adamjee maths

A-LEVEL MATHS / EDEXCEL / FREE RESOURCES

Forces on an inclined plane

Mark scheme

4 questions

Exam questions and marking instructions remain credited to their board.

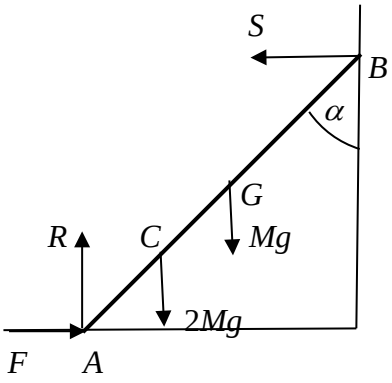
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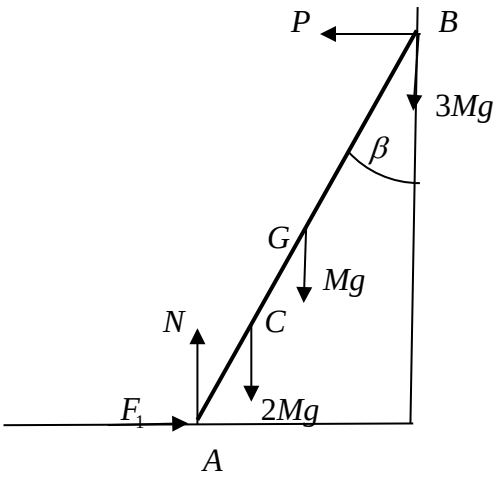
1 June 2025 - Paper 3 Mechanics - Q6

2 June 2024 - Paper 3 Mechanics - Q3

3 June 2022 - Paper 3 Mechanics - Q2

4 June 2022 - Paper 3 Mechanics - Q4

6(a)			
	(↑): (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	M1	3.1a
	M(A): $S \times 2a\cos\alpha = Mga\sin\alpha + 2Mg \times 0.5a\sin\alpha$	A1	1.1b
	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))	M1	3.1a
	Correct equation in S, M, a and α only	A1	1.1b
	<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>: (→): $F = S$ or (↗): $R\cos\alpha + F\sin\alpha = S\sin\alpha + (2Mg + Mg)\cos\alpha$ or (↖): $R\sin\alpha + S\cos\alpha = (2Mg + Mg)\sin\alpha + F\cos\alpha$		
	$S = Mg\tan\alpha$ *	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*): $N \times 2a\sin\beta = Mga\sin\beta + 2Mg \times 1.5a\sin\beta + F_1 \times 2a\cos\beta$	A1	1.1b
	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: $(\uparrow)\ N = Mg + 2Mg + 3Mg$	B1	3.3
	OR: Moments about *A* or *C* or *G*	M1	3.4
	A correct moments equation.	A1	1.1b
	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	B1	3.3
	<u>Possible Moments equations:</u> M(*A*): $2Mg \times 0.5a\sin\beta + Mga\sin\beta + 3Mg \times 2a\sin\beta = P \times 2a\cos\beta$		

	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.	**d**M1	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 $(90^o - \alpha)$, 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 $F_1 \leqslant \mu N$
	A1*	Given answer correctly obtained

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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
	$(F =)\ \mu\times$ 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	$\mu\times$ **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

2(a)(i)	Resolve vertically	M1	3.1b
	F acting UP the plane: **OR** *F* acting DOWN the plane: $(\uparrow) F\sin\alpha + 68.6\cos\alpha = 5g$ $-F\sin\alpha + 68.6\cos\alpha = 5g$ 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: $(\nearrow) F + X\cos\alpha = 5g\sin\alpha$ $-F + X\cos\alpha = 5g\sin\alpha$ $(\rightarrow) F\cos\alpha + X = 68.6\sin\alpha$ $-F\cos\alpha + X = 68.6\sin\alpha$	A1	1.1b
	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 ↙, 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 ($\mathrm{m\,s^{-2}}$) or $\frac{1}{5}g$	A1	1.1b
		(6)	
			(10 marks)

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 **dependen**t on an answer of 9.8 or -9.8 for (a)(i) from a fully correct solution 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^o
		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 $X = 48.9\ldots$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

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. $(\nwarrow), R\cos\theta + T = F\sin\theta + Mg\cos\theta + 2Mg\cos\theta$ $(\nearrow), R\sin\theta + F\cos\theta = Mg\sin\theta + 2Mg\sin\theta$ $(\rightarrow),\ F = T\sin\theta$ 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), $R \times 1.5a\cos\theta = T \times 0.5a + Mg \times 0.5a\cos\theta + F \times 1.5a\sin\theta$		
	$T = 2Mg\cos\theta$ *	A1*	1.1b
		(3)	
4(c)	e.g. Resolve vertically	M1	3.4
	$(\uparrow), R + T\cos\theta = Mg + 2Mg$	A1	1.1b
	$R = \frac{57Mg}{25}$ *	A1*	1.1b
		(3)	
	Other possible equations but F would need to be eliminated. $(\nwarrow), R\cos\theta + T = F\sin\theta + Mg\cos\theta + 2Mg\cos\theta$ $(\nearrow), R\sin\theta + F\cos\theta = Mg\sin\theta + 2Mg\sin\theta$ $(\rightarrow),\ F = T\sin\theta$ 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), $R \times 1.5a\cos\theta = T \times 0.5a + Mg \times 0.5a\cos\theta + F \times 1.5a\sin\theta$		
4(d)	Find an equation containing F e.g. Resolve horizontally	M1	3.4
	$(\rightarrow),\ F = T\sin\theta$	A1	1.1b
	Other possible equations		

	$(\nearrow), R\sin\theta + F\cos\theta = Mg\sin\theta + 2Mg\sin\theta$ $(\rightarrow),\ F = T\sin\theta$ 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 no wrong working seen. 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 no wrong working seen
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 no wrong working seen

Question	Scheme	Marks	AOs