



GuideMyGrades

— YOUR GOALS. OUR EXPERTISE. —

EDEXCEL A LEVEL MATHEMATICS: QUESTIONS BY TOPIC

Forces and Newton's Laws (18)

A Level Mathematics Topic 18

18 questions · 171 marks · Mark schemes included

Pearson Edexcel A Level Mathematics (9MA0), June 2018 - June 2025

 guidemygrades.com

 @Guidemygrades

 @Guidemygrades

 @Guidemygrades

 info@guidemygrades.com

 Piccadilly Business Centre, Unit C, Aldow Enterprise Park
Blackett Street, Manchester, M12 6AE

HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

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.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

QUESTION	SOURCE	MARKS	PAGE
18.2 NEWTON'S SECOND LAW		2 Qs · 12 marks	3
1. Q2	Paper 3: Statistics and Mechanics June2023	4	4
2. Q3 <i>also Topic 17</i>	Paper 3: Statistics and Mechanics June2025	8	6
18.4 NEWTON'S THIRD LAW, EQUILIBRIUM AND CONNECTED PARTICLES		3 Qs · 34 marks	10
3. Q2 <i>also Topic 17</i>	Paper 3: Statistics and Mechanics June2022	10	11
4. Q2 <i>also Topic 17</i>	Paper 3: Statistics and Mechanics November2021	12	15
5. Q3	Paper 3: Statistics and Mechanics June2019	12	19
18.6 FRICTION		13 Qs · 125 marks	22
6. Q1	Paper 3: Statistics and Mechanics June2024	3	23
7. Q3 <i>also Topic 17</i>	Paper 3: Statistics and Mechanics June2024	7	25
8. Q7 <i>also Topic 17</i>	Paper 3: Statistics and Mechanics June2018	8	27
9. Q1	Paper 3: Statistics and Mechanics October2020	9	31
10. Q6 <i>also Topic 19</i>	Paper 3: Statistics and Mechanics June2024	9	35
11. Q3 <i>also Topic 19</i>	Paper 3: Statistics and Mechanics November2021	10	40
12. Q4 <i>also Topic 19</i>	Paper 3: Statistics and Mechanics October2020	10	44
13. Q4 <i>also Topic 19</i>	Paper 3: Statistics and Mechanics June2019	11	48
14. Q4 <i>also Topic 19</i>	Paper 3: Statistics and Mechanics June2022	11	51
15. Q6 <i>also Topic 19</i>	Paper 3: Statistics and Mechanics June2023	13	55
16. Q9 <i>also Topic 19</i>	Paper 3: Statistics and Mechanics June2018	13	60
17. Q2	Paper 3: Statistics and Mechanics June2025	10	64
18. Q6 <i>also Topic 19</i>	Paper 3: Statistics and Mechanics June2025	11	68



QUESTIONS

18 questions · 171 marks · 3 sub-topics



SUB-TOPIC 18.2

NEWTON'S SECOND LAW

Sub-topic 18.2 · 2 questions · 12 marks · lowest tariff first



(Total for Question 2 is 4 marks)







SUB-TOPIC 18.4

NEWTON'S THIRD LAW, EQUILIBRIUM AND CONNECTED PARTICLES

Sub-topic 18.4 · 3 questions · 34 marks · lowest tariff first



Question 2 continued



Question 2 continued



(Total for Question 2 is 10 marks)



2.

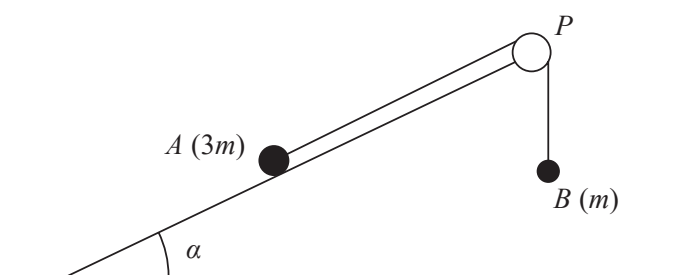


Figure 1

A small stone A of mass $3m$ is attached to one end of a string.

A small stone B of mass m is attached to the other end of the string.

Initially A is held at rest on a fixed rough plane.

The plane is inclined to the horizontal at an angle α , where $\tan \alpha = \frac{3}{4}$

The string passes over a pulley P that is fixed at the top of the plane.

The part of the string from A to P is parallel to a line of greatest slope of the plane.

Stone B hangs freely below P , as shown in Figure 1.

The coefficient of friction between A and the plane is $\frac{1}{6}$

Stone A is released from rest and begins to move down the plane.

The stones are modelled as particles.

The pulley is modelled as being small and smooth.

The string is modelled as being light and inextensible.

Using the model for the motion of the system before B reaches the pulley,

(a) write down an equation of motion for A (2)

(b) show that the acceleration of A is $\frac{1}{10}g$ (7)

(c) sketch a velocity-time graph for the motion of B , from the instant when A is released from rest to the instant just before B reaches the pulley, explaining your answer. (2)

In reality, the string is not light.

(d) State how this would affect the working in part (b). (1)

Question 2 continued

Lined area for writing the answer to Question 2 continued.





Question 2 continued

Lined area for writing the answer to Question 2.

(Total for Question 2 is 12 marks)



Figure 1

Two blocks, A and B , of masses $2m$ and $3m$ respectively, are attached to the ends of a light string.

Initially A is held at rest on a fixed rough plane.

The plane is inclined at angle α to the horizontal ground, where $\tan \alpha = \frac{5}{12}$.

The string passes over a small smooth pulley, P , fixed at the top of the plane.

The part of the string from A to P is parallel to a line of greatest slope of the plane. Block B hangs freely below P , as shown in Figure 1.

The coefficient of friction between A and the plane is $\frac{2}{3}$.

The blocks are released from rest with the string taut and A moves up the plane.

The tension in the string immediately after the blocks are released is T .

The blocks are modelled as particles and the string is modelled as being inextensible.

- (a) Show that $T = \frac{12mg}{5}$ (8)

After B reaches the ground, A continues to move up the plane until it comes to rest before reaching P .

- (b) Determine whether A will remain at rest, carefully justifying your answer. (2)

- (c) Suggest two refinements to the model that would make it more realistic. (2)

Question 3 continued



This image shows a full page of blank, lined paper. It features approximately 28 evenly spaced horizontal gray lines across its entire width, providing a template for handwriting practice or general note-taking. The margins are consistent on all sides.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

(Total for Question 3 is 12 marks)



SUB-TOPIC 18.6

FRICTION

Sub-topic 18.6 · 13 questions · 125 marks · lowest tariff first



(Total for Question 1 is 3 marks)



(Total for Question 3 is 7 marks)







(Total for Question 7 is 8 marks)





Question 1 continued

Lined area for writing the answer to Question 1 continued.



(Total for Question 1 is 9 marks)









3.

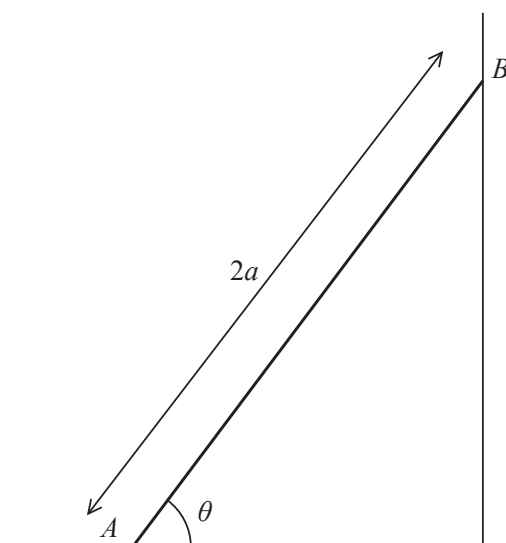


Figure 2

A beam AB has mass m and length $2a$.

The beam rests in equilibrium with A on rough horizontal ground and with B against a smooth vertical wall.

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

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

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

Using the model,

- (a) show that $\mu \geq \frac{1}{2} \cot \theta$ (5)

A horizontal force of magnitude kmg , where k is a constant, is now applied to the beam at A .

This force acts in a direction that is perpendicular to the wall and towards the wall.

Given that $\tan \theta = \frac{5}{4}$, $\mu = \frac{1}{2}$ and the beam is now in limiting equilibrium,

- (b) use the model to find the value of k . (5)





(Total for Question 3 is 10 marks)



4.

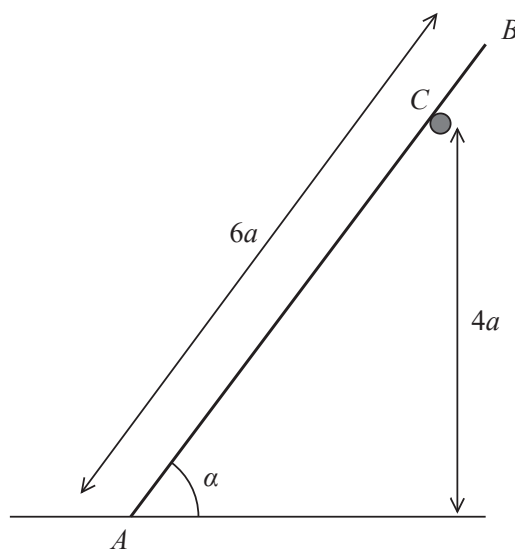


Figure 1

A ladder AB has mass M and length $6a$.

The end A of the ladder is on rough horizontal ground.

The ladder rests against a fixed smooth horizontal rail at the point C .

The point C is at a vertical height $4a$ above the ground.

The vertical plane containing AB is perpendicular to the rail.

The ladder is inclined to the horizontal at an angle α , where $\sin \alpha = \frac{4}{5}$, as shown in Figure 1.

The coefficient of friction between the ladder and the ground is μ .

The ladder rests in limiting equilibrium.

The ladder is modelled as a uniform rod.

Using the model,

(a) show that the magnitude of the force exerted on the ladder by the rail at C is $\frac{9Mg}{25}$ (3)

(b) Hence, or otherwise, find the value of μ . (7)

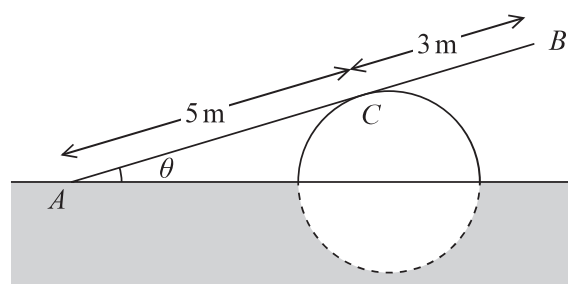


Question 4 continued

Lined area for writing the answer to Question 4 continued.



4.

**Figure 2**

A ramp, AB , of length 8 m and mass 20 kg, rests in equilibrium with the end A on rough horizontal ground.

The ramp rests on a smooth solid cylindrical drum which is partly under the ground. The drum is fixed with its axis at the same horizontal level as A .

The point of contact between the ramp and the drum is C , where $AC = 5$ m, as shown in Figure 2.

The ramp is resting in a vertical plane which is perpendicular to the axis of the drum, at an angle θ to the horizontal, where $\tan \theta = \frac{7}{24}$

The ramp is modelled as a uniform rod.

(a) Explain why the reaction from the drum on the ramp at point C acts in a direction which is perpendicular to the ramp. (1)

(b) Find the magnitude of the resultant force acting on the ramp at A . (9)

The ramp is still in equilibrium in the position shown in Figure 2 but the ramp is not now modelled as being uniform.

Given that the centre of mass of the ramp is assumed to be closer to A than to B ,

(c) state how this would affect the magnitude of the normal reaction between the ramp and the drum at C . (1)

Question 4 continued

[illegible]

[illegible]

(Total for Question 4 is 11 marks)



4.

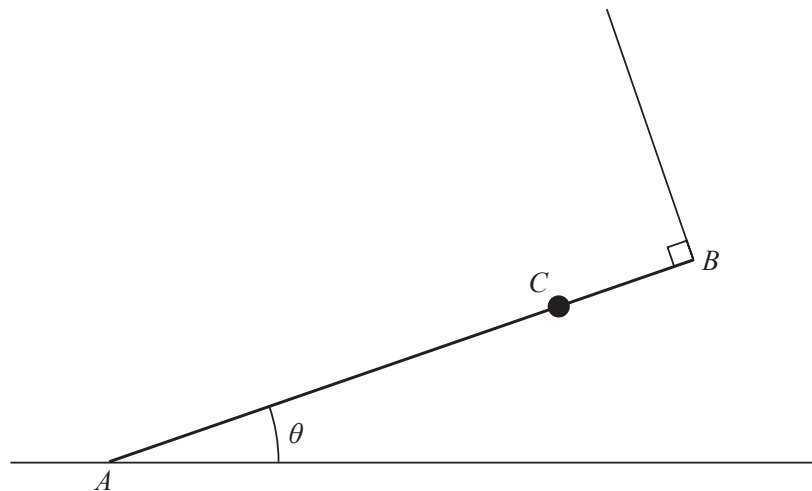


Figure 2

A uniform rod AB has mass M and length $2a$

A particle of mass $2M$ is attached to the rod at the point C , where $AC = 1.5a$

The rod rests with its end A on rough horizontal ground.

The rod is held in equilibrium at an angle θ to the ground by a light string that is attached to the end B of the rod.

The string is perpendicular to the rod, as shown in Figure 2.

- (a) Explain why the frictional force acting on the rod at A acts horizontally to the right on the diagram.

(1)

The tension in the string is T

- (b) Show that $T = 2Mg \cos \theta$

(3)

Given that $\cos \theta = \frac{3}{5}$

- (c) show that the magnitude of the vertical force exerted by the ground on the rod at A is $\frac{57Mg}{25}$

(3)

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

Given that the rod is in limiting equilibrium,

- (d) show that $\mu = \frac{8}{19}$

(4)





Question 4 continued

Handwritten answer area with horizontal lines.

(Total for Question 4 is 11 marks)



6.

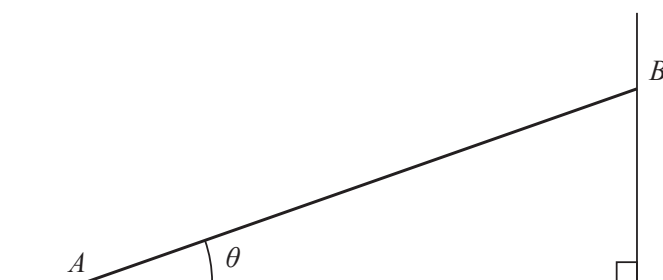


Figure 3

A rod AB has mass M and length $2a$.

The rod has its end A on rough horizontal ground and its end B against a smooth vertical wall.

The rod makes an angle θ with the ground, as shown in Figure 3.

The rod is at rest in limiting equilibrium.

- (a) State the direction (left or right on Figure 3 above) of the frictional force acting on the rod at A . **Give a reason for your answer.**

(1)

The magnitude of the normal reaction of the wall on the rod at B is S .

In an initial model, the rod is modelled as being **uniform**.

Use this initial model to answer parts (b), (c) and (d).

- (b) By taking moments about A , show that

$$S = \frac{1}{2} Mg \cot \theta$$

(3)

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

Given that $\tan \theta = \frac{3}{4}$

- (c) find the value of μ

(5)

- (d) find, in terms of M and g , the magnitude of the resultant force acting on the rod at A .

(3)

In a new model, the rod is modelled as being **non-uniform**, with its centre of mass closer to B than it is to A .

A new value for S is calculated using this new model, with $\tan \theta = \frac{3}{4}$

- (e) State whether this new value for S is larger, smaller or equal to the value that S would take using the initial model. **Give a reason for your answer.**

(1)









9.

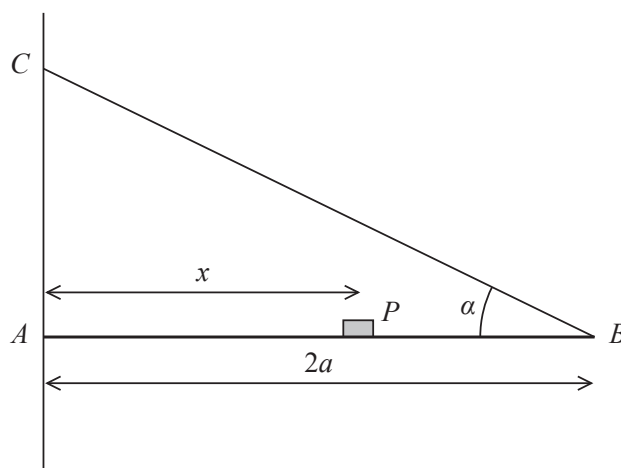


Figure 3

A plank, AB , of mass M and length $2a$, rests with its end A against a rough vertical wall. The plank is held in a horizontal position by a rope. One end of the rope is attached to the plank at B and the other end is attached to the wall at the point C , which is vertically above A .

A small block of mass $3M$ is placed on the plank at the point P , where $AP = x$. The plank is in equilibrium in a vertical plane which is perpendicular to the wall.

The angle between the rope and the plank is α , where $\tan \alpha = \frac{3}{4}$, as shown in Figure 3.

The plank is modelled as a uniform rod, the block is modelled as a particle and the rope is modelled as a light inextensible string.

- (a) Using the model, show that the tension in the rope is $\frac{5Mg(3x + a)}{6a}$ (3)

The magnitude of the horizontal component of the force exerted on the plank at A by the wall is $2Mg$.

- (b) Find x in terms of a . (2)

The force exerted on the plank at A by the wall acts in a direction which makes an angle β with the horizontal.

- (c) Find the value of $\tan \beta$ (5)

The rope will break if the tension in it exceeds $5Mg$.

- (d) Explain how this will restrict the possible positions of P . You must justify your answer carefully. (3)





(Total for Question 2 is 15 marks)



2.



Figure 2

A small box B of mass 2 kg is dragged in a straight line, along a **rough** horizontal plane, at a **constant speed** by a force of magnitude 5 N.

The line of action of the force makes an angle α with the plane, where $\sin \alpha = \frac{3}{5}$, as shown in Figure 2.

- (a) Show that the magnitude of the normal reaction of the plane on the box is 16.6 N. (3)

At the instant when B is at the point O on the plane, the force of magnitude 5 N is removed.

- (b) Describe the motion of the box after the force of magnitude 5 N is removed. (1)

- (c) Find the magnitude of the normal reaction of the plane on the box after the force of magnitude 5 N is removed. (1)

Given that after the force of magnitude 5 N is removed

- the box is modelled as a particle
- air resistance is modelled as being negligible
- the coefficient of friction between the box and the plane is modelled as 0.2
- the speed of the box as it passes through O is 4 m s^{-1}
- the box comes to rest at the point X on the plane

- (d) use the model to find the length OX . (4)

- (e) State one limitation of the model, apart from ignoring air resistance, that could affect your answer to part (d). (1)

Question 2 continued



Question 2 continued





6.

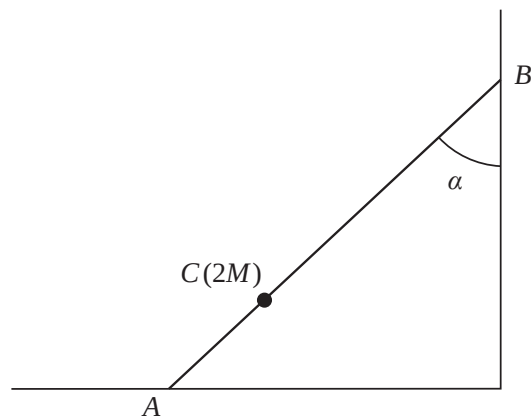


Figure 4

A uniform rod AB has mass M and length $2a$.

A particle of mass $2M$ is attached to the rod at the point C , where $AC = 0.5a$

The rod rests with end A on rough horizontal ground and end B against a vertical wall.

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

The rod is in equilibrium at an angle α to the wall, as shown in Figure 4.

In an initial model

- the vertical wall is modelled as being **smooth**
- the magnitude of the normal reaction of the ground on the rod at A is R
- the magnitude of the force exerted on the rod by the wall at B is S

Using the model,

(a) find R in terms of M and g (1)

(b) show that $S = Mg \tan \alpha$ (3)

In a refined model

- the vertical wall is modelled as being **rough**
- the magnitude of the normal reaction of the ground on the rod at A is R_1

(c) State which is greater, R or R_1 , giving a reason for your answer. (1)





(Total for Question 6 is 11 marks)

72

MARK SCHEMES

official mark schemes



Question	Scheme		Marks	AOs
2(a)	Resolve vertically, $R = 5g = 49$ (N)		B1	1.1b
			(1)	
2(b)	Equation of motion: $28 - F = 5 \times 1.4$		M1	3.1a
	$F = 21$		A1	1.1b
			(2)	
2(c)	$\mu = 0.43$ (2sf required)		B1 ft	3.4
			(1)	
(4 marks)				
Notes:				
2a	B1	Allow either $5g$ or 49 . No penalty for using $g = 9.81$ or 10 . Ignore any working. Must be a positive number. B0 if m is involved. N.B. Could be seen on a diagram, provided it's clearly the reaction.		
2b	M1	Equation with correct terms, dimensionally correct, condone sign errors.		
	A1	cao but allow $\frac{15g}{7}$. Ignore units.		
2c	B1ft	$\mu = \frac{\text{their (b)}}{\text{their (a)}}$. Answer must be a positive number given to 2sf. N.B. B0 if they use $g = 9.81$ or 10 in this part of the question. Do not allow restarts. Allow $\mu > 1$.		

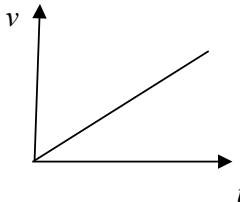
Question	Scheme		Marks	AOs
3(a)	(F =) (i − 1.2j)		B1	3.4
			(1)	
3(b)	v = (−7i + 7.8j) + 2(2i − 2.4j)		M1	2.1
	= (−3i + 3j) (m s ^{−1})		A1	1.1b
			(2)	
3(c)	Use trig to find an equation in a relevant angle		M1	2.1
	e.g. tan α = 1 or −1 or sin α = $\frac{3}{\sqrt{3^2 + 3^2}}$ or $\frac{-3}{\sqrt{3^2 + 3^2}}$ or cos α = $\frac{3}{\sqrt{3^2 + 3^2}}$ or $\frac{-3}{\sqrt{3^2 + 3^2}}$		A1	1.1b
	315°		A1	2.2a
			(3)	
3(d)	$\overrightarrow{OA} = 5(-7i + 7.8j) + \frac{1}{2}(2i - 2.4j) \times 5^2$		M1	3.1a
	= (−10i + 9j) (m)		A1	1.1b
			(2)	
(8 marks)				
Notes: Accept column vectors throughout apart from in the final answer for (a) and (d) which must be in terms of i and j, but only penalise ONCE for the whole question. N.B. For final answers to (a), (b) and (d) , penalise incorrect vector notation.				
3(a)	B1	Must be in terms of i and j Do not accept 0.5 × (2i − 2.4j) Do not need F =		
3(b)	M1	Use of v = u + at or any other complete method, e.g. integration, to find an unsimplified expression for v at t = 2, condone sign errors. N.B. If using integration, must have used t = 0, v = (−7i + 7.8j) to find the constant of integration and included it in their expression for v at t = 2.		
	A1	cao. N.B. Ignore if they go on and find the speed.		
3(c)	M1	Use trig to find an equation in a relevant angle for their v		
	A1	Correct equation.		
	A1	Cao (with or without the degree sign), must come from a correct v N.B. ±45°, ±135°, ±225°, −315° with no working scores M1A1 315° with no working scores all 3 marks.		

3(d)	M1	Use of $\mathbf{r} = \mathbf{ut} + \frac{1}{2}\mathbf{at}^2$ with $t = 5$ or any other complete method, e.g. integration of their $\mathbf{v} = f(t)$ and use of $t = 5$, to find an unsimplified expression for $\overrightarrow{OA}$ (No need to show that $\mathbf{C} = \mathbf{0}$) M0 if they use $\mathbf{u} = \mathbf{0}$
	A1	Must be in terms of $\mathbf{i}$ and $\mathbf{j}$ N.B. Ignore if they go on and find the length OA



Question	Scheme	Marks	AOs
2(a)(i)	Resolve vertically	M1	3.1b
	F acting UP the plane: OR F acting DOWN the plane: $(\uparrow) F \sin \alpha + 68.6 \cos \alpha = 5g$ $-F \sin \alpha + 68.6 \cos \alpha = 5g$	A1	1.1b
	Other possible equations from which X would need to be eliminated to give an equation in F only to earn the M mark are shown below. The equation in F only must then be correct to earn the A mark. Possible equations: $(\nwarrow) 68.6 = X \sin \alpha + 5g \cos \alpha$ (leads to $X = 49$ with $g = 9.8$) F acting UP the plane: OR F acting DOWN the plane: $(\nearrow) F + X \cos \alpha = 5g \sin \alpha$ $-F + X \cos \alpha = 5g \sin \alpha$ $(\rightarrow) F \cos \alpha + X = 68.6 \sin \alpha$ $-F \cos \alpha + X = 68.6 \sin \alpha$		
	9.8 (N) (49/5 is A0) N.B. If sin and cos are interchanged in all equations, this leads to an answer of 9.8 in the wrong direction and can only score (a) (i) M1A0A0 (ii) A0	A1	1.1b
		(3)	
2(a)(ii)	Down the plane (Allow down or downwards or an arrow $\swarrow$, but must appear as the answer to (a) (ii) not just on the diagram.)	A1	2.2a
		(1)	
2(b)	N.B. If they use $R = 68.6$ in this part, the maximum they can score is M1A1M0A0M0A0 If they use $F = 9.8$ or their F from (a) in this part, the maximum they can score is M1A1M0A0M0A0		
	Equation of motion down the plane	M1	2.1
	$5g \sin \alpha - F = 5a$ Allow $(-a)$ instead of a	A1	1.1b
	Resolve perpendicular to the plane	M1	3.1b
	$R = 5g \cos \alpha$	A1	1.1b
	$F = 0.5R$ seen	M1	3.4
	$a = 1.96$ or 2.0 or $2 \text{ (m s}^{-2}\text{)}$ or $\frac{1}{5}g$	A1	1.1b
		(6)	
(10 marks)			

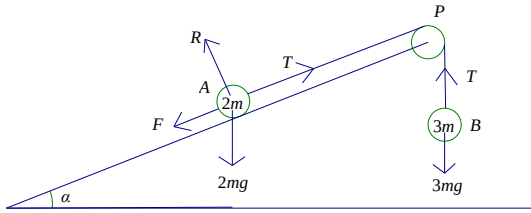
Notes:		
2a (i)	M1	Complete method to obtain an equation in F only . For each equation used, correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved.
	A1	Correct equation in F only, trig does not need to be substituted
	A1	cao (must be positive)
2a (ii)	A1	cao. Note that this mark is dependent on an answer of 9.8 or -9.8 for (a)(i) <u>from a fully correct solution</u> unless they have used $g = 9.81$, in which case the answer will be 9.7 or -9.7 (2sf) see SC2 below. N.B. Allow this mark, if their answer to (a)(i) is fully correct apart from a small error due to use of inaccurate trig i.e using an angle 36.9°
		SC 1: If they use μR at any point (with an unknown μ) for F in part (a), can score (a)(i) max M1A1A0 (a) (ii) A1, where they must have obtained $\mu R = 9.8$ or -9.8 , from correct working . SC 2: If $g = 9.81$ is used consistently throughout 2(a) , (leading to $X = 48.9\dots$ and $F = 9.7$ (2sf)) can score max (a)(i) M1A1A0 (a)(ii) A1
2b	M1	Correct no.of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved.
	A1	Correct equation for their F .
	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved. (N.B. M0 if $R = 68.6$ (N) is used in this equation)
	A1	Correct equation
	M1	Could be seen on a diagram (N.B. M0 if $R = 68.6$ (N) is used)
	A1	Cao. Must be positive.

Question		Scheme	Marks	AOs
2(a)		Equation of motion for A	M1	3.3
		$3mg \sin \alpha - F - T = 3ma$	A1	1.1b
			(2)	
2(b)		Resolve perpendicular to the plane	M1	3.4
		$R = 3mg \cos \alpha$	A1	1.1b
		$F = \frac{1}{6}R$	B1	1.2
		Equation of motion for B OR for whole system	M1	3.3
		$T - mg = ma$ OR $3mg \sin \alpha - F - mg = 3ma + ma$	A1	1.1b
		Complete method to solve for a	DM1	3.1b
		$a = \frac{1}{10}g$ *	A1*	2.2a
			(7)	
2(c)			B1	1.1b
		e.g. acceleration (of B) is constant; dependent on first B1	DB1	2.4
			(2)	
2(d)		e.g. the tensions in the two equations of motion would be different. Tension on A would be different to tension on B	B1	3.5a
			(1)	
(12 marks)				
Notes: N.B. If m's are consistently missing treat as a MR, so max (a) M1A0 (b) M1A0B0M1A1M1A1 (c) B1B1 (d) B1 For (a) and (b), allow verification, but must see full equations of motion.				
2a	M1	Equation in T and a with correct no. of terms, condone sign errors and sin/cos confusion (If one of the 3's is missing, allow M1) N.B. Treat sin(3/5) etc as an A error but allow recovery		
	A1	Correct equation (allow $(-a)$ instead of a in <u>both</u> equations)		

2b	M1	Correct no. of terms, condone sign errors and sin/cos confusion Allow if appears in (a)
	A1	Correct equation
	B1	Seen anywhere in (a) or (b), including on a diagram
	M1	Equation (for B) in T and a with correct no. of terms, condone sign errors and sin/cos confusion OR Whole system equation with correct no. of terms, condone sign errors and sin/cos confusion
	A1	Correct equation
	DM1	Complete method (trig may not be substituted), dependent on M1 in (a) and second M1 in (b) if they use two equations, or second M1 in (b) if they use one equation.
	A1*	Correct answer correctly obtained.
2c	B1	Straight line starting at the origin (could be reflected in the t -axis). B0 if continuous vertical line at the end.
	DB1	Dependent on first B1, for any equivalent statement
2d	B1	B0 if incorrect extras

Question	Scheme	Marks	AOs
	Part (a) is a 'Show that..' so equations need to be given in full to earn A marks		



Question	Scheme	Marks	AO
3(a)			
	$R = 2mg \cos \alpha$	B1	3.4
	$F = \frac{2}{3} R$	B1	1.2
	Equation of motion for A:	M1	3.3
	$T - F - 2mg \sin \alpha = 2ma$	A1	1.1b
	Equation of motion for B:	M1	3.3
	$3mg - T = 3ma$	A1	1.1b
	Complete strategy to find an equation in T , m and g only.	M1	3.1b
	$T = \frac{12mg}{5} \quad *$	A1*	2.2a
	(8)		
(b)	$(F_{\max} =) \frac{16mg}{13} > \frac{10mg}{13}$	M1	2.1
	 so A will not move.	A1	2.2a
	(2)		
(c)	• Extensible string • Weight of string • Friction at pulley e.g. rough pulley • Allow for the dimensions of the blocks e.g. “Do not model blocks as particles”; “(include) air resistance”; “include rotational effects of forces on blocks i.e. spin”	B1 B1	3.5c 3.5c
	(2)		
	(12)		

Marks		Notes
3a	B1	Normal reaction between A and the plane seen or implied, $\cos \alpha$ does not need to be substituted.
	B1	$F = \frac{2}{3}R$ seen or implied anywhere, including part (b)
	M1	Form an equation of motion for A. Must include all relevant terms. Must be the correct mass but condone consistent missing m 's. Condone sign errors and sin/cos confusion
	A1	Correct unsimplified equation (F does not need to be substituted). Allow consistent use of $(-a)$ N.B. If $T - 2mg = 2ma$ is seen with no working, M0A0 unless both B1 marks have been scored.
	M1	Form an equation of motion for B. Must be the correct mass on RHS but condone consistent missing m 's. Condone sign errors and sin/cos confusion.
	A1	Correct unsimplified equation (F does not need to be substituted). Allow consistent use of $(-a)$
		N.B. Allow the 'whole system' equation to replace the equation for A or B. $3mg - F - 2mg \sin \alpha = 5ma$ Must be the correct mass on RHS but condone consistent missing m 's. Condone sign errors and sin/cos confusion.
	M1	Complete method to give an equation in T , m and g only. N.B. Allow θ in the equation if they have defined what θ is: e.g. $\theta = \tan^{-1}(\frac{5}{12})$ This is an <u>independent</u> mark but they must have two simultaneous equations in T and a unless one of the equations is the whole system equation in which case one equation will be in T and a and the other equation will be in a only.
	A1*	Obtain the given answer from correct working using EXACT trig ratios. (not available if using a decimal angle)
3b	M1	Comparison of their $F_{\max}$ ($\frac{2}{3}R$) and their component of weight down the slope, must be comparing numerical values. oe e.g. if they consider the difference N.B. Allow comparison of μ and $\tan \alpha$ with numerical values
	A1	Correctly justified conclusion and no errors seen N.B. If they equate their difference to an ' ma ' term then A0
3c	B1	Deduct 1 mark for each extra (more than 2) incorrect answer up to a maximum of 2 incorrect answers. Ignore extra correct answers. e.g. two correct, one incorrect B1 B0 one correct, one incorrect B1 B0 one correct, two incorrect B0 B0 Ignore incorrect reasons or consequences. Ignore any mention of wind or a general reference to friction.
	B1	

Question	Scheme		Marks	AOs
1(a)	0.5g, $\frac{1}{2}g$ or 4.9 (N) seen		B1	3.4
			(1)	
1(b)	$\frac{2}{7} \times 4.9$ oe seen		M1	3.1a
	1.4, 1.40 or $\frac{1}{7}g$		A1	1.1b
			(2)	
(3 marks)				
Notes: Ignore units in this question. N.B. Use of $g = 9.81$ should only be penalised once for the whole question as should two fractional answers (a) 49/10 (b) 7/5. Penalise the use of $g = 9.81$ the first time you see it. N.B. If $g = 9.81$ is used in (a), B0. If it is then used again in part (b), and they give the answer as 1.4 or 1.40, they can score M1A1 in part (b). If $g = 9.81$ is only used in (b), they can score max M1A0 for (b).				
1a	B1	cao. (must be positive) B0 for a fraction ($\frac{49}{10}$) B0 if they have 0.5g and then clearly use $g = 9.81$ i.e. NOT isw This answer must appear in (a) to earn this mark. If no labelling, give BOD and award as many marks as possible.		
1b	M1	$\frac{2}{7} \times$ their (a) (must be a numerical value) If no answer for (a) or if (a) is incorrect and they don't use it, allow a correct restart i.e. $\frac{2}{7} \times 4.9$ or $\frac{2}{7} \times 0.5g$ or $\frac{2}{7} \times 0.5$ (missing g is not an M error)		
	A1	A0 for a fraction N.B. $X =$ is not needed BUT A0 for F (or P or horizontal force) = a correct answer if they don't go on to state $X = \dots$ If they obtain the correct answer for F and they have said $F = X$ they can score A1.		
		N.B. 1.4, 1.40 or $\frac{1}{7}g$ with no working , scores M1A1		

Question		Scheme	Marks	AOs
3(a)		$(R=)mg \cos \alpha$	M1	3.4
		$= \frac{12}{13} mg$	A1	1.1b
			(2)	
3(b)		Equation of motion down the plane	M1	2.1
		$mg \sin \alpha - F = ma$ or $mg \sin \alpha - F = -ma$	A1	1.1b
		$(F =) \mu \times \text{their } R$	M1	3.4
		$\frac{1}{13} g(5-12\mu)$ *	A1*	2.2a
			(4)	
3(c)		P wouldn't move	B1	2.4
			(1)	
(7 marks)				
Notes:				
3a	M1	Correct no. of terms, condone sin/cos confusion and sign errors, dimensionally correct. Allow use of a different symbol for the angle.		
	A1	Accept $0.92mg$ or better. Must be positive.		
3b	M1	Correct no. of terms, condone sin/cos confusion and sign errors (M0 if they use g for a) N.B. Must be using mg or m not W for the weight.		
	A1	Any correct equation e.g. $mg \sin \alpha = ma + F$ N.B. F does not need to be substituted.		
	M1	$\mu \times \text{their } R$ seen (possibly on a diagram), any trig does not need to be replaced. M0 if they use $\mu = \frac{5}{12}$ M0 for just μR with R not replaced.		
	A1*	Given answer correctly obtained, with at least one further line of working with both trig ratios substituted as fractions. Allow $\frac{g}{13}(5-12\mu)$ or $\frac{g(5-12\mu)}{13}$		
3c	B1	e.g. P (or the particle or the object) would stay at rest, P would not slide down, would not roll down the plane, static equilibrium, equilibrium at rest Allow 'it' for P or just 'stays at rest oe' B0 for wouldn't accelerate, would be in equilibrium (only), would stop N.B. Ignore reasons but not contradictions.		



Question	Scheme	Marks	AOs
7(a)	Resolve vertically	M1	3.1b
	$R + 40\sin\alpha = 20g$	A1	1.1b
	Resolve horizontally	M1	3.1b
	$40\cos\alpha - F = 20a$	A1	1.1b
	$F = 0.14R$	B1	1.2
	$a = 0.396$ or $0.40 \text{ (m s}^{-2}\text{)}$	A1	2.2a
		(6)	
(b)	Pushing will increase R which will increase available F	B1	2.4
	Increasing F will <u>decrease</u> a * GIVEN ANSWER	B1*	2.4
		(2)	
(8 marks)			
Notes:			
(a) M1: Resolve vertically with usual rules applying A1: Correct equation. Neither g nor $\sin\alpha$ need to be substituted M1: Apply $F = ma$ horizontally, with usual rules A1: Neither F nor $\cos\alpha$ need to be substituted B1: $F = 0.14R$ seen (e.g. on a diagram) A1: Either answer			
(b) B1: Pushing increases R which produces an increase in available (limiting) friction B1: F increase produces an <u>a decrease (need to see this)</u> N.B. It is possible to score B0 B1 but for the B1, some “explanation” is needed to say why friction is increased e.g. by pushing into the ground.			



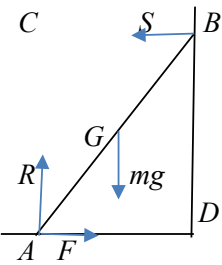
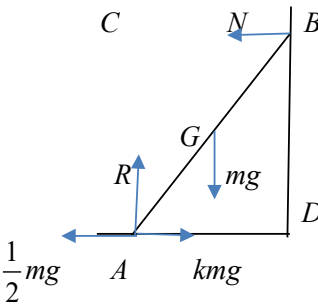
Question	Scheme		Marks	AOs
1.(a)	Resolve perpendicular to the plane		M1	3.4
	$R = mg \cos \alpha = \frac{4}{5} mg$		A1	1.1b
			(2)	
1(b)	Resolve parallel to the plane or horizontally or vertically		M1	3.4
	$F = mg \sin \alpha$ or $R \sin \alpha = F \cos \alpha$		A1	1.1b
	Use $F = \mu R$ and solve for μ		M1	2.1
	$\mu = \frac{3}{4}$ *		A1*	2.2a
			(4)	
1(c)	The forces acting on Q will still balance as the m 's cancel oe Other possibilities: e.g. the <u>friction</u> will increase <u>in the same proportion</u> as the <u>weight component</u> or <u>force down the plane</u> . The <u>force pulling the brick down the plane</u> increases <u>by the same amount</u> as the <u>friction</u> oe This mark can be scored if they do the calculation.		B1	2.4
			(1)	
1(d)	Brick Q slides down the plane with constant speed.		B1	2.4
	No resultant force down the plane (so no acceleration) oe		B1	2.4
	These marks can be scored if they do the calculation.		(2)	
(9 marks)				
Notes:				
1a	M1	Correct no. of terms, condone sin/cos confusion		
	A1	cao with no wrong working seen. $mg \cos 36.86$ is A0		
1b	M1	Correct no. of terms, condone sin/cos confusion		
	A1	Correct equation		
	M1	Must use $F = \mu R$ (not merely state it) to obtain a numerical value for μ . This is an independent M mark.		
	A1*	Given answer correctly obtained		
1c	B1	Must have the 3 underlined phrases/word oe		
1d	B1	Must say constant speed.		
	B1	Any appropriate equivalent statement		



Question	Scheme	Marks	AOs
6.			
6(a)	Take moments about A	M1	3.1a
	$S \times 1.5a = Mga \cos \theta = \left(Mga \times \frac{3}{5}\right)$	A1	1.1b
	$S = \frac{2}{5} Mg$ *	A1*	2.2a
		(3)	
6(b)	N.B. Marks for the equations should be awarded in the order in which they appear on the script.		
	Resolve horizontally:	M1	3.4
	$F = S \sin \theta$	A1	1.1b
	Resolve vertically:	M1	3.3
	$R = Mg - S \cos \theta$	A1	1.1b
	Other possible equations: (any of which is worth max M1A1) (parallel to the rod): $F \cos \theta + R \sin \theta = Mg \sin \theta$ (perp to the rod): $F \sin \theta + Mg \cos \theta = S + R \cos \theta$ M(B): $(S \times 0.5a) + (R \times 2a \cos \theta) = (Mg \times a \cos \theta) + (F \times 2a \sin \theta)$ M(C): $(R \times 1.5a \cos \theta) = (Mg \times 0.5a \cos \theta) + (F \times 1.5a \sin \theta)$ M(G): $(R \times a \cos \theta) = (S \times 0.5a) + (F \times a \sin \theta)$ N.B. If they have more than two equations, mark only those that they use to try to find μ		
	$F = \mu R$ and two of their equations used to solve for μ	DM1	3.1a
	$\mu = \frac{8}{19} = 0.42105\dots$	A1	2.2a

		(6)	
(9 marks)			
Notes:			
6a	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors. Allow use of a different letter for the angle. N.B. They may resolve the weight into two components, parallel and perpendicular to the rod, and then take the moment of each about A, one of which is 0. (see N.B. below) N.B. M0 if one or both a 's aren't there originally.	
	A1	Correct equation, $\cos \theta$ may or may not be replaced by $\frac{3}{5}$ N.B. you may see: $S \times 1.5a = Mg \cos \theta \times a$	
	A1*	Given answer correctly obtained, need to see $\cos \theta = \frac{3}{5}$ used Allow: $S = \frac{2Mg}{5}$ or $\frac{2Mg}{5} = S$ A0 if S is missing	
6b	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors	
	A1	Correct first equation, S does not need to be substituted	
	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors	
	A1	Correct second equation, S does not need to be substituted	
	DM 1	Dependent on previous two M marks for using $F = \mu R$ and two equations to solve for μ	
	A1	Accept 0.42 or better (as g cancels)	



Question	Scheme	Marks	AOs
3(a)			
	Moments equation: (M1A0 for a moments inequality)	M1	3.3
	$M(A), mga \cos \theta = 2Sa \sin \theta$ $M(B), mga \cos \theta + 2Fa \sin \theta = 2Ra \cos \theta$ $M(C), F \times 2a \sin \theta = mga \cos \theta$ $M(D), 2Ra \cos \theta = mga \cos \theta + 2Sa \sin \theta$ $M(G), Ra \cos \theta = Fa \sin \theta + Sa \sin \theta$	A1	1.1b
	$(\uparrow) R = mg$ OR $(\leftrightarrow) F = S$	B1	3.4
	Use their equations (<u>they must have enough</u>) and $F \leq \mu R$ to give an inequality in μ and θ only (allow DM1 for use of $F = \mu R$ to give an equation in μ and θ only)	DM1	2.1
	$\mu \geq \frac{1}{2} \cot \theta^*$	A1*	2.2a
		(5)	
3(b)			
	Moments equation:	M1	3.4
	$M(A), mga \cos \theta = 2Na \sin \theta$ $M(B), mga \cos \theta + 2kmga \sin \theta = 2Ra \cos \theta + \frac{1}{2}mg2a \sin \theta$ $M(D), 2Ra \cos \theta = mga \cos \theta + N2a \sin \theta$ $M(G), kmg a \sin \theta + Na \sin \theta = \frac{1}{2}mga \sin \theta + Ra \cos \theta$	A1	1.1b

	$\text{S.C. } M(C), \quad mga \cos \theta + \frac{1}{2} mg 2a \sin \theta = kmg 2a \sin \theta \quad \text{M1A1B1}$ $1 + \frac{5}{4} = \frac{5k}{2} \quad \text{M1}$ $k = 0.9 \quad \text{A1}$		
	$N = kmg - F \quad \text{OR} \quad R = mg$	B1	3.3
	Use their equations (<u>they must have enough</u>) to solve for k (numerical)	DM1	3.1b
	$k = 0.9 \quad \text{oe}$	A1	1.1b
		(5)	

(10 marks)

Notes:

3a	M1	Any moments equation with correct terms, condone sign errors and sin/cos confusion
	A1	Correct equation
	B1	Correct equation
	DM1	Dependent on M1, for using their equations (<u>they must have enough</u>) and $F \leq \mu R$ to give an inequality in μ and θ only (allow M1 for use of $F = \mu R$ to give an equation in μ and θ only)
	A1*	Given answer correctly obtained with no wrong working seen (e.g. if they use $F = \mu R$ anywhere, A0)
3b	M1	Any moments equation with correct terms, condone sign errors
	A1	Correct equation
	B1	Correct equation
	DM1	Dependent on M1, for using their equations (<u>they must have enough</u>) with trig substituted, to solve for k , which must be numerical.
	A1	cao

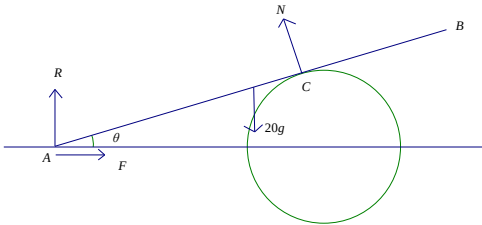
Question	Scheme	Marks	AOs
	Note that $g = 10$; penalise once for whole question if $g = 9.8$		



Question	Scheme	Marks	AOs
4(a)	Take moments about A	M1	3.3
	$N \times \frac{4a}{\sin \alpha} = Mg \times 3a \cos \alpha$	A1	1.1b
	$\frac{9Mg}{25} *$	A1*	1.1b
		(3)	
4(b)	Resolve horizontally	M1	3.4
	$(\rightarrow) F = \frac{9Mg}{25} \sin \alpha$	A1	1.1b
	Resolve vertically	M1	3.4
	$(\uparrow) R + \frac{9Mg}{25} \cos \alpha = Mg$	A1	1.1b
	Other possible equations: $(\nwarrow), R \cos \alpha + \frac{9Mg}{25} = Mg \cos \alpha + F \sin \alpha$ $(\nearrow), Mg \sin \alpha = F \cos \alpha + R \sin \alpha$ $M(C), Mg.2a \cos \alpha + F.5a \sin \alpha = R.5a \cos \alpha$ $M(G), \frac{9Mg}{25}.2a + F.3a \sin \alpha = R.3a \cos \alpha$ $M(B), Mg.3a \cos \alpha + F.6a \sin \alpha = R.6a \cos \alpha + \frac{9Mg}{25}a$ $(F = \frac{36Mg}{125}, R = \frac{98Mg}{125})$		
	$F = \mu R$ used	M1	3.4
	Eliminate R and F and solve for μ	M1	3.1b
	Alternative equations if they have at A: X horizontally and Y perpendicular to the rod. $(\nwarrow), Y + \frac{9Mg}{25} = Mg \cos \alpha + X \sin \alpha$ $(\nearrow), Mg \sin \alpha = X \cos \alpha$ $(\uparrow), \frac{9Mg}{25} \cos \alpha + Y \cos \alpha = Mg$ $(\rightarrow), Y \sin \alpha + \frac{9Mg}{25} \sin \alpha = X$		

		$M(C), Mg.2a \cos \alpha + X.5a \sin \alpha = Y.5a$ $M(G), \frac{9Mg}{25}.2a + X.3a \sin \alpha = Y.3a$ M1A1 M1A1 $M(B), Mg.3a \cos \alpha + X.6a \sin \alpha = Y.6a + \frac{9Mg}{25}a$ $(X = \frac{4Mg}{3}, Y = \frac{98Mg}{75})$ Then $F = \mu R$ becomes: $X - Y \sin \alpha = \mu Y \cos \alpha$ M1 Eliminate X and Y and solve for μ M1		
		$\mu = \frac{18}{49}$ (0.3673.....accept 0.37 or better)	A1	2.2a
			(7)	
(10 marks)				
Notes:				
4a	M1	Correct no. of terms, dim correct, condone sin/cos confusion and sign errors for an equation in N and Mg only. For perp distance allow any of : $\frac{4a}{\sin \alpha}, \frac{4a}{\cos \alpha}, 5a$ but use of any of : $6a, 5a \sin \alpha, 4a \cos \alpha, \dots$ or anything involving $\tan \alpha$ is M0 Also M0 if no a 's in their first equation.		
	A1	Correct equation, trig does not need to be substituted		
	A1*	Given answer correctly obtained.		
4b	M1	Correct no. of terms, dim correct, condone sin/cos confusion and sign errors		
	A1	Correct equation, trig does not need to be substituted but N does.		
	M1	Correct no. of terms, dim correct, condone sin/cos confusion and sign errors		
	A1	Correct equation, trig does not need to be substituted but N does.		
		N.B. The above 4 marks are for any two equations, either resolutions or moments or one of each. Mark best two equations. Equations may appear in part (a) but must be used in (b) to earn marks.		
	M1	Must be used, e.g. seen on the diagram. i.e. M0 if merely quoting it. (M0 if $F = \mu \times \frac{9Mg}{25}$ used)		
	M1	Must have 3 equations (<u>and all 3 previous M marks</u>)		
	A1	Accept 0.37 or better		



Question	Scheme	Marks	AO
4(a)	Drum smooth , or no friction, (therefore reaction is perpendicular to the ramp)	B1	2.4
		(1)	
(b)	N.B. In (b), for a moments equation, if there is an extra $\sin \theta$ or $\cos \theta$ on a length, give M0 for the equation e.g. $M(A): 20g \times 4 \cos \theta = 5N \sin \theta$ would be given M0A0		
			
	Possible equns	M1	3.3
	$(\nearrow): F \cos \theta + R \sin \theta = 20g \sin \theta$	A1	1.1b
	$(\nwarrow): N + R \cos \theta = 20g \cos \theta + F \sin \theta$	M1	3.4
	$(\uparrow) R + N \cos \theta = 20g$	A1	1.1b
	$(\rightarrow): F = N \sin \theta$	M1	3.4
	$M(A): 20g \times 4 \cos \theta = 5N$	A1	1.1b
	$M(B): 3N + R \times 8 \cos \theta = F \times 8 \sin \theta + 20g \times 4 \cos \theta$		
	$M(C): R \times 5 \cos \theta = F \times 5 \sin \theta + 20g \times \cos \theta$		
	$M(G): R \times 4 \cos \theta = F \times 4 \sin \theta + N$		
	(The values of the 3 unknowns are: $N = 150.528; F = 42.14784; R = 51.49312$)		
	Alternative 1: using cpts along ramp (X) and perp to ramp (Y)	M1	3.3
	Possible equations:	A1	1.1b
	$(\nearrow): X = 20g \sin \theta$	M1	3.4
	$(\nwarrow): Y + N = 20g \cos \theta$	A1	1.1b
	$(\uparrow): X \sin \theta + Y \cos \theta + N \cos \theta = 20g$	M1	3.4
	$(\rightarrow): X \cos \theta = Y \sin \theta + N \sin \theta$	A1	1.1b
	$M(A): 20g \times 4 \cos \theta = 5N$	M1	3.4
	$M(B): 20g \times 4 \cos \theta = 8Y + 3N$	A1	1.1b
	$M(C): 20g \times \cos \theta = 5Y$		
	$M(G): 4Y = N \times 1$		
	(The values of the 3 unknowns are: $N = 150.528; X = 54.88; Y = 37.632$)		

	Alternative 2: using horizontal cpt (H) and cpt perp to ramp (S) $(\nearrow): H \cos \theta = 20g \sin \theta$ $(\nwarrow): S + N = H \sin \theta + 20g \cos \theta$ $(\uparrow): S \cos \theta + N \cos \theta = 20g$ $(\rightarrow): H = S \sin \theta + N \sin \theta$ $M(A): 20g \times 4 \cos \theta = 5N$ $M(B): 20g \times 4 \cos \theta + H \times 8 \sin \theta = 8S + 3N$ $M(C): 20g \times \cos \theta + H \times 5 \sin \theta = 5S$ $M(G): 4S = N \times 1 + H \times 4 \sin \theta$	M1	3.3
		A1	1.1b
		M1	3.4
		A1	1.1b
		M1	3.4
		A1	1.1b
	(The values of the 3 unknowns are: $N = 150.528; H = 57.1666...; S = 53.638666...$)		
	Solve their 3 equations for F and R OR X and Y OR H and S	M1	1.1b
	$ \text{Force} = \sqrt{R^2 + F^2}$ Main scheme OR $= \sqrt{X^2 + Y^2}$ Alternative 1 OR $= \sqrt{(H^2 + S^2 - 2HS \cos(90^\circ - \theta))}$ Alternative 2	M1	3.1b
	Magnitude = 67 or 66.5 (N)	A1	2.2a
		(9)	
(c)	Magnitude of the normal reaction (at C) will decrease .	B1	3.5a
		(1)	
		(11)	

Marks		Notes
4a	B1	Ignore any extra incorrect comments.
		Generally 3 independent equations required so at least one moments equation.: M1A1M1A1M1A1. More than 3 equations, give marks for the best 3. For each: M1 All terms required. Must be dimensionally correct so if a length is missing from a moments equation it's M0 Condone sin/cos confusion. A1 For a correct equation (trig ratios do not need to be substituted and allow e.g. $\cos(24/25)$ if they recover <u>Enter marks on ePEN in order in which equations appear.</u> N.B. If reaction at C is not perpendicular to the ramp, can only score marks for M(C) Allow use of (μR) for F
4b	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion.
	A1	Correct unsimplified equation
	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion.
	A1	Correct unsimplified equation
	M1	All terms required, dim correct, condone sin/cos confusion
	A1	Correct unsimplified equation
		N.B. They can find F and R using only TWO equations, the 1st and 7th in the list. Mark the better equation as M2A2 (-1 each error). Mark the second equation as M1A1
Alt 1	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion.
	A1	Correct unsimplified equation
	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion.
	A1	Correct unsimplified equation
	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion.
	A1	Correct unsimplified equation
		N.B. They can find X and Y using only TWO equations, the 1 st and 7 th in the list. Mark the better equation as M2A2 (-1 each error). Mark the second equation as M1A1
Alt 2	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion.
	A1	Correct unsimplified equation
	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion.



	A1	Correct unsimplified equation
	M1	All terms required. Must be dimensionally correct.
	A1	Correct unsimplified equation
		N.B. They can find H and S using only TWO equations, the 1 st and 7 th in the list. Mark the better equation as M2A2 (-1 each error). Mark the second equation as M1A1
	M1	Substitute for trig and solve for their two cpts. This is an independent mark <u>but must use 3 equations</u> (unless it's the special case when 2 is sufficient)
	M1	Use Pythagoras to find magnitude (this is an <u>independent</u> M mark but must have found a value for F (or X) and a value for R (or Y)) OR a complete method to find magnitude e.g. cosine rule but must have found a value for H and a value for S
	A1	Correct answer only
	B1	Ignore reasons

Question	Scheme	Marks	AO
	In this question mark parts (a) and (b) together.		



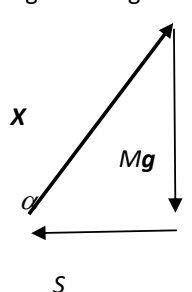
Question	Scheme	Marks	AOs
4(a)	The horizontal component of T acts to the left and since the only other horizontal force is friction, it must act to the right oe	B1	2.4
		(1)	
4(b)	Take moments about A or any other complete method to obtain an equation in T, M and θ only. (see possible equations below that they may use)	M1	3.1b
	$T.2a = Mga \cos \theta + 2Mg \times 1.5a \cos \theta$ (A0 if a 's missing)	A1	1.1b
	Other possible equations but F and R would need to be eliminated. (↖), $R \cos \theta + T = F \sin \theta + Mg \cos \theta + 2Mg \cos \theta$ (↗), $R \sin \theta + F \cos \theta = Mg \sin \theta + 2Mg \sin \theta$ (→), $F = T \sin \theta$ $M(B), R.2a \cos \theta = Mga \cos \theta + 2Mg \times 0.5a \cos \theta + F.2a \sin \theta$ $M(G), Fa \sin \theta + Ta = Ra \cos \theta + 2Mg \times 0.5a \cos \theta$ $M(C), R \times 1.5a \cos \theta = T \times 0.5a + Mg \times 0.5a \cos \theta + F \times 1.5a \sin \theta$		
	$T = 2Mg \cos \theta^*$	A1*	1.1b
		(3)	
4(c)	e.g. Resolve vertically	M1	3.4
	(↑), $R + T \cos \theta = Mg + 2Mg$	A1	1.1b
	$R = \frac{57Mg}{25}^*$	A1*	1.1b
		(3)	
	Other possible equations but F would need to be eliminated. (↖), $R \cos \theta + T = F \sin \theta + Mg \cos \theta + 2Mg \cos \theta$ (↗), $R \sin \theta + F \cos \theta = Mg \sin \theta + 2Mg \sin \theta$ (→), $F = T \sin \theta$ $M(B), R.2a \cos \theta = Mga \cos \theta + 2Mg \times 0.5a \cos \theta + F.2a \sin \theta$ $M(G), Fa \sin \theta + Ta = Ra \cos \theta + 2Mg \times 0.5a \cos \theta$ $M(C), R \times 1.5a \cos \theta = T \times 0.5a + Mg \times 0.5a \cos \theta + F \times 1.5a \sin \theta$		
4(d)	Find an equation containing F e.g. Resolve horizontally	M1	3.4
	(→), $F = T \sin \theta$	A1	1.1b
	Other possible equations		

		$(\nwarrow), R \cos \theta + T = F \sin \theta + Mg \cos \theta + 2Mg \cos \theta$ $(\nearrow), R \sin \theta + F \cos \theta = Mg \sin \theta + 2Mg \sin \theta$ $(\rightarrow), F = T \sin \theta$ $M(B), R.2a \cos \theta = Mga \cos \theta + 2Mg \times 0.5a \cos \theta + F.2a \sin \theta$ $M(G), Fa \sin \theta + Ta = Ra \cos \theta + 2Mg \times 0.5a \cos \theta$ $M(C), R \times 1.5a \cos \theta = T \times 0.5a + Mg \times 0.5a \cos \theta + F \times 1.5a \sin \theta$		
		$F = \mu R$ used i.e. both F and R are substituted.	M1	3.1b
		$\mu = \frac{8}{19} *$	A1*	2.2a
			(4)	
(11 marks)				
Notes:				
4a	B1	Any equivalent explanation		
4b	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors		
	A1	Correct equation, trig does not need to be substituted (Allow: $T.2a = Mga \cos \theta + 3Mga \cos \theta$)		
	A1*	Given answer correctly obtained with <u>no wrong working seen</u> . Allow $2Mg \cos \theta = T$ But not $T = 2 \cos \theta Mg$		
4c	M1	For an equation in R, M, T and θ only Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved		
	A1	Correct equation, T and trig do not need to be substituted		
	A1*	Given answer correctly obtained with <u>no wrong working seen</u>		
4d	M1	For any equation with F in it Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved		
	A1	Correct equation, trig does not need to be substituted		
	M1	Must be used i.e M0 if merely quoting it.		
	A1*	Given answer correctly obtained with <u>no wrong working seen</u>		



Question	Scheme	Marks	AOs
6(a)	The normal reaction at B is acting to the left so it must act to the right, right as it needs to balance (oppose, counter) the force at B , right as it prevents the rod from sliding (slipping, falling), right as the weight (mass) of the rod will mean the rod tends to slip left, mass or weight will be pushing the rod to the left so friction will oppose that. N.B. You may see an arrow on the diagram at A , instead of 'right'. B0 if they say the rod is moving oe Accept towards the wall instead of to the right.	B1	2.4
		(1)	
6(b)	Take moments about A	M1	3.4
	$S \times 2a \sin \theta = Mga \cos \theta$	A1	1.1b
	$S = \frac{1}{2} Mg \cot \theta$	A1*	2.2a
		(3)	
6(c)	Resolve vertically, $R = Mg$	B1	3.3
	Resolve horizontally, $F = S$	B1	3.3
	Other possible equations: Resolve along the rod, $F \cos \theta + R \sin \theta = S \cos \theta + Mg \sin \theta$ Resolve perp to the rod, $R \cos \theta + S \sin \theta = F \sin \theta + Mg \cos \theta$ $M(B), R \times 2a \cos \theta = F \times 2a \sin \theta + Mga \cos \theta$ $M(G), Ra \cos \theta = Fa \sin \theta + Sa \sin \theta$ N.B. When entering these two B marks on ePEN, First B1 is for a vertical resolution, second B1 is for a horizontal resolution, and if either is replaced by a different equation, enter appropriately. If both are replaced by other equations, enter in the order in which they appear in their working.		
	$F = \mu R$	B1	1.2
	$\frac{1}{2} Mg \times \frac{4}{3} = \mu Mg$	dM1	2.1
	$\mu = \frac{2}{3}$ oe Accept 0.67 or better	A1	2.2a
	S.C. For F ,, μR,	B0	
	$\frac{1}{2} Mg \times \frac{4}{3}$,, μMg	M1	

		$\frac{2}{3} \mu$ A0		
		N.B. If $\mu = \frac{2}{3}$ follows this, they could score all the marks.		
			(5)	
6(d)		$\sqrt{F^2 + R^2}$	M1	3.1a
		$\sqrt{\left(\frac{2}{3}Mg\right)^2 + (Mg)^2}$	M1	1.1b
		$\frac{1}{3}Mg\sqrt{13}$ or $1.2Mg$ or better	A1	2.2a
			(3)	
6(e)		New value of S would be larger as the moment of the weight about A would be larger	B1	3.5a
			(1)	
(13 marks)				
Notes:				
6a	B1	Any equivalent appropriate statement.		
6b	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors. N.B. If α 's never appear, M0		
	A1	Correct equation		
	A1*	Correct given answer correctly obtained, with no wrong working seen. Allow $\frac{1}{2}Mg \cot \theta = S$ or $S = \frac{Mg \cot \theta}{2}$ or $\frac{Mg \cot \theta}{2} = S$ or $S = \frac{Mg}{2} \cot \theta$ or similar but NOT $S = \frac{1}{2} \cot \theta Mg$ or similar N.B. Allow m instead of M Must be θ in final answer but allow a different angle in the working.		
6c	B1	cao		
	B1	cao		
	B1	Seen anywhere, e.g. on the diagram		
	dm1	Using $F = \mu R$, their two equations and substitute for trig (not necessarily correctly) to produce an equation in μ only. This mark is dependent on the 3 previous B marks.		
	A1	Accept 0.67 or better		

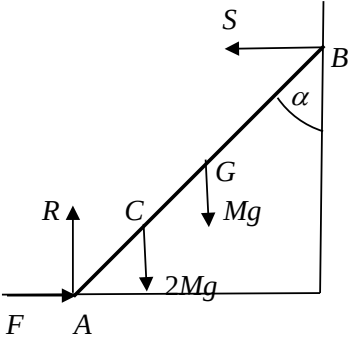
6d	M1	Use of Pythagoras with square root to find the required magnitude, but F and R do not need to be substituted
	M1	Substitute for their F and their R in terms of Mg and take square root to obtain magnitude in terms of M and g only. N.B. Must be using Pythagoras
		ALTERNATIVE: Using trig on triangle of forces  M1: $X = \frac{Mg}{\sin \alpha}$ or $\frac{S}{\cos \alpha}$ M1: substitute for $\sin \alpha$ or $\cos \alpha$ and S, where $\tan \alpha = \frac{Mg}{S} (= \frac{3}{2})$, to obtain X in terms of M and g only.
	A1	Any equivalent surd form or $1.2Mg$ or better Must be in terms of M and g
6e	B1	Correct answer and any equivalent appropriate statement.

Question	Scheme	Marks	AOs
9(a)	Moments about A (or any other complete method)	M1	3.3
	$T2a \sin \alpha = Mga + 3Mgx$	A1	1.1b
	$T = \frac{Mg(a+3x)}{2a \sin \frac{3}{5}} = \frac{5Mg(3x+a)}{6a}$ * GIVEN ANSWER	A1*	2.1
		(3)	
(b)	$\frac{5Mg(3x+a)}{6a} \cos \alpha = 2Mg$ OR $2Mg \cdot 2a \tan \alpha = Mga + 3Mgx$	M1	3.1b
	$x = \frac{2a}{3}$	A1	2.2a
		(2)	
(c)	Resolve vertically OR Moments about B	M1	3.1b
	$Y = 3Mg + Mg - \frac{5Mg(3 \cdot \frac{2a}{3} + a)}{6a} \sin \alpha$ $2aY = Mga + 3Mg(2a - \frac{2a}{3})$ Or: $Y = 3Mg + Mg - \left(\frac{2Mg}{\cos \alpha} \right) \sin \alpha$	A1ft	1.1b
	$Y = \frac{5Mg}{2}$ N.B. May use $R \sin \beta$ for Y and/or $R \cos \beta$ for X throughout	A1	1.1b
	$\tan \beta = \frac{Y}{X}$ or $\frac{R \sin \beta}{R \cos \beta} = \frac{5Mg}{2Mg}$	M1	3.4
	$= \frac{5}{4}$	A1	2.2a
		(5)	
(d)	$\frac{5Mg(3x+a)}{6a} \leq 5Mg$ and solve for x	M1	2.4
	$x \leq \frac{5a}{3}$	A1	2.4
	For rope not to break, block can't be more than $\frac{5a}{3}$ from A or Or just: $x \leq \frac{5a}{3}$, if no incorrect statement seen. N.B. If the correct inequality is not found, their comment must mention 'distance from A'.	B1 A1	2.4
		(3)	
(13 marks)			

Notes:**(a)****M1:** Using $M(A)$, with usual rules, or any other complete method to obtain an equation in a , M , x and T only.**A1:** Correct equation**A1*:** Correct PRINTED ANSWER, correctly obtained, need to see $\sin \alpha = \frac{3}{5}$ used.**(b)****M1:** Using an appropriate strategy to find x . e.g. Resolve horizontally with usual rules applying OR Moments about C . Must use the given expression for T .**A1:** Accept $0.67a$ or better**(c)****M1:** Using a complete method to find Y (or $R \sin \beta$) e.g. resolve vertically or Moments about B , with usual rules**A1 ft:** Correct equation with their x substituted in T expression or using $T = \frac{2Mg}{\cos \alpha}$ **A1:** Y (or $R \sin \beta$) = $\frac{5Mg}{2}$ or $2.5Mg$ or $2.50Mg$ **M1:** For finding an equation **in $\tan \beta$ only** using $\tan \beta = \frac{Y}{X}$ or $\tan \beta = \frac{X}{Y}$ This is independent but must have found a Y .**A1:** Accept $\frac{-5}{4}$ if it follows from their working.**(d)****M1:** Allow $T = 5Mg$ or $T < 5Mg$ and solves for x , showing all necessary steps (M0 for $T > 5Mg$)**A1:** Allow $x = \frac{5a}{3}$ or $x < \frac{5a}{3}$. Accept $1.7a$ or better.**B1: Treat as A1.** For any appropriate equivalent fully correct comment or statement. E.g. maximum value of x is $\frac{5a}{3}$ 

Question	Scheme	Marks	AOs
N.B. Penalise the use of $g = 9.81$ ONCE (the first time it is used) for the whole question.			
2(a)	Resolve vertically	M1	3.4
	$(\uparrow) 5 \sin \alpha + R = 2g$ oe	A1	1.1b
	$(R =) \quad 19.6 - 3 = 16.6 \text{ (N)}^*$	A1*	1.1b
		(3)	
2(b)	The box decelerates, slows down, loses speed or velocity, will come to a stop or rest, loses momentum	B1	2.4
		(1)	
2(c)	$(S =) \quad 19.6 \text{ or } 20 \text{ (N)}$	B1	3.3
		(1)	
2(d)	Equation of motion along the plane: $-F = 2a$ or $F = 2a$	M1	3.4
	$F = 0.2 \times \text{their } S$	B1	1.1b
	$0^2 = 4^2 - 2 \times 0.2g \times d$ or $0^2 = 4^2 + 2 \times 0.2g \times d$ or $4^2 = 0^2 + 2 \times 0.2g \times d$	M1	3.1b
	$(OX =) \quad 4.1 \text{ (m) or } 4.08 \text{ (m)}$	A1	1.1b
	OR		
	Work done against friction = Fd	M1	3.4
	$F = 0.2 \times \text{their } S$	B1	1.1b
	$0.2 \times 2g \times d = \frac{1}{2} \times 2 \times 4^2$	M1	3.1b
	$(d = OX =) \quad 4.1 \text{ (m) or } 4.08 \text{ (m)}$	A1	1.1b
		(4)	
2(e)	the box (it) has been modelled as a particle the box (it) will have size or shape or dimensions the coefficient of friction has been modelled as being constant the coefficient of friction may not be exactly 0.2 or may vary the friction may vary B0 : the ground may not be horizontal, an inaccurate value of g has been used, has not considered wind, the angle may not be accurate, any reference to the particle having mass (or not having mass). Ignore any reference to air resistance.	B1	3.5b
		(1)	

(10 marks)		
Notes:		
2(a)	M1	Form an equation in R and α only, with correct number of terms, condone sign errors and sin/cos confusion, $\sin \alpha$ may or may not be substituted. N.B. $3 + R = 2g$ oe, with no evidence of resolving the 5 N, e.g. not using $\sin \alpha$, is M0.
	A1	Correct equation, $\sin \alpha$ may or may not be substituted.
	A1*	Given answer correctly obtained, with at least one line of working.
2(b)	B1	Any equivalent statement. B0 if any incorrect extras e.g. box is stationary or at rest, doesn't move, will stop moving.
2(c)	B1	Accept $2g$ if g is not substituted for. B0 if they use $g = 9.81$ unless they have already been penalised in part (a).
2(d)	M1	Correct number of terms. Condone an extra g in ma term. M0 if 2 is missing. N.B. M0 if they use a vertical force for F e.g. $2g$ or 16.6
	B1	Seen (e.g. on a diagram) or implied.
	M1	Complete method to form an equation in d ($= OX$) only, condone sign errors, using their calculated acceleration from an attempt at using $F = ma$ M0 if clearly using μ (0.2) or $-\mu$ for a without any calculation.. e.g. may find t first: $0 = 4 - 0.2gt \Rightarrow t = \frac{20}{g} (= \frac{100}{49})$ then $d = 4 \times \frac{20}{g} - \frac{1}{2} \times 0.2g \times \left(\frac{20}{g}\right)^2$ or $d = 0 - \frac{1}{2} \times (-0.2g) \times \left(\frac{20}{g}\right)^2$ or $0^2 = 4^2 + 2 \times (-0.2g) \times d$
	A1	Either answer. A0 for $\frac{40}{g}$
2(e)	B1	Any equivalent statement which refers to the model. B0 if incorrect extras.

Question	Scheme	Marks	AOs
6(a)			
	($\uparrow$): ($R =$) $3Mg$	B1	3.4
		(1)	
6(b)	N.B. Allow consistent use of a different letter for the angle in the working but must be α in the final answer. BOD if their a's and α's look the same. EITHER: Obtain an equation in S, M, a and α only, by taking moments about A M(A): $S \times 2a \cos \alpha = Mga \sin \alpha + 2Mg \times 0.5a \sin \alpha$ OR Obtain an equation in S, M, a and α only, by taking moments about B, C or G and resolving once and eliminating F and R (N.B. $R = 3Mg$ from (a)) Correct equation in S, M, a and α only <u>Possible Moments equations:</u> M(B): $R \times 2a \sin \alpha = Mga \sin \alpha + 2Mg \times 1.5a \sin \alpha + F \times 2a \cos \alpha$ or M(C): $F \times 0.5a \cos \alpha + S \times 1.5a \cos \alpha = R \times 0.5a \sin \alpha + Mg \times 0.5a \sin \alpha$ or M(G): $Sa \cos \alpha + Fa \cos \alpha + 2Mg \times 0.5a \sin \alpha = Ra \sin \alpha$ <u>Possible resolution equations:</u> ($\rightarrow$): $F = S$ or ($\nearrow$): $R \cos \alpha + F \sin \alpha = S \sin \alpha + (2Mg + Mg) \cos \alpha$ or ($\nwarrow$): $R \sin \alpha + S \cos \alpha = (2Mg + Mg) \sin \alpha + F \cos \alpha$		
	$S = Mg \tan \alpha$ *	A1*	2.2a

		(3)	
6(c)	The friction force at B will provide an extra upward (not just vertical) force so R_1 will be less i.e. R will be greater. R (is greater than R_1) as the friction act against the weight of the rod. R (is greater) as the friction acts in the same direction as R_1 R (is greater) as the friction holds the rod up as well. $R = 3Mg = R_1 + F$ so R will be greater N.B. Allow R_1 will be smaller with a correct reason. B0 R is greater as there is no friction from the wall.	B1	3.5a
		(1)	
6(d)	N.B. Allow consistent use of a different letter for the angle and could score FULL marks.		
	EITHER: Moments about B or D , the intersection of the normals	M1	3.4
	$M(B): N \times 2a \sin \beta = Mga \sin \beta + 2Mg \times 1.5a \sin \beta + F_1 \times 2a \cos \beta$ or $M(D):$ $F_1 \times 2a \cos \beta = Mga \sin \beta + 2Mg \times 0.5a \sin \beta + 3Mg \times 2a \sin \beta$	A1	1.1b
	and resolve vertically: $(\uparrow) N = Mg + 2Mg + 3Mg$	A1	1.1b
	OR: Moments about A or C or G	B1	3.3
	A correct moments equation.	M1	3.4
	A correct resolution (N.B. Treat as a B mark so M0A0A1 is a possible score)	A1	1.1b
	A correct second resolution or a correct second moments equation	A1	1.1b
	<u>Possible Moments equations:</u> $M(A):$ $2Mg \times 0.5a \sin \beta + Mga \sin \beta + 3Mg \times 2a \sin \beta = P \times 2a \cos \beta$	B1	3.3

		N.B. (You may see the first 2 terms collected as a single term) or M(C): $0.5aF_1 \cos \beta + 1.5Pa \cos \beta = 0.5Na \sin \beta + 0.5Mga \sin \beta + 3Mg \times 1.5a \sin \beta$ or M(G): $F_1a \cos \beta + Pa \cos \beta + 2Mg \times 0.5a \sin \beta = Na \sin \beta + 3Mga \sin \beta$ <u>Possible resolution equations:</u> ($\uparrow$): $N = Mg + 2Mg + 3Mg$ ($\rightarrow$): $F_1 = P$ (or $P = \mu N$) ($\nearrow$): $F_1 \sin \beta + N \cos \beta = P \sin \beta + (3Mg + Mg + 2Mg) \cos \beta$ ($\nwarrow$): $N \sin \beta + P \cos \beta = (3Mg + Mg + 2Mg) \sin \beta + F_1 \cos \beta$		
		(N.B. $F_1 = P = 2Mg$)		
		Use of $F_1 = \mu N$, their equations (which must be correct) and $\tan \beta = \frac{1}{2}$, to obtain an equation in μ only. N.B. This mark is only available if the previous 4 marks have all been earned.	dM1	3.1a
		$\mu = \frac{1}{3}$ *	A1*	2.2a
			(6)	
(11 marks)				
Notes:				
6(a)	B1	Cao. Must be in terms of M and g .		
6(b)	M1	M(A): Correct no. of terms, dim correct, condone sin/cos confusion and sign errors		
	A1	Correct equation in S , M , a and α only. N.B. Must see use of $0.5a$		
	A1*	Given answer correctly obtained. (Must be in α but allow a different angle used in the equations). Penalise incorrect use of brackets. e.g. if they use $(90^\circ - \alpha)$, penalise missing brackets. N.B. Must see at least one line of intermediate working which will involve : like terms collected, division by $\cos \alpha$, which does not need to be seen explicitly, division by 2 in some order. N.B. Allow the order of the terms on the RHS to be different and allow m for M.		
		OR		
	M1	M(B) or M(C) or M(G) and a resolution and elimination of F and R. Both equations used must have correct no. of terms, dim correct, condone sin/cos confusion and sign errors		



	A1	Correct equation in S , M , a and α only
	A1*	Given answer correctly obtained. N.B. Must see at least one line of intermediate working which will involve : like terms collected and division by $\cos \alpha$
6(c)	B1	Correct explanation B0 if any incorrect extras
6(d)		N.B. If there is a combination of the two alternatives, mark both and award the higher mark. If there are errors in their equations for both methods and the total mark out of 4 is the same, enter the first 4 marks on ePEN for whichever of the 2 methods they use to try to find μ . If they don't try and find μ , enter marks for the EITHER method.
		EITHER
	M1	M(B) or M(D): Correct no. of terms, dim correct, condone sin/cos confusion and sign errors, allow use of a different letter, θ say, for β . (θ could even be α) N.B. Condone consistent missing a 's N.B. M0 if they are clearly using R from part (a) for N .
	A1	Correct equation with at most one error
	A1	Correct equation
	B1	Correct vertical resolution
		OR
	M1	M(A or C or G): Correct no. of terms, dim correct, condone sin/cos confusion and sign errors, allow use of a different letter, θ say, for β . (θ could even be α) N.B. Condone consistent missing a 's N.B. M0 if they are clearly using S from part (b) for P
	A1	Correct equation
	A1	This is treated as a B mark for a correct resolution, seen or implied.
	B1	For another correct resolution or another correct moments equation (NOT about B) seen or implied.
		N.B. when entering marks on ePEN for the two resolutions, if only ONE is correct enter as A1 B0.
	dM1	Dependent for using $F_1 = \mu N$ and their correct equations, to produce an equation in μ only. N.B. Allow if they use $F_1 \leq \mu N$
	A1*	Given answer correctly obtained