GCE

Further Mathematics A

Y533/01: Mechanics

AS 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.

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 Assessor 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**

Annotation	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
BP	Blank Page
Seen	
Highlighting	

Other abbreviations in mark scheme	Meaning
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.

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. 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 **3 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 B (MEI) the rubric is not specific about the level of accuracy required, so this statement reads "2 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. 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	AO	Guidance	
1	(a)		$e = \frac{0 - -2.8}{4 - 0} = 0.7$	**B1** **[1]**	1.1	oe e.g. $\frac{2.8}{4} = 0.7$	B0 for -0.7
	(b)		Impulse on $P = \Delta mv = \pm(2.5\times4 - 2.5\times(-2.8))$ = 17 (Ns) in the direction of *P*'s final travel oe	**M1** **A1** **B1** **[3]**	1.1 1.1 1.1	Finding change in *P*'s momentum Do not allow -17 for magnitude Could be shown on diagram (may be seen in part (a)) Away from the wall	Allow 1 slip but not wrong sign inside the brackets Ignore left or right unless qualified, e.g. with a diagram or further explanation Ignore "towards P"
	(c)		17 (Ns) in the opposite direction (to their previous direction) oe	**B1FT** **B1** **[2]**	2.2a 2.2a	FT their magnitude of impulse from **(b)** Direction of P's initial travel If "left" mentioned in part (a), then accept "right" as opposite direction. NB If I = 0, then award B0B0	Positive value only, ignore units Towards the wall, but not "away from P"

Question			Answer	Marks	AO	Guidance	
2	(a)	(i)	$a = \frac{v^2}{r} = \frac{12^2}{1.8}$ = 80 (ms^{-2})	B1 [1]	1.1		
	(a)	(ii)	Towards *O*	B1FT [1]	1.2	Acceleration in part (a) must be > 0 for this mark	
	(b)	(i)	$v = r\omega$ = 1.8×8 = 14.4 (ms^{-1})	B1 [1]	1.1		
	(b)	(ii)	$a = r\omega^2$ = 1.8×8^2 (= 115.2) => $T = ma$ = 0.4× "115.2" = 46.1 (N)	M1 A1 [2]	1.1 1.1	Using formula for radial acceleration and $F = ma$ with tension as only force. 46.08	
	(c)		KE = ½×0.4×"14.4"^{2} (J) (= 41.472 J) "41.472" = 0.4gh => h = 10.579... so $\theta = \sin^{-1}$(10.579.../20) = awrt 31.9(°)	M1 M1 A1 [3]	1.1 1.1 1.1	Finding 'initial' energy... ...and equating to final PE. Or … = $0.4g \times 20\sin\theta$ NB as degrees are specified in the question, an answer in radians (e.g. 0.557) scores A0	Allow sin/cos confusion if expressing h in terms of θ **SCB2** for θ = 31.9° from a non-energy method e.g. *suvat*: $14.4^2 = 2 \times 9.8 \times h$ => h = 10.579...

Question			Answer	Marks	AO	Guidance	
3	(a)		$[g] = LT^{-2}$ $[T =] (LT^{-2})^{\alpha}L^{\beta}M^{\gamma}$	**B1** **M1**	2.5 3.3	Notation must be fully correct Forming a dimensional equation between the quantities with $[c] = 1$ soi and their $[g]$	M, L, T and nothing else. Do not allow extra terms
			M: $\gamma = 0$	**B1**	1.1	Allow $\beta = 0$ if using MT^{-2} for [g]	MLT^{-2} may also be seen (=> $\gamma = ½$ later).
			L: $\alpha + \beta = 0$ and T: $1 = -2\alpha$	**M1**	3.4	Equating their $g^{\alpha}l^{\beta}m^{\gamma}$ to T (soi) and deriving equations for L and T (possibly M and T if g is incorrect)	Allow e.g. $0 = L^{\alpha} + L^{\beta}$ if recovered by stating $\alpha + \beta = 0$
			$\alpha = -½$, $\beta = ½$	**A1**	1.1	Could be embedded as eg $\tau = c\sqrt{\frac{l}{g}}$	At least one of the two M marks should be scored for this mark Allow A1 if correct values obtained using MLT^{-2}.
				[5]			
	(b)	(i)	$\tau' = c\sqrt{\frac{4l}{g}} = 2c\sqrt{\frac{l}{g}}$	**M1**	3.4	Using the model to consider length quadrupling and all other parameters (except τ) staying the same (must see $\sqrt{4} = 2$ or equivalent for *their* β)	Could see eg $\tau = cl^{\frac{1}{2}}g^{-\frac{1}{2}}$ $\tau' = c(4l)^{\frac{1}{2}}g^{-\frac{1}{2}} = 2cl^{\frac{1}{2}}g^{-\frac{1}{2}}$
			So the period (or τ) is doubled.	**B1FT**	2.2a	or just "so period doubles" oe FT their value of β	SC B1 for "no change" (with reason given) if using MT^{-2} for [g] and consistent with their equations
				[2]			
	(b)	(ii)	If mass quadruples, there is no change to the period (or τ) since there is no dependency on m ($\gamma = 0$)	**B1**	3.5a	Answer must include **both** behaviour (no change to period) *and reason* (no dependency on m), i.e. not just 'no effect'	Allow SC B1 for time doubling (with reason given) if using MT^{-2} or LMT^{-2} for [g] and consistent with their equations.
				[1]			

Question			Answer	Marks	AO	Guidance	
4			**Method using $P = \frac{WD}{t}$**				
			Energy lost to resistance = 12×90 (J)	**B1**	1.1	1080	
			Acquired KE = ½×5×18^2 (J)	**B1**	3.1b	810	
			Acquired PE = 5×g×90×0.2 (J)	**B1**	1.1	90g or 882	Ignore wrong sign
			90 = ½(18 + 0)t => t = 10	**M1**	3.1b	Use of suvat to find time taken	Or average speed = ½(18 + 0)
			Average power = (“810 + 882 + 1080”) / “10”	**M1**	1.1	Using Power = WD / time Or Energy/dist x average speed	Allow 1 error e.g. missing energy term or sign error but not extra terms
			= 277 (W)	**A1**	2.2a	277.2	
				[6]			
			Alternative method using $P = Fv$			Only award marks from one of the two solutions.	e.g. do not award for acceleration if seen as part of an energy solution.
			Weight down the slope = 5g x 0.2	**B1**		9.8N	
			$a = \frac{18^2}{2 \times 90}$	**B1**		1.8ms^{-2}; no other values of u, v or s allowed.	Or finding KE (= 810)
			ma = 5 × “1.8”	**B1FT**		9N	Or $ma = \frac{\text{“810”}}{90}$
			Average speed = ½(18 + 0)	**M1**		= 9m/s; Or $P_{(max)}$ = (12 + “9.8” + “9”) × 18 (= 554.4) Or $t = \frac{90}{\text{”9”}}$ $(= 10s)$	Allow 1 error e.g. missing energy term or sign error but not extra terms
			Average power = (12 + “9.8” + “9”) × “9”	**M1**		Driving force × average speed Or $P_{av} = \frac{P_{max}}{2} = \frac{\text{“554.4”}}{2}$	Allow 1 error as per above
			= 277 (W)	**A1**		277.2	
				[6]			

Question			Answer	Marks	AO	Guidance	
5	(a)			**M1**	3.3	Attempt at conservation of momentum	4 terms, each of correct form. Condone 1 error, e.g. sign error
				M1	1.1	Attempt at NEL	Allow 1 error, but not approach and separation speeds reversed.
			$m_Au_A + 5(-2) = m_A(-3.25) + 5(0.5)$ $\frac{0.5-(-3.25)}{u_A-(-2)} = 0.75$	**A1**	1.1	Both equations correct and consistent with each other	FT their value of m_A if substituted into the COLM equation.
			$3.75 = 0.75u_A + 1.5 \Rightarrow u_A = \ldots$ $3m_A - 10 = -3.25m_A + 2.5 \Rightarrow 6.25m_A = 12.5$ $\Rightarrow m_{A=\ldots}$	**M1**	1.1	Solving to find u_A or m_A	From their attempt at COLM and/or NEL
			$u_A = 3$ $m_A = 2$	**A1** **[5]**	1.1	Both correct, could be BC	Both correct from correct equations implies the last M1
	(b)		KE Before $= \frac{1}{2} \times "2" \times "3"^2 + \frac{1}{2} \times 5 \times 2^2$ $=19$ (J)	**B1FT**	1.1	Total KE before (FT their values for u_A and m_A)	Allow one slip
			KE After $= \frac{1}{2} \times "2" \times 3.25^2 + \frac{1}{2} \times 5 \times 0.5^2$ $= 11.1875$ (J)	**M1**	1.1		Allow one slip
			% KE Lost $= (1 - \frac{11.1875}{19}) \times 100 = 41.11 \ldots$ Hence $\approx 41\%$ **AG**	**A1** **[3]**	2.2a		

	(c)		$5(0.5) + 3(–5.5) = 5V_B + 3V_C$	**M1**	1.1	Attempt at conservation of momentum	4 terms, each of correct form. Allow one error NB V_B = -3.25 may be substituted from the start.
			$e = \frac{V_C - V_B}{0.5 - (-5.5)}$	**M1**	1.1	Attempt at NEL	Allow one error, but not approach and separation speeds reversed.
			$V_C – V_B = 6e$ and $5V_B + 3V_C = –14$	**A1**	1.1	Both equations correct and consistent with each other May be unsimplified	Could see e.g. $V_C + V_B$ if assumed to be going in opposite directions, e.g. if V_B is assumed to be negative
			$3V_C – 3V_B = 18e \Rightarrow 8V_B = –14 – 18e$ $\Rightarrow V_B = \frac{-14-18e}{8} = \frac{-7-9e}{4}$	**M1**	1.1	Solving their two COLM/NEL equations simultaneously to reach an expression for V_B or V_C in terms of e only. $V_C = \frac{-14+30e}{8} = \frac{-7+15e}{4}$	Or getting an equation for e if V_B = -3.25 previously substituted Allow 1 error
			No further collision => $V_B \geq –3.25$ oe	**B1**	3.1b	Correct condition for no further collision. Condone >, allow '=', but not '<' or "≤"	Must be consistent with previous equations; Award this for substituting V_B = -3.25 into both equations at the start
			$\frac{-7-9e}{4} \geq –3.25 \Rightarrow –7 – 9e \geq –13$ $\Rightarrow 9e \leq 6 \Rightarrow e \leq \frac{2}{3}$ But $0 \leq e \leq 1$ so $0 \leq e \leq \frac{2}{3}$	**A1** **[6]**	1.1	Inequality signs must be correct and lower limit of 0 required.	

Question			Answer	Marks	AO	Guidance	
6			$P = Fv$ => $12000 = D \times v_{max}$	**B1**	3.1b	$P = Fv$ used correctly to link "driving force" (D) and maximum speed.	Could be embedded in $F = ma$ equation. Or $\frac{12000}{10}$ seen (as driving force)
			At maximum speed $D - R = 0$ so $P/v_{max} - kv_{max} = 0$	**M1**	1.1	Statement of $F = ma$ with $a = 0$ with $R = kv_{max}$ used	Could have value(s) embedded.
			$=> \frac{12000}{10} - 10k = 0 => k = 120$	**A1**	1.1	$v_{max} = 10$, $P = 12000$	May be seen embedded
			$D - R = ma => \frac{12000}{v} - "120"v = 360 \times 1.5$	**M1***	3.1b	Statement of $F = ma$ with $P = Dv$ and $R = kv$ and $m = 360$ and $a = 1.5$ used	May see $v = \frac{12000}{540+120v}$ using $v = \frac{P}{D}$
			=> $12000 - 120v^2 = 540v$ [=> $2v^2 + 9v - 200 = 0$]	**M1dep**	1.1	Rearranging to 3-term quadratic equation	
			$(2v + 25)(v - 8) = 0$ => $v = 8$ [or $v = -12.5$]	**A1**	1.1	Both values correct if present, A fully correct solution implies the previous M mark www	Could be BC
			But speed must be positive, so speed is 8 (ms^{-1})	**A1FT**	3.2a	Both values seen and rogue solution explicitly rejected, with valid reason. FT solutions to their quadratic (if a negative solution is validly rejected). Reason could be that velocity and resistive force must be in opposite directions (have opposite signs). Accept reference to scalar nature of speed	Insufficient explanations: "Going forward"; "Cannot be negative as it is accelerating"/"acceleration is in the positive direction"; "a cannot be positive when v is negative, because power is positive";
				[7]			

Question			Answer	Marks	AO	Guidance	
7	(a)		$I = \Delta mv \Rightarrow 44.1 = 3.5u$ $\Rightarrow u = 44.1 / 3.5 = 12.6$ (ms^{-1})	B1	3.3	Use of impulse-momentum principle to find initial speed	
			Initial KE = ½×3.5×"12.6"^{2} (= 277.83 J)	B1FT	1.1	FT their u	
			PE = $3.5g \times 5.4(1 - \cos\theta)$	M1	3.4	PE with allowance made for change in height in terms of θ and use of mgh	Could see separate PE terms and/or errors in sign(s) of PE term(s). Allow sin/cos confusion
			"277.83" = $3.5g \times 5.4(1 - \cos\theta)$	M1	3.4	Conservation of energy with final KE set to 0	Their initial KE must be > 0
			$\Rightarrow \cos\theta = -½ \Rightarrow \theta = 2\pi/3$	A1	1.1	or awrt 2.09 (2.09439…)	Radians only
			Alternative Method $I = \Delta mv \Rightarrow 44.1 = 3.5u$ $\Rightarrow u = 44.1 / 3.5 = 12.6$ (ms^{-1})	B1		Use of impulse-momentum principle to find initial speed	
			Initial KE = ½×3.5×"12.6"^{2} (= 277.83 J)	B1FT		FT their u	
			PE = $3.5g \times$ h and "277.83" = $3.5g \times$ h	M1		NB h = 8.1m	Probably using a diagram
			$\cos\theta = (\pm)\frac{5.4 - "8.1"}{5.4}$ oe	M1		Or $sin\alpha = \frac{8.1-5.4}{5.4}$ oe (to the horizontal)	NB $\alpha = \frac{\pi}{6}$ Allow sin/cos confusion
			$\theta = \frac{2\pi}{3}$	A1		$\theta = \frac{\pi}{6} + \frac{\pi}{2} = \frac{2\pi}{3}$	May be explained by a diagram
				[5]			
	(b)		"277.83" = "$3.5g \times 5.4(1 - \cos\theta)$" + $20 \times k\theta \times 5.4$	M1	3.4	Applying work-energy principle with their PE and KE and an energy loss term	FT their previous values; k may be positive or negative, e.g. $\frac{\pi}{180}$ Allow use of h instead of θ
			$277.83 = 185.22 - 185.22\cos\theta + 108\theta$ $343 + 686\cos\theta = 400\theta$ $343(1 + 2\cos\theta) = 400\theta$	A1	1.1	AG. Rearranging convincingly to AG.	
				[2]			

	(c)		Energy lost to resistance = $20\times5.4\times1.306$ J (=141.048 J) $141.048 = 3.5\times9.8h$ $h = 4.11$ (m)	**M1** **M1** **A1**	3.4 3.4 1.1	Using "$r\theta$" and 20 to find work done against resistance Using W-E principle (ie lost energy would manifest as more PE) 4.112…	
			Alternative method: $5.4(1 - \cos(\text{“}2\pi/3\text{”}))$ [= "8.1"] $5.4(1 - \cos(1.306))$ [= 3.986...] "8.1" – 3.986… = 4.11(m) (3 sf)	**M1** **M1** **A1**		Finding maximum height predicted by first model (may be seen in part (a). Award this mark if re-used in part (c)) Finding maximum height predicted by second model 4.09-4.11 (m)	Allow sin/cos confusion NB $\theta = 2.09$ gives 8.079… Allow FT of their θ from part (a)
				[3]			
	(d)		Take into account the mass and/or weight of the rod (which is unlikely to be negligible)	**B1** **[1]**	3.5c	Or other sensible improvement. eg making resistance to motion dependent on speed or account for rod not being perfectly inextensible etc. Allow reference to size and shape of the particle, but not just a generalisation such as: "do not model as a particle" Allow the idea that tension may cause the rod to extend or affect the friction at the hinge, but not just tension on its own. Allow the idea that there could be some spin in particle P or motion in and out of the plane	Ignore using (light inextensible) string instead of a rod. Ignore gravity as resistive force. Ignore reference to friction at the hinge. Ignore reference to tangential acceleration or speed. Splitting resistance into air resistance and friction must be justified as an improvement, e.g. reference to air resistance not being constant, or reason why friction may not be constant.

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