OCR
Oxford Cambridge and RSA

GCE

Further Mathematics B MEI

Y431/01: Mechanics minor

A Level

Mark Scheme for June 2023

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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MARKING INSTRUCTIONS

PREPARATION FOR MARKING

RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: RM A*ssessor Online Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **number of required** standardisation responses.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 40% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

Text Instructions

1. **Annotations and abbreviations**

Annotation in scoris	**Meaning**
✓and ✗	
BOD	Benefit of doubt
FT	Follow through
ISW	Ignore subsequent working
M0, M1	Method mark awarded 0, 1
A0, A1	Accuracy mark awarded 0, 1
B0, B1	Independent mark awarded 0, 1
SC	Special case
^	Omission sign
MR	Misread
Highlighting	
Other abbreviations in mark scheme	**Meaning**
E1	Mark for explaining a result or establishing a given result
dep*	Mark dependent on a previous mark, indicated by *
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working
AG	Answer given
awrt	Anything which rounds to
BC	By Calculator
DR	This indicates that the instruction **In this question you must show detailed reasoning** appears in the question.

2. Subject-specific Marking Instructions for A Level Mathematics B (MEI)

a Annotations should be used whenever appropriate during your marking. The A, M and B annotations must be used on your standardisation scripts for responses that are not awarded either 0 or full marks. It is vital that you annotate standardisation scripts fully to show how the marks have been awarded. For subsequent marking you must make it clear how you have arrived at the mark you have awarded.

b An element of professional judgement is required in the marking of any written paper. Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct solutions leading to correct answers are awarded full marks but work must not be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained; key steps in the working must always be looked at and anything unfamiliar must be investigated thoroughly. Correct but unfamiliar or unexpected methods are often signalled by a correct result following an apparently incorrect method. Such work must be carefully assessed. When a candidate adopts a method which does not correspond to the mark scheme, escalate the question to your Team Leader who will decide on a course of action with the Principal Examiner.
If you are in any doubt whatsoever you should contact your Team Leader.

c The following types of marks are available.

M
A suitable method has been selected and *applied* in a manner which shows that the method is essentially understood. Method marks are not usually lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, e.g. by substituting the relevant quantities into the formula. In some cases the nature of the errors allowed for the award of an M mark may be specified.

A
Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated Method mark is earned (or implied). Therefore M0 A1 cannot ever be awarded.

B
Mark for a correct result or statement independent of Method marks.

E
A given result is to be established or a result has to be explained. This usually requires more working or explanation than the establishment of an unknown result.

Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer as part of a wrong argument.

d When a part of a question has two or more 'method' steps, the M marks are in principle independent unless the scheme specifically says otherwise; and similarly where there are several B marks allocated. (The notation 'dep*' is used to indicate that a particular mark is dependent on an earlier, asterisked, mark in the scheme.) Of course, in practice it may happen that when a candidate has once gone wrong in a part of a question, the work from there on is worthless so that no more marks can sensibly be given. On the other hand, when two or more steps are successfully run together by the candidate, the earlier marks are implied and full credit must be given.

e The abbreviation FT implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A and B marks are given for correct work only – differences in notation are of course permitted. A (accuracy) marks are not given for answers obtained from incorrect working. When A or B marks are awarded for work at an intermediate stage of a solution, there may be various alternatives that are equally acceptable. In such cases, what is acceptable will be detailed in the mark scheme. If this is not the case please, escalate the question to your Team Leader who will decide on a course of action with the Principal Examiner.
Sometimes the answer to one part of a question is used in a later part of the same question. In this case, A marks will often be 'follow through'. In such cases you must ensure that you refer back to the answer of the previous part question even if this is not shown within the image zone. You may find it easier to mark follow through questions candidate-by-candidate rather than question-by-question.

f Unless units are specifically requested, there is no penalty for wrong or missing units as long as the answer is numerically correct and expressed either in SI or in the units of the question. (e.g. lengths will be assumed to be in metres unless in a particular question all the lengths are in km, when this would be assumed to be the unspecified unit.) We are usually quite flexible about the accuracy to which the final answer is expressed; over-specification is usually only penalised where the scheme explicitly says so. When a value is given in the paper only accept an answer correct to at least as many significant figures as the given value. This rule should be applied to each case. When a value is not given in the paper accept any answer that agrees with the correct value to 2 s.f. Follow through should be used so that only one mark is lost for each distinct accuracy error, except for errors due to premature approximation which should be penalised only once in the examination. There is no penalty for using a wrong value for *g*. E marks will be lost except when results agree to the accuracy required in the question.

g Rules for replaced work: if a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests; if there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others. NB Follow these maths-specific instructions rather than those in the assessor handbook.

h For a genuine misreading (of numbers or symbols) which is such that the object and the difficulty of the question remain unaltered, mark according to the scheme but following through from the candidate's data. A penalty is then applied; 1 mark is generally appropriate, though this may differ for some units. This is achieved by withholding one A mark in the question. Marks designated as cao may be awarded as long as there are no other errors. E marks are lost unless, by chance, the given results are established by equivalent working. 'Fresh starts' will not affect an earlier decision about a misread. Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

i If a graphical calculator is used, some answers may be obtained with little or no working visible. Allow full marks for correct answers (provided, of course, that there is nothing in the wording of the question specifying that analytical methods are required). Where an answer is wrong but there is some evidence of method, allow appropriate method marks. Wrong answers with no supporting method score zero. If in doubt, consult your Team Leader.

j If in any case the scheme operates with considerable unfairness consult your Team Leader.

Question			Answer	Marks	AOs	Guidance	
1	(a)		$[\text{Force}] = \text{MLT}^{-2}$	B1	1.1		
			$[\text{Velocity}] = \text{LT}^{-1}$	B1	1.1		
			$[\text{Density}] = \text{ML}^{-3}$	B1	1.2		
				[3]			
	(b)		$[\text{RHS}] = \left(\text{LT}^{-1}\right)^2 \left(\text{ML}^{-3} \cdot \text{M}^2\right)^{\frac{1}{3}}$	M1	1.1	Use expressions from **(a)** to express $u^2(\rho m^2)^{\frac{1}{3}}$ dimensionally.	
			$= \left(\text{LT}^{-1}\right)^2 \left(\text{M}^3\text{L}^{-3}\right)^{\frac{1}{3}} = \text{L}^2\text{T}^{-2} \cdot \text{ML}^{-1} = \text{MLT}^{-2} = [\text{LHS}]$	A1	1.1	Convincingly reached.	
				[2]			
	(c)		Model predicts that when air density is doubled, drag force should increase by factor of $\sqrt[3]{2}$. oe	B1	3.5b	Or by contradiction	
				[1]			
	(d)		$\text{MLT}^{-2} = \left(\text{ML}^{-3}\right)^{\alpha} \left(\text{LT}^{-1}\right)^{\beta} \left(\text{L}^2\right)^{\gamma}$ $M : \alpha = 1$ $L : -3\alpha + \beta + 2\gamma = 1$ $T : -\beta = -2$	M1	3.3	Setting up equations in $\alpha, \beta \text{ and } \gamma$ using given equation and their dimensions for **(a)**	
			$\alpha = 1$ and $\beta = 2$	A1ft	3.4	Follow through from **(a)**	
			$-3 + 2 + 2\gamma = 1.\ 2\gamma = 2\ \ \gamma = 1$	A1ft	1.1	Follow through from **(a)**	
				[3]			

Question			Answer	Marks	AOs	Guidance	
2	(a)		Driving force = resistance = $\frac{P}{12}$	B1	3.3	soi	
			$1400g\sin 7° - \frac{P}{12} = 1400 \times 0.8$	M1	3.4	Attempt at N2L, correct number of terms and weight resolved (but condone sign errors and sin/cos confusion)	
				B1	1.1	Correct weight component if seen in **(a)** or **(b)**	
			$\Rightarrow P = 6624.568\ldots$	A1	1.1		
				[4]			
	(b)		$\frac{16000}{v} - 1400g\sin 7° - \frac{6624.568\ldots}{12} = 0$	M1	3.3	Attempt at N2L with zero acceleration – correct number of terms (condone sign errors) FT their value of P or resistive force from **(a)**	
			$\Rightarrow v = 7.1939\ldots$	A1	1.1		
				[2]			

Question			Answer	Marks	AOs	Guidance	
3	(a)		Let the speed of P when it reaches B be u m s^{-1}.				
			Frictional force $=\frac{2}{3}\times 0.5g$	**B1**	**3.3**		
			Either $\frac{1}{2}\times 0.5u^2-\frac{2}{3}\times 0.5g\times 0.6=0$ Or $a=-\frac{2}{3}g$, so $0^2=u^2-2\times\frac{2}{3}g\times 0.6$	**M1**	**3.4**	If using WEP, both KE and WD against friction terms need to be present.	
			Let the speed of Q be v m s^{-1} after collision with P.				
			COLM: $0.5\times 6=0.5\times -2.8+2v$	**M1**	**3.3**	Three terms. Condone sign error.	
			$u=2.8$ and $v=2.2$	**A1**	**1.1**	or if both seen in **(b)** and **(c)**	
			Coefficient of restitution between P and Q $=\frac{2.2+2.8}{6}$	**M1**	**3.3**	Attempt at $v_{\text{sep}}\div v_{\text{app}}$. Allow sign errors but not num/dem switch.	
			$=\frac{2.2+2.8}{6}=\frac{5}{6}$ $(=0.8333\ldots)$	**A1**	**1.1**		
				[6]			
	(b)		$0.5\left(2.8-\left(-6\right)\right)=4.4$ N s	**B1**	**3.3**	Use "their" value for u	
			towards A.	**B1**	**1.1**	oe eg 'towards B', 'in the direction CB'	
				[2]			
	(c)		Let the coefficient of friction between Q and AB be μ.				
			Speed of Q when it reaches B is 2.2 m s^{-1}	**B1**	**3.4**	Use "their" value for v	
			Either $\frac{1}{2}\times 2\times 2.2^2-2g\mu\times 0.3=0$ Or $a=-g\mu$, so $0^2=2.2^2-2g\mu\times 0.3$	**M1**	**3.1b**		
			$\mu=\frac{121}{147}$ $(=0.823129\ldots)$	**A1**	**1.1**	cao	
				[3]			

Question			Answer	Marks	AOs	Guidance	
4	(a)		Let the tension in the string be T N.				
			$T = 5g$	B1	1.1		
			$T = 10g\sin\theta$	M1	1.1	Attempt to resolve tangentially. Condone cos for sin	
			$\sin\theta = \frac{1}{2} \Rightarrow \theta = 30$	A1	2.2a		
				[3]			
	(b)		$\frac{1}{2}\times 10v^2 + \frac{1}{2}\times 5v^2$ $= 10g(2\cos 35 - 2\cos 45) - 5g\left(\frac{10}{360}\times 2\pi \times 2\right)$	M1 B1 B1	3.4 3.1a 1.1	Attempt at conservation of energy; two PE terms present and at least one KE term. Correct PE term for Q Correct PE term for P	
			$v = 0.805\,(\text{m s}^{-1})$	A1	2.2b	0.8047065…	
				[4]			
	(c)		e.g. we have assumed that in the subsequent motion that Q does not reach the pulley before P arrives at the point where $\theta = 45$ or the length of string from AP is equal to the arc length AP as P is small and or the pulley size is negligible	B1	2.4		
				[1]			

Question			Answer	Marks	AOs	Guidance	
5	(a)		$H\cos\theta + 5g\cos 40° = 11g$ $H\sin\theta = 5g\sin 40°$	M1 A1	3.3 1.1	Attempt to resolve both horizontally and vertically	Correct number of terms
			$\tan\theta = \frac{5g\sin 40°}{11g - 5g\cos 40°} \Rightarrow \theta = 24.14487\ldots°$	A1	1.1		
			and $H \approx 77.0$	A1	1.1	$H = 77.000260\ldots$ so accept 77.	
			Or triangle of forces method:				
			Force triangle with • sides H, $5g$ and $11g$, • 40° between $5g$ and $11g$, • θ between H and $11g$.	M1			
			$H^2 = (5g)^2 + (11g)^2 - 2(5g)(11g)\cos 40°$	A1			
			$\Rightarrow H \approx 77.0$	A1			
			$\theta = \frac{(11g)^2 + T^2 - (5g)^2}{2\cdot T\cdot 11g} = 24.14487\ldots°$	A1			
				[4]			
	(b)		Friction $= 5g\sin 30°$ Normal contact $= 7g - 5g\cos 30°$	M1 A1	3.3 1.1	Resolving vertically and horizontally for the beam	
			$\mu_{\min} = \frac{5g\sin 30°}{7g - 5g\cos 30°} = 0.936374\ldots$	A1	1.1		
				[3]			
	(c)		Taking moments about the point of contact between beam and floor:				
			$5g\cos 30° \cdot 3\cos\phi = 5g\sin 30° \cdot 3\sin\phi + 7g \cdot \frac{3}{2}\cos\phi$ or $5g\cos(\phi + 30°) \cdot 3 = 7g \cdot \frac{3}{2}\cos\phi$	M1* A2	3.1b 1.1 1.1	Taking moments: dimensionally consistent; correct number of terms for their method. All correct. A1 for one error.	
			$\Rightarrow 5\sqrt{3} = 5\tan\phi + 7$	M1dep*	1.1	Obtaining tan (oe)	
			$\Rightarrow \tan\phi = \frac{5\sqrt{3} - 7}{5} \Rightarrow \phi = 18.36878\ldots°$	A1	2.2a		
				[5]			

Question			Answer	Marks	AOs	Guidance	
6	(a)		Let the centre of mass lie x cm above the base.				
			Total area $=\pi\cdot 4^2+2\pi\cdot 4\cdot 18\,(=160\pi)$	**B1**	**1.1**	Expression for correct total area of container	
			$160\pi\cdot x=16\pi\cdot 0+144\pi\cdot 9$	**M1**	**1.1**	Table of values idea with correct number of terms	
			$\Rightarrow x=8.1$	**A1**	**1.1**	**AG** must be convincingly shown.	
				[3]			
	(b)		**DR**				
			Total mass $=400+16\pi\cdot h\cdot 1\,(=400+16\pi h)$	**B1**	**1.1**	Expression for correct total mass of container and water	
			$(400+16\pi h)\,y=400\times 8.1+16\pi h\cdot \frac{1}{2}h$	**M1**	**1.1**	Table of values idea with correct number of terms	
			$(400+16\pi h)\,y=3240+8\pi h^2$ $\Rightarrow y=\dfrac{3240+8\pi h^2}{400+16\pi h}=\dfrac{405+\pi h^2}{50+2\pi h}$	**A1**	**2.2a**		
			$\dfrac{\mathrm{d}y}{\mathrm{d}h}=\dfrac{(50+2\pi h)\cdot 2\pi h-\left(405+\pi h^2\right)\cdot 2\pi}{(50+2\pi h)^2}$	**M1***	**3.1a**	Attempt to differentiate using quotient rule.	
			Least value of y occurs when $(50+2\pi h)\cdot 2\pi h-\left(405+\pi h^2\right)\cdot 2\pi=0$	**M1dep***	**2.1**	Setting the numerator of **their** expression to zero.	
			$\Rightarrow \pi h^2+50h-405=0$ $\Rightarrow h=5.90736\ldots$	**A1**	**2.2a**		
				[6]			
	(c)		Let the centre of mass of the water lie d cm above the base.				
			$16\pi\times 13.5\times 6.75=\left(16\pi\times 13.5-\frac{4}{3}\pi\times 3^3\right)d+\frac{4}{3}\pi\times 3^3\times 3$	**M1**	**3.1b**		
			$\Rightarrow 180\pi d=1350\pi\Rightarrow d=7.5$	**A1**	**2.2a**	**AG** must be convincingly shown.	
				[2]			
	(d)		Total mass $=400+\left(16\pi\times 13.5-\frac{4}{3}\pi\cdot 3^3\right)+\frac{4}{3}\pi\cdot 3^3\cdot 4\,(=400+324\pi)$	**B1**	**1.1**		
			$(400+324\pi)\,z=400\times 8.1+1350\pi+\frac{4}{3}\pi\times 3^3\times 4\times 3$	**M1**	**3.1b**	Table of values idea with correct number of terms	

Question			Answer	Marks	AOs	Guidance	
			$\Rightarrow z = 6.233491\ldots$	A1	2.2a		
				[3]			

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