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

Notes:		
1a (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**)
1a (ii)	A1	cao. Note that this mark is **dependen**t 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 36.9º
		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 μR = 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…and F = 9.7 (2sf)) can score max (a)(i) M1A1A0 (a)(ii) A1
1b	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)	$(4\mathbf{i}-\mathbf{j})+(\lambda\mathbf{i}+\mu\mathbf{j})=(4+\lambda)\mathbf{i}+(-1+\mu)\mathbf{j}$	M1	3.4
	Use **ratios** to obtain an equation in λ and μ *only*	M1	2.1
	$\dfrac{(4+\lambda)}{(-1+\mu)}=\dfrac{3}{1}$ or $\dfrac{\frac{1}{4}(4+\lambda)}{\frac{1}{4}(-1+\mu)}=\dfrac{3}{1}$	A1	1.1b
	$\lambda-3\mu+7=0$ * Allow $0=\lambda-3\mu+7$ but nothing else.	A1*	1.1b
		(4)	
(b)	$\lambda=2 \Rightarrow \mu=3$; Resultant force $=(6\mathbf{i}+2\mathbf{j})$ (N)	M1	3.1a
	$(6\mathbf{i}+2\mathbf{j})=4\mathbf{a}$ **OR** $\lvert(6\mathbf{i}+2\mathbf{j})\rvert=4a$	M1	1.1b
	Use of $\mathbf{r}=\mathbf{u}t+\frac{1}{2}\mathbf{a}t^2$ with $\mathbf{u}$ = **0**, their **a** and t = 4 : **Or** they may integrate their **a** twice with **u** = **0** and put t = 4 : $\mathbf{r}=\frac{1}{2}\times\frac{(6\mathbf{i}+2\mathbf{j})}{4}4^2=(12\mathbf{i}+4\mathbf{j})$	DM1	2.1
	$\sqrt{12^2+4^2}$	M1	1.1b
	ALTERNATIVE 1 for last two M marks: Use of $s=ut+\frac{1}{2}at^2$, with u = 0, their a and t = 4 : DM1 $s=\frac{1}{2}\times\sqrt{1.5^2+0.5^2}\times 4^2$ Use of Pythagoras to find mag of **a** : $a=\sqrt{1.5^2+0.5^2}$ M1		
	ALTERNATIVE 2 for last two M marks: Use of $s=ut+\frac{1}{2}at^2$, with u = 0, their a and t = 4 : DM1 $s=\frac{1}{2}\times\left(\frac{\sqrt{6^2+2^2}}{4}\right)\times 4^2$ Use of Pythagoras to find $\lvert(6\mathbf{i}+2\mathbf{j})\rvert$: $=\sqrt{6^2+2^2}$ M1		
	$\sqrt{160}$, $2\sqrt{40}$, $4\sqrt{10}$ oe or 13 or better (m)	A1	1.1b
		(5)	
			(9 marks)

Notes: Accept column vectors throughout

2a	M1	Adding the two forces, **i**'s and **j**'s must be collected (or must be a **single** column vector) seen or implied
	M1	Must be using ratios; Ignore an equation e.g. $(4+\lambda)\mathbf{i}+(-1+\mu)\mathbf{j}=3\mathbf{i}+\mathbf{j}$ if they go on to use ratios.

		However, if they write $4+\lambda=3$ and $-1+\mu=1$ then $3(-1+\mu)=3$ so $4+\lambda=3(-1+\mu)$ with no use of a constant, it's M0 They may use the acceleration, with a factor of $\frac{1}{4}$ top and bottom, see alternative **Allow one side of the equation to be inverted**
	A1	Correct equation
	A1*	Given answer correctly obtained. Must see at least one line of working, with the LH fraction 'removed'**.**
2b	M1	Adding $\mathbf{F}_1$ and $\mathbf{F}_2$ to find the resultant force, λ and μ must be substituted **N.B.** M0 if they use $\mu=2$ coming from $-1+\mu=1$ in part (a).
	M1	Use of $\mathbf{F}=4\mathbf{a}$ Or $\lvert\mathbf{F}\rvert=4a$, where **F** is <u>their</u> resultant. (including 3**i** + **j**) This is an independent mark, so could be earned, for example, if they have subtracted the forces to find the 'resultant' **N.B.** M0 if only using $\mathbf{F}_1$ or $\mathbf{F}_2$
	DM 1	Dependent on previous M mark for **Either**: use of $\mathbf{r}=\mathbf{u}t+\frac{1}{2}\mathbf{a}t^2$ with **u** = **0**, their **a** and t = 4 to produce a displacement vector **Or** : integrate twice, with **u** = **0**, their **a** and t = 4 to produce a displacement Vector **Or**: use of $s=ut+\frac{1}{2}at^2$ with u = 0, their a and t = 4 to produce a length
	M1	Use of Pythagoras, with square root, to find the magnitude of their displacement vector, **a** or **F (**M0 if only using $\mathbf{F}_1$ or $\mathbf{F}_2$) depending on which method they have used.
	A1	cao

Question	Scheme	Marks	AOs
3(a)	Resolve vertically, $R = 5g = 49$ (N)	B1	1.1b
		(1)	
3(b)	Equation of motion: $28 - F = 5 \times 1.4$	M1	3.1a
	$F = 21$	A1	1.1b
		(2)	
3(c)	$\mu = 0.43$ (2sf required)	B1 **ft**	3.4
		(1)	
			(4 marks)

Notes:

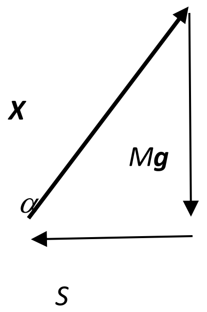
3a	B1	Allow either 5*g* or 49. No penalty for using $g = 9.81$ or 10. Ignore any working. Must be a positive number. B0 if *m* is involved. **N.B**. Could be seen on a diagram, provided it's clearly the reaction.
3b	M1	Equation with correct terms, dimensionally correct, condone sign errors.
	A1	cao but allow $\frac{15g}{7}$. Ignore units.
3c	B1**ft**	$\mu = \frac{\text{their (b)}}{\text{their (a)}}$. **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
4(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)	
4(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)	
4(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
	$\frac{1}{2}Mg \times \frac{4}{3} = \mu Mg$	**d**M1	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		

	$\frac{2}{3}$,, μ A0 **N.B**. If $\mu = \frac{2}{3}$ follows this, they could score all the marks.		
		(5)	
4(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 1.2*Mg* or better	A1	2.2a
		(3)	
4(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:

4a	B1	Any equivalent appropriate statement.
4b	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors. **N.B.** If *a*'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 $S = \frac{1}{2}\cot\theta\ \mathrm{Mg}$ or similar **N.B.** Allow *m* instead of *M* Must be θ in final answer but allow a different angle in the working.
4c	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

4d	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: $X = \dfrac{Mg}{\sin\alpha}$ or $\dfrac{S}{\cos\alpha}$ M1: substitute for $\sin\alpha$ or $\cos\alpha$ and *S*, where $\tan\alpha = \dfrac{Mg}{S}$ $(= \dfrac{3}{2})$, to obtain *X* in terms of *M* and *g* only.
	A1	Any equivalent surd form or 1.2*Mg* or better Must be in terms of *M* and *g*
4e	B1	Correct answer and any equivalent appropriate statement.