OCR
Oxford Cambridge and RSA

GCE

Further Mathematics A

Y533/01: Mechanics

AS 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.

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)		$2.4m\ (+ 0(3m)) = (m + 3m)v$	M1	1.1	Conservation of momentum with A and B having some post-'collision' velocity and initial momentum > 0	Treat consistent calculation using $m_B = m$ (possibly combined with $m_A = 3m$) as MR. Can be awarded if seen in **(b)**
			$4v = 2.4 \Rightarrow v = 0.6$ so speed of B is 0.6 ($m\,s^{-1}$)	A1	1.1		$m_B = m_A = m \Rightarrow v = 1.2$ $m_B = m,\ m_A = 3m \Rightarrow v = 1.8$
				[2]			
	(b)		Impulse on B = change in B's momentum = $3m \times 0.6\ (- 0(3m))$	M1	1.1	Using $I = \Delta mv$	
			so magnitude of impulse is $1.8m$ (Ns)	A1	1.1	Do not allow -1.8m	$m_B = m_A = m \Rightarrow I = 1.2m$ $m_B = m,\ m_A = 3m \Rightarrow I = 1.8m$
				[2]			

Question			Answer	Marks	AO	Guidance	
2	(a)		Initial KE = ½ × $3u^2$	**B1**	3.4	Used in solution	$1.5u^2$
			PE when at rest = $3g\times(3.2 - 3.2\cos 60°)$	**M1**	3.1b	$24g/5$ or 47.04 or 4.8g. Attempt to use *mgh* to find the PE at the instant that *P* comes to rest Use of suvat is M0	Assuming zero PE level at lowest point. Otherwise this mark is for attempting to find the difference between PE when at rest and PE at the bottom
			$\frac{3}{2}u^2 = \frac{24g}{5}$	**M1**	3.4	Using energy conservation and their expressions to set up an equation in u^2	
			$u = 5.6$	**A1**	1.1	No need to eliminate negative value explicitly here	
				[4]			
	(b)		Assume that air resistance is negligible	**B1**	3.3	Any sensible specific assumption E.g. no air resistance *P* is a particle/has no dimensions "No resistance to motion" "No energy is lost to the surroundings" "No other forces acting" are insufficient	Ignore references to assumptions stated in the question, e.g. no friction between *P* and the surface, "other forces", "does not come off the surface"
				[1]			

Question			Answer	Marks	AO	Guidance	
3	(a)		$F = 80\cos40° = 45a$ $\Rightarrow a = 80\cos40° / 45$	M1	1.1	Using $F = ma$ with a resolved component of the pulling force and m (not mg) to find a	1.36185… Or $mv = Ft$ (= 306.4)
			$s = 0.8\times5 + ½ \text{“}1.36185...\text{”}\times5^2$	M1	1.1	Using *suvat* equation(s) with their value of a to find the distance travelled (21.0232... m)...	...or final velocity ($v = 0.8 + ½\times1.36185...\times5$ (=7.609283...)) Or $v = \frac{Ft}{m} + 0.8$ $(= \frac{306.4}{45} + 0.8)$
			WD by pull = $80\cos40°\times21.0232...$	M1	1.1	Their component of force × their distance If a = 0 used (e.g. 245Nm) then only this mark can be awarded.	...or change in KE = $½\times15\times(7.609283...^2 - 0.8^2)$
			= awrt 1290 (J)	A1	1.1		1288.377…
				[4]			
	(b)	(i)	$v = 0.8 + 1.36185...\times5 = 7.609283...$ and use in KE = $½ mv^2$	M1	1.1	Attempt to use suvat equation with their a to find the velocity after 5 seconds (with no vertical component) and using this to attempt to find the KE (may be seen in (a))	Or WD + initial KE (= 14.4) Must be initial and not final KE, and combined with WD from part (a)
			so KE = $½\times45\times7.609283...^2$ = awrt 1300 (J)	A1	1.1	$Or\ 14.4 + 1288$	1302.777…
				[2]			
	(b)	(ii)	Work done should equal the *increase* in (kinetic) energy so no account has been made of the fact that the crate has some initial energy.	B1	2.4		Ignore reference to any kind of resistive force
				[1]			
	(c)		Av Power = $80\cos40°\times21.0232...$ / 5 = awrt 258 (W)	B1FT	1.1	Their (1290)/5 Or average velocity × resolved force $(= 0.5(0.8 + 7.609283…) \times 80\cos40)$	257.675… B0 if $a = 0$ used
				[1]			
	(d)		Impulse = *Their* (horizontal) Force × time [= $80\cos40°\times5$]	M1	1.1	or = change in crate's momentum = 45(“7.609283”... – 0.8)	Must lead to an answer > 0
			= awrt 306 (N s)	A1	1.1		
				[2]			

Question			Answer	Marks	AO	Guidance	
4	(a)		450/0.5 – 150 = 240*a*	**M1**	3.3	Using *F* = *ma* with *m* substituted in and a force derived from *P* = *Fv* and the resistance force as negative	
			a = 3.125 so the maximum acceleration is awrt 3.13 ($m\,s^{-2}$)	**A1**	1.1		
				[2]			
	(b)		210 = *Dv*	**M1**	3.4	Use of "*P* = *Fv*" or $p = \frac{Fd}{t}$ with 210 substituted in	
			Constant speed => *a* = 0 => 210/*v* = 150	**M1**	2.2a	Using *F* = *ma* with *a* = 0 to deduce the required force (soi)	$210 = \frac{150d}{t}$
			v = 1.4	**A1**	1.1		Or $t = \frac{150 \times 350}{210}$ oe
			t = 350 / 1.4 = 250 so 250 seconds	**A1**	1.1	4 minutes 10 seconds	
				[4]			
	(c)		The model assumes that the power and hence driving force is constant but in practice this will not be the case (since the oars go in and out of the water periodically) Or: Rower may get tired (& reduce power output). Or: Speed may vary, hence power will vary (if the force/resistance is constant).	**B1**	3.5b	Detailed knowledge of the mode of propulsion of a rowing boat is not required. If mentioning change of resistance, force or speed, this must be linked to power output.	Allow any response along the lines that any human way of providing power will not in practice be constant.
				[1]			

Question			Answer	Marks	AO	Guidance	
5	(a)	(i)	$5m + (–3)m = (–2)m + mv_B$	M1	3.4	Conservation of momentum	u_A must be $> u_B$ oe
			$v_B = 4$	A1	1.1		
			in the direction of motion of A before the collision oe	A1	1.1	Must be clearly stated or shown, e.g. consistent with arrow on diagram	Direction of B is reversed
				[3]			
		(ii)	$e = (4 – (–2)) / (5 – (–3))$	M1	3.4	Attempt at restitution - condone sign error as long as consistent	$0 \leq (\pm)e \leq 1$ Must have sufficient detail, e.g. 6/8 on its own is M0.
			$= 6/8 = ¾$	A1	1.1	AG	
				[2]			
		(iii)	Initial KE = $½×4×5^2 + ½×4×(–3)^2 = 68$ (J) Final KE = $½×4×(–2)^2 + ½×4×4^2 = 40$ (J)	M1	3.4	Attempt to calculate total initial or final KE Both values must be positive	Or KE loss for $A = ½×4×5^2 – ½×4×(–2)^2 = 42$ J or KE gain for $B = ½×4×4^2 – ½×4×3^2 = 14$ J
			so loss is $68 – 40 = 28$ (J)	A1	1.1		42 J – 14 J = 28 J
				[2]			
	(b)		$e = 4 / 4 = 1$	B1FT	1.1	FT their v_B provided that $0 < e \leq 1$ (using their values in (a))	Allow e = 1 without working, provided (a)(i) is correct
			The collision is perfectly elastic.	B1FT	1.2	FT their e provided that $0 < e \leq 1$ (using their values in (a))	Do not accept phases such as "completely elastic"
				[2]			
	(c)		$(–2)m + (–4)m = mV_A + mV_B$	M1*	3.1b	Conservation of momentum with consistent signs. $2V_A + 2V_B = –12$	(if "positive" direction reversed: $2m + 4m = mV_A + mV_B$) M0 if approach speed < 0
			$¾ = (V_B – V_A) / ((–2) – (–4))$	M1*	3.1b	Restitution with consistent signs $2V_B – 2V_A = 3$	Allow use of e (e.g. $V_B - V_A = \pm 2e$)
			$2V_A + 2V_B = –12$ $2V_B – 2V_A = 3$ $V_B = …$ or $V_A = …$	M1dep	1.1	Attempt to solve both their equations simultaneously and reach a solution for V_A or V_B	Allow use of e (e.g. $V_A = \pm(3 + e)$ or $V_B = \pm(3 - e)$)
			$V_B = –2.25$ or $V_A = –3.75$	A1	1.1		A numerical value is required here (may be implied by a correct final answer).
			Impulse on A = change in A's momentum $= 4(–3.75 – (–2)) = –7 \Rightarrow 7$(Ns)	A1	1.1	Ignore wrong units	ISW e.g. any statements regarding direction of travel
				[5]			

Question			Answer	Marks	AO	Guidance	
6	(a)		$[P] = MLT^{-2} / L^2 = ML^{-1}T^{-2}$	B1	1.1	Penalise wrong dimensional symbols only once as accuracy mark.	Penalise + instead of × when combining dimensions only once as accuracy mark
				[1]			
	(b)		$[½mu^2]$ or $[½mv^2]$ or $[W] = ML^2T^{-2}$	M1	1.1	½ not necessary	
			$[mP] = M^2L^{-1}T^{-2}$ so the equation is dimensionally inconsistent	A1	2.1	Correct dimensions for mP and conclusion	
				[2]			
	(c)		$[RHS] = [M^0]L^{\alpha+\beta}T^{-(\alpha+\beta-\gamma)}$ oe	M1	3.4	eg RHS has no M	
			while LHS has M^1 so the equation must be dimensionally inconsistent	A1ft	2.4	or "some M" oe Or "no M" compared to LHS Ignore one minor slip in L or T	and $[W] = ML^2T^{-2}$ so comparing indices leads to a contradiction Allow incorrect expression for $[W]$ from part (b), provided it includes an element of M
				[2]			
	(d)	(i)	Because there are 4 unknowns and DA can only give us a maximum of 3 equations	B1	2.4	Must be specific comparison. Or 3 equations in 4 unknowns seen (condone one slip), with appropriate comment about the equations in L and T at least	Must show all 3 equations, not just the two that involve α, β and δ
				[1]			
	(d)	(ii)	$ML^2T^{-2} = L^3T^{-3}L^{\beta}T^{-2\beta}M^{\gamma}T^{\delta}$	B1ft	3.4	Correct dimensional expansion of both sides with $\alpha = 3$ substituted at some point (using their $[W]$)	$M^{\gamma}\ L^{3+\beta}T^{\delta-3-2\beta}$ Award if seen in part (i) (with $\alpha = 3$)
			M: $1 = \gamma$, L: $2 = 3 + \beta$, T: $-2 = \delta - 3 - 2\beta$	M1	1.1	Correctly comparing indices for all three dimensions. Allow 1 slip	M0 if M does not appear on both sides of the dimensional equation
			$\beta = -1$, $\gamma = 1$, $\delta = -1$	A1	1.1		
				[3]			

	(d)	**(iii)**	The resultant formula is $W = \frac{ku^3m}{at}$. This is unlikely to be correct since it suggests, for example, that the total work done becomes (very) small or negligible	**B1**	3.5a	Correct conclusion from their $\delta \leq 0$ Condone "not correct/incorrect" Answers referring to t = 0 are not valid for this question	Condone statements such as "… because work done decreases as time increases" oe, (which contradicts the expectation of a positive relationship between W and t)
				[1]			

Question			Answer	Marks	AO	Guidance	
7	(a)		For P: $\leftrightarrow\ T_{S_1} = 1.5 \times 5\omega^2$ (= $7.5\omega^2$)	**M1**	3.1b	NII for particle P using $a = r\omega^2$ T_{S_1} and T_{S_2} must be in terms of ω (may be seen later e.g. by using $\omega = \frac{v_P}{5}$ or $\omega = \frac{v_Q}{5\sin\theta}$ oe)	Condone use of m and r SC1 only for omitting the element of m, or for using a specific value of ω to get the result that $T_{S_1} = T_{S_1}$.
			For Q: $\leftrightarrow\ T_{S_2} \sin\theta = 1.5r\omega^2$	**M1**	1.1	Resolving tension for Q and using NII in the horizontal with $a = r\omega^2$	Allow sin/cos confusion Allow use of specific value of θ Allow use of $r\sin\theta$ or $r\cos\theta$
			$r = 5\sin\theta \Rightarrow T_{S_2} = \dfrac{1.5 \times 5\sin\theta \times \omega^2}{\sin\theta} = 7.5\omega^2$ $\therefore T_{S_1} = T_{S_2}$	**A1**	1.1	AG Two identical expressions clearly seen.	A0 if a specific value of θ has been used
				[3]			
	(b)		P: $\frac{1}{2} \times 1.5v^2 = 39.2$, so $v^2 = \frac{784}{15}$	**M1**	1.1	Using kinetic energy is 39.2 to find v or v^2	$v^2 = 52.666\ldots$, $v = \frac{28\sqrt{15}}{15} = 7.229\ldots$ (allow 7.22)
			$t_P = \dfrac{2\pi}{\omega_P} = \dfrac{2\pi \times 5}{v} = \dfrac{5\sqrt{15}\pi}{14}$	**A1**	1.1	Use of "$\omega = \frac{2\pi}{t}$" and finding the time using "$v = r\omega$" for P. NB $t_P = 4.3454\ldots$, $\omega_P \approx 1.45$ Allow 4.33-4.35	Allow unsimplified. Penalise inexact value only at the end
			Q: $\omega_Q = \frac{v}{5\sin\theta}$ (= $\frac{28\sqrt{15}}{75}$)	**B1**	1.1	Use of "$v = r\omega$" for Q with correct radius Or $t_Q = \frac{2\pi \times 5\sin\theta}{v}$ (may be seen later) Or $\omega_Q = \omega_P \sin\theta$	May be seen later as $\omega_Q = \frac{v}{4} = \frac{7}{\sqrt{15}}$ or $t_Q = \frac{2\pi}{\omega_Q} = \frac{4\sqrt{15}\pi}{14}$ B0 for assuming specific value of θ (and for subsequent marks)
			Q: $\updownarrow T_{S_2}\cos\theta = 1.5g$	**M1**	1.1	Resolving the tension vertically and balancing with weight (condone missing g here)	$4g = 39.2$ Condone use of m

			$Q: \leftrightarrow\ T_{S_2} \sin\theta = 1.5a = \frac{1.5v^2}{5\sin\theta}$	**M1**	1.1	Resolving tension horizontally and using NII and $a = \frac{v^2}{r}$ with correct radius Or: $T_{S_2} = 7.5\left(\frac{v}{5\sin\theta}\right)^2$	Could see use of $v^2 = \frac{784}{15}$ here so $T_{S_2} sin\,\theta = 1.5a = \frac{1176}{75\,sin\,\theta}$ Condone use of m and r
			$\frac{sin^2\theta}{cos\,\theta} = \frac{\left(\frac{1.5v^2}{5}\right)}{1.5g} = \frac{v^2}{5g} = \frac{784}{15\times5g} = \frac{16}{15}$ $15(1-cos^2\theta) = 16\,cos\,\theta$ $(\Rightarrow 15c^2 + 16c - 15 = 0)$	**M1**	2.3	Finding an equation in θ, using $v^2 = \frac{784}{15}$ and substituting $\sin^2\theta = 1 - \cos^2\theta$ to get an equation in $\cos\theta$ only	
			((5c – 3)(3c + 5) = 0 =>) $\cos\theta = 3/5$ since $\cos\theta$ cannot be –5/3) $\Delta t = \frac{5\sqrt{15}\pi}{14} - \frac{4\sqrt{15}\pi}{14} = \frac{\sqrt{15}}{14}\pi$, so difference in time periods is $\frac{\sqrt{15}}{14}\pi$ (s) oe	**A1**	1.1	Allow $\cos\theta = 3/5$ or $\sin\theta = 4/5$ to appear without working. Use of "$\omega = \frac{2\pi}{t}$" and finding the time difference. (For reference: 0.86909…)	or $t_Q = \frac{2\pi r}{v} = \frac{2\pi\times5\sin\theta}{v}$ $= \frac{2\pi\times5\times\frac{4}{5}}{\sqrt{\frac{784}{15}}} = \frac{4\sqrt{15}\pi}{14}$
				[7]			

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