GCE

Further Mathematics B MEI

Y431/01: Mechanics minor

A Level

Mark Scheme for June 2024

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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.

4. **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.

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 *. The * may be omitted if only one previous M mark
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 question included the instruction: In this question you must show detailed reasoning.

5. Subject Specific Marking Instructions

a. Annotations must be used during your marking. For a response awarded zero (or full) marks a single appropriate annotation (cross, tick, M0 or ^) is sufficient, but not required.

For responses that are not awarded either 0 or full marks, you must make it clear how you have arrived at the mark you have awarded and all responses must have enough annotation for a reviewer to decide if the mark awarded is correct without having to mark it independently.

It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

Award NR (No Response)
- if there is nothing written at all in the answer space and no attempt elsewhere in the script
- OR if there is a comment which does not in any way relate to the question (e.g. 'can't do', 'don't know')
- OR if there is a mark (e.g. a dash, a question mark, a picture) which isn't an attempt at the question.

Note: Award 0 marks only for an attempt that earns no credit (including copying out the question).

If a candidate uses the answer space for one question to answer another, for example using the space for 8(b) to answer 8(a), then give benefit of doubt unless it is ambiguous for which part it is intended.

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 always 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 method mark may usually be implied by a correct answer unless the question includes the DR statement, the command words "Determine" or "Show that", or some other indication that the method must be given explicitly.

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.
- When a value is not given in the paper accept any answer that agrees with the correct value to 2 s.f. unless a different level of accuracy has been asked for in the question, or the mark scheme specifies an acceptable range.
  NB for Specification A the rubric specifies 3 s.f. as standard, so this statement reads "3 s.f".

Follow through should be used so that only one mark in any question is lost for each distinct accuracy error.
Candidates using a value of 9.80, 9.81 or 10 for g should usually be penalised for any final accuracy marks which do not agree to the value found with 9.8 which is given in the rubric.

g. Rules for replaced work and multiple attempts:
- If one attempt is clearly indicated as the one to mark, or only one is left uncrossed out, then mark that attempt and ignore the others.
- If more than one attempt is left not crossed out, then mark the last attempt unless it only repeats part of the first attempt or is substantially less complete.
- if a candidate crosses out all of their attempts, the assessor should attempt to mark the crossed out answer(s) as above and award marks appropriately.

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 or B mark in the question. Marks designated as cao may be awarded as long as there are no other errors.

If a candidate corrects the misread in a later part, do not continue to follow through. E marks are lost unless, by chance, the given results are established by equivalent working. Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

i. If a calculator is used, some answers may be obtained with little or no working visible. Allow full marks for correct answers, provided that there is nothing in the wording of the question specifying that analytical methods are required such as the bold "In this question you must show detailed reasoning", or the command words "Show" or "Determine". 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)		Gain in kinetic energy $= \frac{1}{2} \cdot 1500 \cdot 30^2 - \frac{1}{2} \cdot 1500 \cdot 20^2 \, (= 375000)$	**M1**	**3.3**	Attempt to find the change in kinetic energy.	
			$5000t = 375000$	**M1**	**1.1**	Attempt at considering power as rate of work done.	
			$\Rightarrow t = 75$	**A1** **[3]**	**1.1**		
	(b)		Driving force $= 5000 \div 25 \, (= 200)$	**B1**	**3.3**	soi	
			So $a = 200 \div 1500 = 0.13(333\ldots)$	**B1** **[2]**	**1.1**	Accept $\frac{2}{15}$	

Question			Answer	Marks	AOs	Guidance	
2	(a)		$M \cdot L \cdot T^{-2}$	**B1** **[1]**	**1.2**		
	(b)		$9.8 \div 2.2 = 4.454545\ldots \approx 4.45$	**B1** **[1]**	**1.1**	AG	
	(c)		5×10^5 Pa $= 5 \times 10^5 \div 4.45(45\ldots) \div 39.4^2$ psi ≈ 72.3 psi which is less than the pressure in the tyre.	 **M1** **M1** **A1**	 **1.1** **1.1** **2.2a**	 Correct method converting N to lbf. Correct method converting m^2 to in^2. Conclusion clearly compares two values.	 72.4 if 4.45 used
			Or 80 psi $= 80 \times 4.4545\ldots \times 39.4^2$ Pa ≈ 553000 which is greater than the pressure on the diver.	 **M1** **M1** **A1**		 Correct method converting lbf to N. Correct method converting in^2 to m^2. Conclusion clearly compares two values.	
				[3]			
	(d)		$[\text{Pressure}] = M \cdot L \cdot T^{-2} / L^2 = M \cdot L^{-1} \cdot T^{-2}$ $[\text{Energy}] = \left[\frac{1}{2}mv^2\right] = M \cdot (L \cdot T^{-1})^2 = M \cdot L^2 \cdot T^{-2}$ or $[Energy] = [Fd] = M \cdot L \cdot T^{-2} \cdot L = M \cdot L^2 \cdot T^{-2}$ So $[\text{Energy density}] = M \cdot L^2 \cdot T^{-2} / L^3 = M \cdot L^{-1} \cdot T^{-2}$ which is the same as the dimensions of pressure.	**B1** **M1** **A1** **[3]**	**1.1** **1.2** **2.4**	 Using some known formula (e.g. KE, GPE, EPE, work, to derive the dimensions of energy). Show dimensions are consistent.	

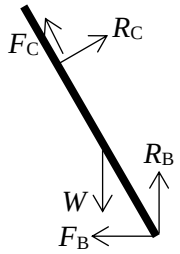
Question			Answer	Marks	AOs	Guidance	
3	(a)	(i)	$\frac{1}{2}\times 6\times u^2 - 4\times 3.5 = 6g\times 3.5\sin 25°$	M1	3.3	Attempt at WEP; must have 3 terms.	
				B1	1.1	Correct GPE term.	
			$\Rightarrow u = 5.8(01575\ldots)$	A1	1.1		
				[3]			
		(ii)	Energy from C to A: $6g\times(3.5+x)\sin 25° - 4(3.5+x) = \frac{1}{2}\times 6\times 5.801575\ldots^2$	M1	3.3	Attempt at WEP; must have 3 terms.	
				A1FT	1.1	Correct equation in x FT their value of u from part **(a)**	
			$\Rightarrow x = 1.3(42928\ldots)$	A1FT	1.1	Follow through their value u	
			Or energy from B to A: $\frac{1}{2}\times 6\times u^2 + 6gx\sin 25° - 4(7+x) = \frac{1}{2}\times 6\times u^2$	M1	3.3	Attempt at WEP; must have 4 terms.	
				A1FT	1.1	Correct equation in x FT their value of u from part **(a)**.	
			$\Rightarrow x = 1.3(42928\ldots)$	A1FT	1.1	Follow through their value u	
				[3]			
			If energy methods not used for **both** (a) (i) and (a) (ii) award for correct answers.				
			$u = 5.8(01575\ldots)$	SC1		cao	
			$x = 1.3(4298\ldots)$	SC1		cao	
				[2]			
	(b)		Frictional force $= 2$ N	B1	3.4		
			$R = 6g\cos 25°$	M1	1.1	Component of the normal contact force – allow sin/cos mix	
			So $\mu = \frac{2}{6g\cos 25°} = 0.0375298\ldots$	A1	2.2b	Awrt 0.038	
				[3]			

Question			Answer	Marks	AOs	Guidance
4	(a)		Let the velocities of A and B after impact be v_A and v_B, in the direction $\overrightarrow{AB}$.			
			$3\times1=3v_A+1v_B$	M1	3.3	Attempt at COLM.
			$v_B-v_A=e\times1$	M1	3.3	Attempt at NEL
			$\Rightarrow 3=3v_A+v_A+e\Rightarrow v_A=\frac{1}{4}(3-e)$	A1	3.4	AG (note speed requested)
			$v_B=\frac{1}{4}(3-e)+e=\frac{3}{4}(1+e)$	A1	1.1	
				[4]		
	(b)		$\frac{1}{2}\cdot3\cdot\left[\frac{1}{4}(3-e)\right]^2+\frac{1}{2}\cdot1\cdot\left[\frac{3}{4}(1+e)\right]^2=0.79\left[\frac{1}{2}\cdot3\cdot1^2\right]$	M1	3.3	Using the information to set up an equation in e with their expressions.
				A1FT	1.1	Correct equation FT their expressions from part **(a)**.
			$\Rightarrow e=0.4$	A1	1.1	
				[3]		
	(c)		If they had different radii, the impact could not be direct.	B1	3.5b	Accept explanations that there cannot be a vertical impulse/force for motion to continue horizontally only.
				[1]		
	(d)		Let the velocities of C and D after impact be v_C and v_D, in the direction $\overrightarrow{CD}$.			
			$\frac{2}{3}(u+1)=2\left(v_D-(-1)\right)$	M1	3.3	Attempt at impulse-momentum equation: condone incorrect signs.
			$\Rightarrow v_D=\frac{1}{3}u-\frac{2}{3}$	A1	1.1	
			$1\cdot u-2\cdot1=1\cdot v_C+2\cdot\left(\frac{1}{3}u-\frac{2}{3}\right)$	M1	3.3	Attempt at COLM: condone incorrect signs.
			$v_C=u-2-\frac{2}{3}u+\frac{4}{3}=\frac{1}{3}u-\frac{2}{3}$ which is the same as v_D so they have the same velocity afer impact.	A1	2.2a	
			Or			
			$-\frac{2}{3}(u+1)=v_C-u$	M1	3.3	Attempt at impulse-momentum equation: condone incorrect signs.

Question			Answer	Marks	AOs	Guidance
			$\Rightarrow v_C = \frac{1}{3}u - \frac{2}{3}$ which is the same as v_D so they have the same velocity afer impact.	**A1**	**2.2a**	
			Or			
			Let the velocities of C and D after impact be v_C and v_D, in the direction $\overrightarrow{CD}$.			
			$\frac{2}{3}(u+1) = 2(v_D - (-1))$	**M1**	**3.3**	Attempt at impulse-momentum equation: condone incorrect signs.
			$u - 2 = v_C + 2v_D$	**M1**	**3.3**	Attempt at COLM: condone incorrect signs.
			$u = v_C + 2v_D + 2$ Substitute into the Impulse-momentum equation			
			$3v_D = v_c + 2v_D$	**A1**	**1.1**	For correct equation eliminating u
			$v_C = v_D$	**A1**	**2.2a**	AG For correct argument leading to equality
	(e)		$\frac{\frac{1}{2}\cdot 3\cdot\left(\frac{1}{3}u - \frac{2}{3}\right)^2}{\frac{1}{2}\cdot 1\cdot u^2 + \frac{1}{2}\cdot 2\cdot 1^2}$	**M1**	**3.1b**	Attempt at formulating an expression in u to represent the fraction of energy remaining or lost.
			$= \frac{u^2 - 4u + 4}{3u^2 + 6}\left(= \frac{1 - \frac{4}{u} + \frac{4}{u^2}}{3 + \frac{6}{u^2}}\right)$	**M1**	**1.1**	Simplifying to a form where the limit can be taken or is apparent.
			$\to \frac{1}{3}$ as $u \to \infty$ so the fraction of energy lost tends to $\frac{2}{3}$.	**A1**	**2.2a**	cao **must** follow correct expressions for V_C *and* V_D
				[3]		

Question			Answer	Marks	AOs	Guidance	
5	(a)		Total area $= \frac{1}{2}\cdot(30+120)\cdot 90 = 6750$	B1	1.1		
			$6750\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = 1350\begin{pmatrix}20\\ 30\end{pmatrix} + 2700\begin{pmatrix}45\\ 45\end{pmatrix} + 2700\begin{pmatrix}80\\ 30\end{pmatrix}$	B1	1.2	Correct centre of mass for triangle (implied by correct position vector in either of first or third term on RHS).	
				M1	3.3	Fully correct equation for either x or y.	
			$\Rightarrow \bar{x} = 54$	A1	1.1	AG: some manipulation required in order to obtain answer.	
			and $\bar{y} = 36$	A1	1.1		
				[5]			
	(b)		If M is the centre of mass, it must lie within BCD, so in the extreme cases it lies on either BD or CD.			Follow through incorrect $\bar{y}$	
			If it lies on BD, then $\frac{36-0}{54-d} = \frac{90-36}{60-54}$ $(\Rightarrow d = 50)$	M1FT	3.1b	Considering gradients or equations of lines.	
			or in form $y = 9x - 450$	A1FT	1.1	One correct equation (implied by one correct limit).	
			If it lies on CD, then $\frac{36-0}{54-d} = \frac{90-36}{30-54}$ $(\Rightarrow d = 70)$				
			or in form $y = -\frac{9}{4}x + \frac{315}{2}$				
			So $50 \le d \le 70$.	A1FT	2.2a	Range must be clearly stated, in words if not using inequalities or set notation.	
				[3]			
	(c)		Let the forces exerted on B, C and D be R_B, R_C and R_D N. $R_B + R_C + R_D = 100$	B1	1.1	Considering vertical equilibrium.	
			Take moments about a line parallel to x-axis eg. $y = 90$: $90R_D = 54 \times 100$	M1	1.1		

Question			Answer	Marks	AOs	Guidance	
			Take moments about a line parallel to y-axis eg. $x = 30$: $30R_B + 33R_D = 24 \times 100$	**M1**	**3.3**		
			$R_D = 60$, $R_B = 14$ and $R_C = 26$	**A1** **[4]**	**2.2a**		

Question			Answer	Marks	AOs	Guidance	
6	(a)		Take moments about eg. B: $30x - 15 \times 6 = 42$ $\Rightarrow x = 4.4$	**M1** **A1** **[2]**	**1.1** **1.1**	Taking moments about a suitable point and equating this to the magnitude of the couple.	
	(b)			 **B1** **B1** **[2]**	 **1.1** **3.3**	Accept different labels in this question. Dimensions need not be shown. Any 3 correct forces shown. All forces correctly shown.	Normal contact force at C perpendicular to beam, acting away from step, in roughly the correct position. Frictional contact force at C acting towards A parallel to the beam. Weight vertically downwards, in roughly the correct position (must be clearly below the halfway point). Both frictional and normal components of the contact force at B.

Question			Answer	Marks	AOs	Guidance	
	(c)	(i)	Taking moments about eg. B: $R_C \times 4.5 = W \times \sqrt{3}\cos 60°$	M1*	3.1b	Taking moments about a suitable point.	
				M1*	3.1b	Attempt at N2L both horizontally and vertically. Must have correct number of terms in each. Condone sin/cos transposition.	
			$R_B + R_C \sin 30 + F_C \sin 60 = W$ $R_C \cos 30 = F_C \cos 60 + F_B$	A1	1.1		
			Or				
			Taking moments about CoM: $R_B\sqrt{3}\cos 60° = R_c(4.5 - \sqrt{3}) + F_B\sqrt{3}\sin 60$	M1*	3.1b		
			$R_C \cos 30 = F_C \cos 60 + F_B$	M1*	3.1b	Resolving horizontally. Condone sin/cos transposition.	
				A1	1.1		
			$\frac{\sqrt{3}}{2}R_C - \frac{1}{2}F_C = \mu\left(W - \frac{1}{2}R_C - \frac{\sqrt{3}}{2}F_C\right)$ $\frac{\sqrt{3}}{2}R_C - \frac{\mu}{2}R_C = \mu\left(W - \frac{1}{2}R_C - \frac{\sqrt{3}}{2}\mu R_C\right)$ $\Rightarrow \frac{\sqrt{3}}{9}\left(\frac{\sqrt{3}}{2}\right) - \frac{\mu}{2}\left(\frac{\sqrt{3}}{9}\right) = \mu\left(1 - \frac{1}{2}\left(\frac{\sqrt{3}}{9}\right) - \frac{\sqrt{3}}{2}\mu\left(\frac{\sqrt{3}}{9}\right)\right)$ $\frac{3}{18} - \frac{\sqrt{3}}{18}\mu = \mu - \frac{\sqrt{3}}{18}\mu - \frac{3}{18}\mu^2$ $\Rightarrow \mu^2 - 6\mu + 1 = 0$	M1dep* A1 [5]	3.4 2.1	Using both $F_B = \mu R_B$ and $F_C = \mu R_C$ to obtain an equation in μ only AG – so sufficient working must be shown	
		(ii)	$\mu = 0.171(5728...)$ or $3 - 2\sqrt{2}$ only	B1	3.2a	Must be clear that only this value (of the two possible roots of the quadratic) is the coefficient of friction	

Question			Answer	Marks	AOs	Guidance	
			The other root $(3+2\sqrt{2})$ cannot be the coefficient of friction as e.g. when μ takes this value $R_B < 0$ which is not possible $\left(R_B = \frac{(4.5-\sqrt{3})W}{4.5(1-\mu\sqrt{3})}\right)$ as the direction of R_B must be vertically upwards.	**B1** **[2]**	**2.3**	Any valid reason for the rejection of the larger of the two roots – note that 'because $\mu<1$' only is **B0**	

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