $R \cos \theta \times 6a + W \cos \theta \times 6a = F \sin \theta \times 6a + kW \times 3a$ - M(C): $W \cos \theta \times 3a + R \cos \theta \times 9a = 5W \cos \theta \times 3a + F \sin \theta \times 9a$ - M(B): $kW \times 3a + R \cos \theta \times 12a = 5W \cos \theta \times 6a + F \sin \theta \times 12a$	
	Second relevant equation	M1
	Correct unsimplified equation	A1
	Use of $F = \mu R$ to form an equation in μ only	DM1
	$\mu = \frac{280}{342} \left(= \frac{140}{171} \right) = 0.8187....$	A1
		(6)
		(10)
	Notes	
	Note that an extra g in a resolution or moments equation is an accuracy error and not a method error.	
6(a)		
M1	Complete method eg moments about A. All required terms present and no extra. Dimensionally correct, product of perpendicular force and distance (a and W present throughout). Condone sign errors and sin/cos confusion. Condone R_c (or similar) instead of kW .	
A1	Unsimplified equation with at most one error	
A1	Correct unsimplified equation	
A1*	Obtain given answer from correct working. Trig replaced and R_c (or similar) replaced in terms of k . At least one line of working required	

	between the equation and the given answer. Do not accept embedded value for k .	
6(b)		
M1	First relevant equation. All required terms present and no extra. Dimensionally consistent. Condone sign errors and sin/cos confusion.	
A1	Correct unsimplified equation. Trig does not need to be replaced. Condone R_c (or similar) instead of kW .	
M1	Second relevant equation. To be relevant it must be possible to use with the first equation to find μ (at least one equation must be a horizontal, vertical, parallel or perpendicular resolution). All required terms present and no extra. Dimensionally consistent. Condone sign errors and sin/cos confusion.	
A1	Correct unsimplified equation. Trig does not need to be replaced. Condone R_c (or similar) instead of kW .	
DM1	Depending on the two previous M marks. Use of $F = \mu R$ to reach $\mu = \dots$	
A1	$\frac{280}{342} \left(= \frac{140}{171} \right) = 0.8187\dots$ Accept 0.82 or better	



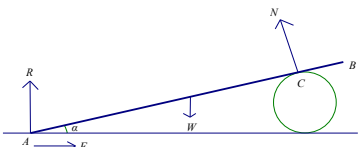
Question	Scheme	Marks	
			
7(a)	CLM	M1	
	$10mu - 6mu = 5mx + 2my$ $(4u = 5x + 2y)$	A1	
	Impact law	M1	
	$y - x = 5ue$	A1	
	$4u = 5x + 2x + 10ue (= 7x + 10ue)$	DM1	
	$(x > 0 \Rightarrow) 10ue < 4u$	DM1	
	$\Rightarrow 0, e < \frac{2}{5}$ o.e.	A1	
		(7)	
7(b)	Impulse momentum equation	M1	
	$\frac{60}{7}mu = 2m(3u - (-y))$ or $-\frac{60}{7}mu = 5m(x - 2u)$	A1	
	Solve to find a correct expression for either x or y $\left(y = \frac{9}{7}u, x = \frac{2}{7}u \text{ but may not be seen explicitly}\right)$	DM1	
	Use both impulse equations and impact law with their x and y to form an equation in e (and u). $5ue = \frac{9}{7}u - \frac{2}{7}u$	Using CLM and impact law from part (a) to form an equation in e (and u). For example $\frac{2u}{7} = \frac{4u - 10eu}{7}$	M1
	$e = \frac{1}{5u} \left(\frac{9}{7}u - \frac{2}{7}u \right) = \frac{1}{5} *$	A1*	
		(5)	
7(c)			
	Speed of $Q = \frac{1}{3} \times \frac{9}{7}u \left(= \frac{3}{7}u \right)$	B1ft	
	Magnitude of impulse = $\frac{1}{7} \times \frac{60}{7}mu$	M1	
	$= \frac{60}{49}mu$	A1	

7a			NB: This is a “show that” question. The working must give a clear indication of where the lengths in the moments equation come from. Check the diagram. Could be resolving or using similar triangles. Might have resorted to using a calculator to evaluate the angles. Each term should include a trig ratio
	Moments about A	M1	Or an alternative complete method to form an equation in T . Condone sign errors and sine / cosine confusion. Need all terms and dimensionally consistent. (accept with no a)
	$12W \times 4a \sin \theta + W \times 8a \sin \theta = 5a \times T \sin 2\theta$ or $48aW \sin \theta + 8aW \sin \theta = 8aT \sin \theta$ $48aW \sin \theta + 8aW \sin \theta$ or $= 3aT \cos \theta + 4aT \sin \theta$ $\left(48 \times \frac{3}{5}W + 8 \times \frac{3}{5}W = T \times 10 \times \frac{3}{5} \times \frac{4}{5} \right)$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation Allow A1A0 if angle DCB used and not in terms of θ If no trig in the moments equation then M0 – given answer, so no BOD
	$56W = 8T \Rightarrow T = 7W$ *	A1*	Obtain given answer from correct working
		[4]	
7b	First equation e.g. resolve horizontally	M1	Condone sign errors and sine / cosine confusion
	$(\pm)H = T \sin \theta \left(= \frac{21}{5}W \right)$	A1	Correct unsimplified equation Alt: resolving parallel to the rod: $13W \cos \theta = T \cos 2\theta + R \cos \alpha$
	Second equation e.g. resolve vertically	M1	Condone sign errors and sine / cosine confusion
	$(\pm)V + T \cos \theta = 13W \left(V = \frac{37}{5}W \right)$	A1	Correct unsimplified equation Alt resolving perpendicular to the rod: $13W \sin \theta = R \sin \alpha + T \sin 2\theta$
	Another alternative is to use a second moments equation e.g. $M(C): 5a \times R \sin \alpha + W \times 3a \sin \theta = 12W \times a \sin \theta$ $M(B): R \sin \alpha \times 8a + T \sin 2\theta \times 3a = 12W \times 4a \sin \theta$		
	$\alpha^\circ = \tan^{-1} \frac{3}{4} - \tan^{-1} \frac{H}{V}$ or $\tan^{-1} \frac{V}{H} - \tan^{-1} \frac{4}{3}$	DM1	Complete method to obtain α Dependent on the two preceding M marks Alt gives $R \sin \alpha = \frac{27}{25}W, R \cos \alpha = \frac{211}{25}$
	$\alpha = 7.3$	A1	7.29205... or better. Mark 0.127 radians as a misread
		[6]	

QUESTION NUMBER	SCHEME	MARKS
6		
6(a)	A complete method to find an equation in T, m, g, k (and α).	M1
	E.g. Moments about A $(T \cos \alpha \times 2d) = (mg \times d) + (kmg \times 2d)$	A1, A1
	$T = \frac{mg\sqrt{29}}{4}(2k+1) *$	A1*
		(4)
6(b)	Vertical equation	M1
	Correct equation Eg Vertical equilibrium $Y + T \cos \alpha = mg + kmg$	A1
	Horizontal equation	M1
	Correct equation Eg Horizontal equilibrium $X = T \sin \alpha$	A1
	Use of $\tan \theta = \frac{Y}{X}$ to form an equation in k only	M1
	$k = \frac{11}{10} \text{ or } 1.1$	A1
		(6)
		(10)
	Notes for question	
6(a)		
M1	A complete method to find an equation in T, m, g, k and α or size of angle at B, say β . Dimensionally correct with all required terms. Condone sign errors and sin/cos confusion. 'g' missing, count as one accuracy error	
A1	Correct unsimplified equation(s) with at most one error.	
A1	Correct unsimplified equation(s).	
A1*	Complete method to substitute trig and correctly obtain the given answer. At least one line of working between the equation and the given answer. Note: $\cos \alpha = \frac{2}{\sqrt{29}}, \sin \alpha = \frac{5}{\sqrt{29}}, \tan \alpha = \frac{5}{2}$ $\sin \beta = \cos \alpha, \cos \beta = \sin \alpha, \tan \beta = \frac{2}{5}$ Allow factor as $(2k+1)$ or $(1+2k)$	
6(b)		

M1	Resolve vertically. Dimensionally correct with all terms required. Condone sign errors and sin/cos confusion. Must be using correct angle	
A1	Correct unsimplified equation. Allow for Y downwards ie +/-Y	
M1	Resolve horizontally. Dimensionally correct with all terms required. Condone sign errors and sin/cos confusion. Must be using correct angle.	
A1	Correct unsimplified equation.	
M1	Use of $\tan \theta = \frac{Y}{X}$ to form an equation in k only, so +/-1/8 or +/-8 must have been used. Allow for Y downwards ie -Y/X, consistent with first use of their Y	
A1	Correct value for k . Must be exact .	
	N.B For X and Y allow use of $R \cos \theta$ and $R \sin \theta$ or N and μN	



Question Number	Scheme	Marks
6a	 Resolve vertically $\uparrow R + N \cos \alpha = W$ Take moments about A $7aN = 4a \cos \alpha \times W$ Obtain equation in R, W and α $N = W \times \frac{4}{7} \cos \alpha \Rightarrow$ $R = W - \frac{4}{7} W \cos^2 \alpha$ $= W \left(1 - \frac{4}{7} \cos^2 \alpha \right) *$ Alternative equations $R \sin \alpha + F \cos \alpha = W \sin \alpha$ $N + R \cos \alpha = W \cos \alpha + F \sin \alpha$ $W.3a \cos \alpha + F.7a \sin \alpha = R.7a \cos \alpha$ First 4 marks for alternative methods	M1 A1 M1 A1 DM1 A1* (6) M1 A1 M1 A1 DM1 A1* (6)
6a M1	A1 Correct unsimplified equation M1 A1 Correct unsimplified equation DM1 Solve for R in terms of W. Dependent on the 2 preceding M marks A1* Obtain given answer from correct working Alt: Parallel to the rod Perpendicular to the rod Moments about C M1 Equation in R. All terms needed. Condone sin/cos confusion and sign errors A1 Correct unsimplified equation M1 Sufficient additional equations to solve for R in terms of W. Dimensionally correct. All terms needed. Condone sin/cos confusion and sign errors A1 Correct unsimplified equation	

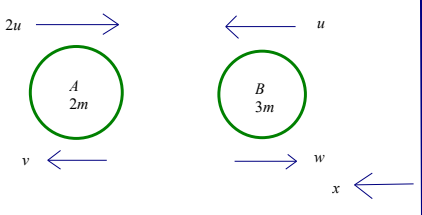


Question Number	Scheme	Marks	Notes
6a			
	$M(A): 3 \times 30g \times \frac{1}{2} + 70g \times 2 \times \frac{1}{2} = N \times \frac{6\sqrt{3}}{2}$	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion and sign errors. Allow with sin/cos 60°
	$(45g + 70g = 3\sqrt{3}N)$	A1	Correct unsimplified
	$\uparrow: R = 100g$	B1	B0 if they have $F_B \neq 0$
	$\leftarrow: F = N = 217(N) \left(\frac{115g}{3\sqrt{3}} \right)$	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 <i>their</i> R, F
	$= 1000(N)$	A1	Dependent on the preceding M mark
Alt6a	$M(B): 30g \times 3 \cos 60^\circ + 70g \times 4 \cos 60^\circ$ $= R \times 6 \cos 60^\circ - F \times 6 \sin 60^\circ$ $M(\text{base wall}) \quad 3R = \frac{3}{2} \cdot 30g + 2 \cdot 70g + 3\sqrt{3}N$	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion and sign errors. Allow with sin/cos 60°
	$(45g + 140g = 3R - 3\sqrt{3}F)$	A1	
	$\uparrow: R = 100g$	B1	
	$3\sqrt{3}F = 115g, \quad F = \frac{115g}{3\sqrt{3}}$	B1	Solve for F 216.891.....
	$\sqrt{(100g)^2 + 217^2}$	DM1	Use of Pythagoras with <i>their</i> R, F
	$= 1000(N)$	A1	
		[6]	
6b	$F = 0.4 \times 100g (= 392)$	M1	Use of $F = \mu R$ with their value for R
	$M(A): F \times 3\sqrt{3} = 70g \times \frac{x}{2} + 30g \times \frac{3}{2}$	M1	($F \neq 217$) Allow for moments about B to find distance from the top
	$40g \times 3\sqrt{3} = 35gx + 45g$	A1	Equation in x (distance from ground) only
	$(AD =) x = 4.65(m)$	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

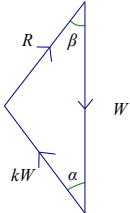
4a	Impulse-momentum equation for P:	M1	Correct use of $I = mv - mu$: Evidence of subtraction (can go straight to + you do not need to see $-(-)$) and dimensionally correct. Use of $3m$
	$15mv = 3m(2v - (-u))$	A1	Correct unsimplified equation
	$9mv = 3mu \Rightarrow u = 3v$ *	A1*	Obtain given answer from correct working
4a alt	Impulse-momentum equation for Q and CLM:	M1	CLM dimensionally consistent, all 4 terms, condone sign error(s). Correct use of $I = mv - mu$: Evidence of subtraction and dimensionally correct. Use of $5m$
	$15mv = 5m(v + ku)$, $k = 2\frac{v}{u}$ and substitute into CLM: $3mu - 5m\frac{2v}{u}u = 5mv - 6mv$	A1	Correct unsimplified equation in u and v
	$\Rightarrow u = 3v$ *	A1*	Obtain given answer from correct working
		(3)	
4b	Impulse-momentum equation for Q or use of CLM:	M1	Dimensionally consistent. All relevant terms.
	$15mv = 5m(v - (-ku))$ or $3mu - 5mku = 5mv - 6mv$	A1	Correct unsimplified equation
	$10v = 5ku = 15kv \Rightarrow k = \frac{2}{3}$	A1	Correct only. Accept 0.67 or better
		(3)	
4c	Use of impact law:	M1	Must be used the right way round. Condone sign error(s)
	$2v + v = e(u + ku)$ $\left(= e \times 3v \times \frac{5}{3} \right)$	A1ft	Correct unsimplified equation. Follow their k .
	$\Rightarrow e = \frac{3}{5}$	A1	Correct only
		(3)	

4d	Change in KE	M1	Allow for gain rather than loss. Dimensionally correct. Need to use all 4 terms and to be using the correct values for mass.
	$\frac{1}{2} \times 3m(u^2 - (2v)^2) + \frac{1}{2} \times 5m((ku)^2 - v^2)$	A1	Correct unsimplified equation. Allow for gain rather than loss. A0 if an error occurs before they form a single expression
	$\left(\frac{1}{2} \times 3m(5v^2) + \frac{1}{2} \times 5m(3v^2) = 15mv^2\right)$		NB: $15mv^2 = \frac{5}{3}mu^2$
	$\lambda = 15$	A1	Correct only. Accept $15mv^2$
		(3)	

Question	Scheme	Marks	Notes
5a			
	Moments about A:	M1	Dimensionally correct. Include all relevant terms. Condone sign error(s) and sin/cos confusion.
	$15g \times 3 \cos 75^\circ$ $= F_B \times 6 \cos 75^\circ + R_B \times 6 \sin 75^\circ$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation
	$15g \times 3 \cos 75^\circ$ $= R_B \times 1.2 \cos 75^\circ + R_B \times 6 \sin 75^\circ$	M1	Use of $F_B = 0.2R_B$ in their attempt at the moments equation. Seen in part (a), not just on the diagram.
	$R_B = 19(\text{N})$ or $R_B = 18.7(\text{N})$	A1	2 sf or 3 sf Ignore if go on to find the total force at A
		(5)	
5b	They need to form 2 equations. Mark them in the order seen. M1A1 for each correct equation		
	Resolve horizontally:	M1	First equation. Include all relevant terms. Dimensionally correct. Condone sign error(s) and sin/cos confusion
	$F_A = R_B (= 18.6925, \dots)$	A1	Correct unsimplified equation
	Resolve vertically:	M1	Second equation. Include all relevant terms. Dimensionally correct. Condone sign error(s) and sin/cos confusion
	$R_A + F_B = 15g$ ($R_A = 143.26, \dots$)	A1	Correct unsimplified equation
	M1A1 for alternatives e.g. moments about B		$15g \times 3 \cos 75^\circ$ $= R_A \times 6 \cos 75^\circ - F_A \times 6 \sin 75^\circ$
	Use $F_A = \mu R_A$ to solve for μ	D M1	Dependent on the 2 preceding M marks
	$\mu = 0.13$ or better	A1	g cancels (0.1304784...)
		(6)	

4a			
	Use of CLM	M1	Need all terms, dimensionally correct. Condone sign errors.
	$4mu - 3mu = 3mw - 2mv$ $(u = 3w - 2v)$	A1	Correct unsimplified equation
	Use of impact law	M1	Used correctly. Condone sign errors
	$v + w = 3eu$	A1	Correct unsimplified equation. Signs consistent with their CLM equation
	$\begin{cases} u = 3w - 2v \\ 6eu = 2w + 2v \end{cases}$	DM1	Dependent on both preceding M marks. Solve to find speed of B.
	$\Rightarrow 5w = u + 6eu, \quad w = \frac{1}{5}u(1 + 6e) \quad *$	A1*	Obtain given answer from correct working
		[6]	
4b	$v = 3eu - w = \frac{u}{5}(9e - 1)$	B1	Check their diagram / directions and allow $v = \frac{u}{5}(1 - 9e)$ if correct for their working. Any equivalent form. Must be seen or used in (b)
	$x = \frac{u}{7}(1 + 6e)$	B1	Seen or implied. Accept $\pm$
	Second collision if $\frac{u}{7}(1 + 6e) > \frac{u}{5}(9e - 1)$	M1	Correct inequality to find the upper limit for e , using their v and x
	$(0 <) e < \frac{4}{11}$	A1	Final answer. Or equivalent. Do not need to mention the lower limit, but if they do it must be stated correctly (strict inequality).
		[4]	

5a			
	Angle ACO is a right angle or state that AB is a tangent hence triangle is $5a$, $12a$, $13a$ *	B1*	Or equivalent explanation of given answer . They need to say why it is a 5, 12, 13 triangle. If they say nothing, check the diagram to see if there is a right angle marked.
		[1]	
5b	Moments about A :	M1	Dimensionally correct equation Condone sin / cos confusion
	$W \times 8a \cos \alpha = kW \times 12a$ $\left(W \times 8a \times \frac{12}{13} = kW \times 12a \right)$	A1	Correct unsimplified equation
	$k = \frac{8}{13}$ *	A1*	Obtain given answer from correct working. Need to see correct substitution for $\cos \alpha$ and correct final statement.
		[3]	
5c	$\leftrightarrow R_H = kW \sin \alpha$	M1	First equation e.g. resolve horizontally. Condone sin/cos confusion
	$= \frac{8W}{13} \times \frac{5}{13} = \frac{40W}{169}$	A1	Correct unsimplified expression for R_H
	$\uparrow R_V + kW \cos \alpha = W$	M1	Second equation e.g. resolve vertically. Condone sin/cos confusion and sign errors.
	$R_V = W - \frac{8W}{13} \times \frac{12}{13} = \frac{73W}{169}$	A1	Correct unsimplified expression for R_V
	$ R ^2 = (R_V)^2 + (R_H)^2$	DM1	Dependent on the two preceding M marks. Method to obtain the magnitude, e.g. correct use of Pythagoras
	$ R = \frac{W}{169} \sqrt{40^2 + 73^2}$ $= \frac{\sqrt{6929}}{169} W = \frac{\sqrt{41}}{13} W$	A1	Accept $0.49W$ or better Allow $\sqrt{\frac{41W^2}{169}}$ or correct unsimplified form. ISW
	$\tan \theta^\circ = \frac{73}{40} \quad (=1.825)$	DM1	Dependent on the first 2 M marks. Method to obtain the angle, e.g. correct use of trigonometry to find a relevant angle (θ or $90 - \theta$)
	$\theta = 61 \quad (61.3)$	A1	61 or better (61.2796...)
		[8]	
	See overleaf for alternatives		
5c Alt 1	$P = W \sin \alpha$	M1	First equation e.g. resolve parallel to the rod. Condone sin/cos confusion.

	$= \frac{5W}{13}$	A1	Correct unsimplified expression for parallel component
	$Q + kW = W \cos \alpha$	M1	Second equation e.g. resolve perpendicular to the rod. Condone sin/cos confusion and sign errors.
	$Q = \frac{12}{13}W - \frac{8}{13}W = \frac{4W}{13}$	A1	Correct unsimplified expression for perpendicular component
	$ R = \sqrt{P^2 + Q^2}$	DM1	Dependent on the first 2 M marks. Correct use of Pythagoras
	$ R = \frac{W}{13} \sqrt{4^2 + 5^2} = \frac{\sqrt{41}}{13}W$	A1	Accept $0.49W$ or better Allow correct unsimplified form
	$\theta^\circ = \tan^{-1} \frac{5}{12} + \tan^{-1} \frac{4}{5}$	DM1	Dependent on the first 2 M marks. Correct use of trig to find the required angle
	$\theta = 61 \quad (61.3)$	A1	61 or better (61.2796...)
		[8]	
5c Alt2		M1 A1	Vector diagram showing the three forces acting Correctly configured
	Use of Cosine Rule:	M1	Correct use of cosine rule for their triangle
	$R^2 = W^2 + (kW)^2 - 2W(kW)\cos \alpha$	A1	Correct unsimplified equation.
	$R^2 = W^2 + \frac{64}{169}W^2 - \frac{16}{13} \times \frac{12}{13}W^2 \left(= \frac{41}{169}W^2 \right)$	DM1	Solve for R. Dependent on the first 2 M marks
	$ R = \frac{\sqrt{41}}{13}W$	A1	Accept $0.49W$ or better
	$\frac{R}{\sin \alpha} = \frac{kW}{\sin \beta} \quad \left(\sin \beta = \frac{8}{13} \times \frac{\sqrt{41}}{13} \times \frac{5}{13} \right)$	DM1	Dependent on the first M mark. Correct method to find a relevant angle e.g. by use of sine rule
	$\theta = 90 - 28.7 = 61.3$	A1	61 or better (61.2796...)
		[8]	
		(12)	

Q	Mark Scheme	Marks	Marking guidance
3.	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	Accept equivalent e.g. $\mathbf{I} + m\mathbf{u} = m\mathbf{v}$. Dimensionally correct and must be using subtraction (but could be the wrong way round). The use of 7 in place of the velocity in the impulse momentum equation is M0 unless they recover. See below
	$0.2(\mathbf{v} - 4\mathbf{i} + 3\mathbf{j}) = \lambda(\mathbf{i} + \mathbf{j})$ $((x-4)\mathbf{i} + (y+3)\mathbf{j}) = 5\lambda\mathbf{i} + 5\lambda\mathbf{j}$	A1	Correct unsimplified vector equation or pair of separate equations for the $\mathbf{i}$ and $\mathbf{j}$ components. Condone column vectors with $\mathbf{i}$ and $\mathbf{j}$ included in the components.
	Use of Pythagoras for the speed	M1	Correct use of Pythagoras and 49 for their speed
	$x^2 + y^2 = 49$	A1	Correct unsimplified equation for their x, y
	Form quadratic in x, y or λ and solve for λ	DM1	Dependent on both previous M marks. $x^2 + -(x-7)^2 = 49$ or $(y+7)^2 + -y^2 = 49$ or $(5\lambda+4)^2 + (5\lambda-3)^2 = 49$
	$\lambda = \frac{3}{5}$ or $\lambda = -\frac{4}{5}$	A1	Or equivalent
*** *** *** *** *** *** ***	Special case: Candidates who use 7 as a vector can score a maximum of M1A0M1A0 for $1.4^2 = +(\lambda \cdot 0.8)^2 + -(\lambda \cdot 0.6)^2$ or equivalent DM1A0 for forming and solving a quadratic in λ .		This maximum of 3 marks is only available for those candidates who “recover”. So, if all you see is $\lambda \lambda \mathbf{i} + -\mathbf{j}$ $1.4 \quad 0.2 \quad 4(\mathbf{i}-3\mathbf{j})$ they score M0M0M0 If they recover to go on to form a “sensible” equation using Pythagoras then they can score the first 2 M marks, and potentially the third M1 as well.
		(6)	
3 alt			
	Form vector triangle	M1	Dimensionally correct. Allow incorrect configuration
	Correct triangle and correct lengths	A1	In speeds or momentum but not a mixture
	Use scalar product to find cosine of angle	M1	Or equivalent method
	$\cos \theta = -\frac{1}{5\sqrt{2}}$	A1	Allow $\pm$
	Form equation in λ $(2\lambda^2 + .4\lambda - 0.96 = 0)$	DM1	e.g. by use of cosine rule Dependent on the first 2 M marks
	$\lambda = \frac{3}{5}$ or $\lambda = -\frac{4}{5}$	A1	Or equivalent
		(6)	

Q	Mark Scheme	Marks	Marking guidance
4 (a)	$\lambda^2 + 2\lambda - 3 = 0 = (\lambda + 3)(\lambda - 1)$	M1	Set j component = 0 and solve for λ
	$\Rightarrow \lambda = 1$	A1	Only. Seen or implied. Accept $t = 1$
	Use $\mathbf{a} = \frac{d\mathbf{v}}{dt}$	M1	Attempt derivative of both components with respect to t . Powers going down. Condone errors in dealing with the signs / indices for the square root. The answer must be a vector.
	$= \frac{-1}{2\sqrt{5-t}} \mathbf{i} + (2t+2) \mathbf{j}$	A1	Any equivalent form
	$= -\frac{1}{4} \mathbf{i} + 4 \mathbf{j}$	A1	Only. Any equivalent form. ISW if they go on to find the magnitude.
		5	
4 (b)	Use $\mathbf{s} = \int \mathbf{v} dt$	M1	Attempt integral of both components. (M0 if they have assumed that one component is zero) Powers going up. Condone errors in dealing with the signs / indices for the square root.
	$\mathbf{s} = \left(-\frac{2}{3}(5-t)^{\frac{3}{2}} (+A) \right) \mathbf{i} + \left(\frac{1}{3}t^3 + t^2 - 3t (+B) \right) \mathbf{j}$	A1 A1	Unsimplified expression with error in at most one term Correct unsimplified expression. Allow with no constant(s) of integration
	Use $t = 1, \mathbf{s} = -2\mathbf{i} + \mathbf{j}$	DM1	Use of initial condition to find constant(s) of integration. Dependent on the previous M1.
	$\mathbf{s} = \left(-\frac{2}{3}(5-T)^{\frac{3}{2}} + \frac{10}{3} \right) \mathbf{i} + \left(\frac{1}{3}T^3 + T^2 - 3T + \frac{8}{3} \right) \mathbf{j}$	A1	Any equivalent form for the position vector
		5	
		(10)	

Q	Mark Scheme	Marks	Marking guidance
5 (a)	$AD = \sqrt{(2a)^2 + (5a)^2} = \sqrt{29}a$ *	B1*	Correct use of Pythagoras to show given answer from correct working (need a on both sides)
		1	
5 (b)	M(A): $W \times 4a \cos \theta = N \times 5a$	M1	Dimensionally correct equation in a . Allow if a cancelled. Condone sin/cos confusion
	$W \times 4a \times \frac{5}{\sqrt{29}} = N \times 5a$	A1	Correct unsimplified equation. Allow with $\cos \theta$. NB: $5a = \sqrt{29}a \cos \theta$
	$N = \frac{4}{\sqrt{29}}W$ *	A1*	Obtain given answer from correct working
		3	
5 (c)	The candidates need to form sufficient equations to solve for k and $\tan \alpha$. There should be two independent equations. Allow M1A1 for the first equation seen, and M1A1 for the second equation. If there are more than 2 equations, award the marks for the equations used to solve for k and $\tan \alpha$. If they stop after forming the equations, allow the marks for the best 2 equations.		
	Resolve vertically	M1	Requires all relevant terms. Condone sin / cos confusion
	$V + N \cos \theta = W$ $\left(V = \frac{9}{29}W \right)$ or $kW \sin \alpha + N \cos \theta = W$	A1	Correct unsimplified equation. Need not substitute for trig.
	Resolve horizontally	M1	Requires all relevant terms. Condone consistent sin / cos confusion
	$H = N \sin \theta \left(= \frac{8}{29}W \right)$ or $kW \cos \alpha = N \sin \theta \left(= \frac{8}{29}W \right)$	A1	Correct unsimplified equation. Need not substitute for trig.
	Possible alternative equation for M1A1 using M(C): $aW \cos \theta + 5aH \sin \theta = 5aV \cos \theta$ or $aW \cos \theta = kW \times 5a \sin(\alpha - \theta)$		
	Use Pythagoras to obtain k : $k^2 = \left(\frac{9}{29} \right)^2 + \left(\frac{8}{29} \right)^2$	DM1	Correct use of perpendicular components. Dependent on the first 2 M marks

	$k = \frac{\sqrt{145}}{29} = \sqrt{\frac{5}{29}}$	A1	Correct only. Any equivalent exact form (ISW but 0.415 with no exact answer seen is A0)
	Use trig to obtain $\tan \alpha$	DM1	Dependent on the first 2 M marks
	$\tan \alpha = \frac{9}{8}$	A1	Correct only. Must be a simplified number. Do not accept answer including W
		8	
5 (c) alt	Resolve parallel to rod	M1	Requires all relevant terms. Condone sin / cos confusion
	$F = W \sin \theta \left(= \frac{2}{\sqrt{29}} W \right)$	A1	Correct unsimplified equation. Need not substitute for trig.
	Resolve perpendicular to rod	M1	Requires all relevant terms. Condone consistent sin / cos confusion
	$E + N = W \cos \theta \left(E = \frac{1}{\sqrt{29}} W \right)$	A1	Correct unsimplified equation. Need not substitute for trig.
	Possible alternative equation for M1A1 using M(C) : $aW \cos \theta + 5aH \sin \theta = 5aV \cos \theta$ or $aW \cos \theta = kW \times 5a \sin(\alpha - \theta)$		
	Use Pythagoras to obtain k	M1	Correct use of Pythagoras
	$k = \frac{1}{\sqrt{29}} \sqrt{1+4} = \sqrt{\frac{5}{29}}$	A1	Correct only
	Use trig to obtain $\tan \alpha$: $\tan(\alpha - \theta) = \frac{1}{2} = \frac{\tan \alpha - \frac{2}{5}}{1 + \frac{2}{5} \tan \alpha}$	DM1	Use of trig to obtain expression in $\tan \alpha$
	$\tan \alpha = \frac{9}{8}$	A1	Correct only
		8	
		(12)	

6(a)	M(A), $S \times 1.5a = mga \cos \theta$	M1A1
	$S = \frac{2mg \cos \theta}{3} *$	A1*
	N.B. Allow RHS in any equivalent form with the same terms in any order.	(3)
6(b)	$V = mg - S \cos \theta$	M1A1
	$*V = \frac{mg}{3} (3 - 2 \cos^2 \theta)$	A1*
		(3)
6(c)	$\frac{4}{7}V$ seen or implied	B1
	Horizontal: $F = S \sin \theta$ Other possible equations: Perp to rod: $F \cos \theta + V \sin \theta = mg \sin \theta$ Parallel to rod: $F \sin \theta + mg \cos \theta = V \cos \theta + S$ M(B): $F \times 2a \sin \theta + mga \cos \theta = V \times 2a \cos \theta + S \times 0.5a$ M(C): $F \times 1.5a \sin \theta + mg \times 0.5a \cos \theta = V \times 1.5a \cos \theta$ M(G): $Fa \sin \theta + S \times 0.5a = Va \cos \theta$	M1A1
	e.g. $\frac{4}{7} \times \frac{mg}{3} (3 - 2 \cos^2 \theta) = \frac{2mg \cos \theta}{3} \times \sin \theta$	DM1
	Divide by $\cos^2 \theta$ to produce an equation in $\tan \theta$	DM1
	$6 \tan^2 \theta - 7 \tan \theta + 2 = 0$	A1
		(6)
		(12)
Notes for question 6		
6(a)	M1 for moments about A equation, dimensionally correct, correct no. of terms, condone sin/cos confusion and sign errors N.B. M0 if a 's missing	
	A1 for a correct equation (allow a different letter for S e.g. R_C provided it's clear that $R_C = S$)	
	A1* for given answer correctly obtained including " $S =$ " but not necessarily in the final line of working..	
6(b)	M1 for resolving vertically, correct no. of terms, condone sin/cos confusion and sign errors	
	A1 for a correct equation (allow a different letter for V e.g. R_A provided it's clear that $R_A = V$)	
	A1* for obtaining the given answer from fully correct working including " $V =$.." but not necessarily in the final line of working. N.B. If S is never seen, can score max M1A1A0*	
6(c)	N.B. The first 3 marks below can be earned if the 'equations' appear in (a) or (b).	