GCE

Further Mathematics A

Y533/01: Mechanics

AS Level

Mark Scheme for June 2022

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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.

Text Instructions

1. Annotations and abbreviations

Annotation in RM assessor	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.

2. Subject-specific Marking Instructions for A Level Mathematics A

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)		$50 \times 2.1 + 70 \times -0.8 = 50 \times 0.35 + 70 \times v_B$ v_B = 0.45	M1 A1 [2]	1.1 1.1	Conservation of momentum with correct masses and velocities substituted in	Allow one sign error Using $\Delta\rho_1 = -\Delta\rho_2$ e.g. $50 \times 2.1 - 50 \times 0.35 = 70 \times v_B - 70 \times -0.8$
	(b)		$\pm e$ = ("0.45" – 0.35)/(2.1 – –0.8) (oe) 1/29 or awrt 0.0345	M1 A1 [2]	1.1 1.1	NEL with correct velocities substituted in	Allow one sign error NB "0.45" + 0.35 is M0 unless clearly going in opposite directions
	(c)		eg initial KE for A = ½×50×2.1^2 so KE loss = ½×50×2.1^2 + ½×70×0.8^2 – (½×50×0.35^2 + ½×70×0.45^2) oe 122.5 J	M1 M1 A1 [3]	1.1 1.1 1.1	Correct calculation of any initial or final KE (using their values) Attempt to find difference between total final KE and total initial KE Must be positive	110.25, 3.0625, 22.4, 7.0875 NB 132.65 – 10.15 If evaluating each object separately, then 107.875 + 15.3125 (must be sum) Or 123J
	(d)		Not perfectly elastic since (kinetic) energy is lost	B1 [1]	2.4	or since $e < 1$ or $e \neq 1$	Prefer to be specific but accept "energy" only

Question			Answer	Marks	AO	Guidance	
2	(a)		$I = mv - mu$ = 0.2×24 – 0.2×–14 7.6 Ns	M1 A1 [2]	1.1 1.1	Use of $I = \pm\Delta mv$ soi	If 4.8 – 2.8, then must be clear evidence of sign error in the second velocity, e.g. ±(0.2×24 – 0.2×14) Magnitude must be > 0
	(b)		Initial (kinetic) energy = ½×0.2×24^2	B1	1.1	Use of $\frac{1}{2}mv^2$ (in an attempt to calculate initial KE of puck)	57.6
			Final (potential) energy = 0.2g×15sin10°	M1	1.1	Use of mgh (in an attempt to calculate final PE of puck)	5.105... Allow sin/cos confusion NB count use of g = 9/GPE = 4.688… as a slip
			Work done against resistance = R×15	M1	1.1	Use of "$W = Fd$"	
			15R + 0.2g×15sin10° = $\frac{1}{2}$×0.2×24^2	M1	3.4	Balancing their energies (3 terms)	All terms must be in correct direction and dimensionally correct
			awrt 3.50 N	A1	1.1		If N2L used **SC2** for 3.50 N www
				[5]			

Question			Answer	Marks	AO	Guidance	
3			Initial PE = $m\times9.8\times4.2(1-\cos\pi/3)$	**M1**	3.1b	Calculation of initial energy. Assuming that the lowest point is the 0 PE level.	Do not allow use of suvat
			Speed is lowest when *B* reaches the top	**B1**	2.2a	oe soi e.g. cons of energy seen	If not stated explicitly, then award for any energy equation that leads to $u > 8$
			Energy at top = $\frac{1}{2}\times m\times4^2 + m\times9.8\times(2\times4.2)$	**M1**	1.1	(= 90.32*m*). Adding PE and KE at the top.	
			$m\times9.8\times4.2(1-\cos\pi/3) + \frac{1}{2}mu^2$ = their energy at top	**M1**	1.1	($20.58m + \frac{1}{2}mu^2 = 90.32m$) Adding PE and KE at start and equating	Consistent dimensions
			$u > 0 \Rightarrow u$ = awrt 11.8	**A1**	1.1	Must be positive	$u^2 = 139.48$
			Alternative solution				
			Change in PE = $m \times 9.8 \times 4.2 \times (1 + \cos\frac{\pi}{3})$	**M1**		61.74*m*	i.e. initial position has zero GPE
			Speed is lowest when *B* reaches the top	**B1**			
			Change in KE = $\pm\frac{1}{2}m(4^2 - u^2)$	**M1**		May be seen in balanced equation	
			$m \times 9.8 \times 4.2 \times \left(1 + \cos\frac{\pi}{3}\right) = -\frac{1}{2}m(4^2 - u^2)$ oe	**M1**		Or $\frac{1}{2}mu^2 = \frac{1}{2}m \times 4^2 + m \times 9.8 \times 4.2 \times (1 + \cos\frac{\pi}{3})$	Equating their gain of PE with their loss of KE (signs must be correct)
			$u > 0 \Rightarrow u$ = awrt 11.8	**A1**			
				[5]			

Question			Answer	Marks	AO	Guidance	
4			$F = 250 / v$	**B1**	1.1	Used in the solution in either direction	Do not award if equating *D* with *Fr*
			Up:	**M1**	1.1	N1L (or balancing forces)	$F = 124.689...$
			$(\pm)F - 80g\sin4° - 70 = 0$			Opposing forces must be in same direction	Allow sin/cos confusion Allow 40° instead of 4° confusion
			v = awrt 2.00	**A1**	1.1	2.004987… Accept 2 m/s but not e.g. 2.01 NB 2.005 to 4sf	Do not accept negative value unless clearly justified e.g. if downwards is defined as negative
			Down:	**M1**	1.1	N1L (or balancing forces)	$F = 15.310...$
			$F + 80g\sin4° - 70 = 0$				
			v = awrt 16.3	**A1**	1.1		
				[5]			

Question			Answer	Marks	AO	Guidance	
5			$a = v^2 / r$ or $r\omega^2$ or $v\omega$	**B1**	1.2	Use of correct form for centripetal acceleration (soi); NB a = 155.55…	Do not allow for conical pendulum
			$70 = 0.45v_{max}^2 / 3.5$ or $0.45\times3.5\omega_{max}^2$	**M1**	3.1b	Use of NII with their a Forces must all be horizontal	
			$70/3 = 2\pi\times3.5 / T_{min}$ or $20/3 = 2\pi / T_{min}$	**M1**	1.1	Use of correct formula to relate v or ω to the period	From v_{max} = 70 / 3 (or awrt 23.3) or ω_{max} = 20 / 3 (or awrt 6.67)
			So minimum time is awrt 0.942 s	**A1** **[4]**	1.1	$3\pi/10$	SC2 for use of conical pendulum leading to correct answer (SC1 if correct to 2sf (0.94))

Question			Answer	Marks	AO	Guidance	
6	(a)		$[v] = LT^{-1}$	**B1**	1.2	Used in solution	Penalise wrong basic terms only once
			$[u^\alpha a^\beta t^\gamma] = L^\alpha T^{-\alpha} L^\beta T^{-2\beta} T^\gamma$	**B1**	3.3	Correctly finding the dimensions of $u^\alpha a^\beta t^\gamma$ in terms of α, β and γ	Allow unsimplified
			$1 = \alpha + \beta$ or $-1 = -\alpha - 2\beta + \gamma$	**M1**	3.4	Equating their dimensions L and T	
			$\Rightarrow \alpha = 1 - \beta$	**A1**	1.1		
			$\Rightarrow \gamma = \beta$	**A1** **[5]**	1.1	www	If extra term such as M is included, then B1B0M1A0A0
	(b)		For straight line graph t^γ must be 1 (or constant or t^0) or t (or t^1)...	**M1**	3.1b	For clear understanding that the relationship must be of the form $v = mt + c$ where both mt and c must take the form $[k]u^\alpha a^\beta t^\gamma$	Or could see e.g. $v = u^{1-\beta}a^\beta t^\beta$ with $\beta = 1 \Rightarrow v = at$ and $\beta = 0 \Rightarrow v = u$
			...(so $\gamma = 0$ or 1) so $\beta = 0$ or 1	**A1** **[2]**	1.1		SC1 for $\beta = 1$ using direct proportion or unsupported but www e.g. $\beta = -1$
	(c)		v must be the sum of terms like $ku^\alpha a^\beta t^\gamma$	**M1**	2.1	AG. (or $k_1u + k_2at$ or $mt + c$)	Award if at least one term seen, must have k, u, a and t
			$v = k_1u + k_2at$ and $v = u$ when $t = 0 \Rightarrow k_1 = 1$	**A1**	3.4		
			and $v = u + a$ when $t = 1 \Rightarrow k_1 = 1$ so $v = u + at$	**A1** **[3]**	2.2a		

Question			Answer	Marks	AO	Guidance	
7	(a)		Mom^{m}: $1\times1.79 + 2.74\times-0.08 = v_P + 2.74v_Q$	**M1**	3.3	Attempt at equating momentum before and after collision between P and Q with 4 terms.	1.5708 Allow 1 incorrect mass and one sign slip
			Rest^{n}: $e = -(v_P - v_Q)/(1.79 - -0.08)$	**M1**	3.3	Attempt at using NEL. Accept global sign error. Allow sign error in u_Q provided that this is shown clearly	$v_Q - v_P = 1.87e$
				A1	1.1	Both equations correct	
			$v_P = v_Q - 1.87e$ and $v_P = 1.5708-2.74v_Q$ $\rightarrow v_Q - 1.87e = 1.5708 - 2.74v_Q$	**M1**	1.1	Attempt at solving simultaneously e.g. by substituting for v_P	Or using elimination: $1.5708 = v_P + 2.74v_Q$ and $1.87e = v_Q - v_P$ $1.5708 + 1.87e = 3.74v_Q$
			$v_Q = (1.5708 + 1.87e)/3.74 = 0.42 + 0.5e$ **AG**	**A1**	1.1	AG. Intermediate working must be shown Final value must be positive	So $v_Q = 0.42 + 0.5e$
				[5]			
	(b)		$v_P = v_Q - 1.87e = 0.42 - 1.37e$	**M1**	1.1	Deriving v_P from the equations and/or answer in **(a)**	Or $1.5708 = v_P + 2.74(0.42 + 0.5e)$
			After Q hits wall: $w_Q = \pm e(0.42 + 0.5e)$	**M1**	3.1b	$(-)e \times$ their v_Q	
			No 2nd collision so their $v_P \leq v_Q$ soi	**B1**	2.2a	Condition on velocities given no 2nd collision occurs Allow strict inequality for this mark	If using left hand reference then $v_P \geq v_Q$
			$0.42 - 1.37e \leq \pm e(0.42 + 0.5e)$	**M1***	3.1b	Condone any inequality or equality sign	Must be derived from an attempt at v_P and w_Q in terms of e
			$e^2 - 1.9e + 0.84 \leq 0$	**M1dep***	1.1	Rearranging to 3-term inequality	Must see zero on one side of the inequality
			Critical values for e; 1.2, 0.7	**A1FT**	1.1	BC (correct CVs for their inequality, which must be a 3-term quadratic)	NB if $w_Q = 0.42e + 0.5e^2$ then expect to see -3.80 and 0.221 At least one value must be positive
			$0.7 \leq e \leq 1.2$ and $0 \leq e \leq 1 \Rightarrow 0.7 \leq e \leq 1$	**A1**	2.3	cao Do not allow strict inequality	If derived from equality, then inequality must be fully justified.
				[7]			

Question			Answer	Marks	AO	Guidance	
8	(a)		The velocity of incoming chemical is directed into the pipe or There is no work done on the liquid as it enters the pipe	**B1** **[1]**	3.3	There is no change in KE is insufficient Comments relating to energy changes as the liquid enters the tube	Do not accept trivial statements such as constant velocity Ignore "other resistances" Ignore any comments relating to changes of energy within the tube, or changes in density/compressibility
	(b)		In one hour, increase in KE = $½ \times 1500 \times (14.3^2 - 6.2^2)$	**B1**	3.4	Change in KE soi Could be divided by 3600 (42.6… – 8.00… = 34.59…) for 1 second (Or = 83.025 for 1 kg)	153367.5 – 28830 = 124537.5 NB may be seen in part c) Could also see reference to 2.354kg in 5.65s to go through the tube
			In one hour, increase in PE = $1500 \times 9.8 \times 35 \sin 26°$	**M1**	3.4	Allow cos26° but not 1500g×35 Could be divided by 3600 (= 62.65…) (Or 150.36… for 1kg)	225541.955... NB may be seen in part c)
			Rate at which work is done against resistance in the tube is 40×6.2	**B1**	1.1	Or work done against resistance = $40 \times (6.2 \times 3600) = 892800$J Allow 40 × 35 if divided by 5.65s	248W Do not allow if the resistance is treated as a driving force or used to find a driving force of 40N.
			Power at which the pump is working is $\frac{\Delta KE + \Delta PE}{3600} + "40(6.2)"$	**M1**	3.1b	oe: could have total energy ÷ 3600 Allow if 40 × 35 used and added to the total energy	Must be dimensionally correct
			345 W	**A1**	1.1	Accept any valid units for power.	Do not allow use of suvat
			Alternative Method (At the start): PE = 0 and KE = ½×1500×6.2^2 and final KE = ½×1500×14.3^2	**B1**		oe, e.g. initial and final KE seen in a balanced equation	Could be expressed per second or for 1kg or for 35m (5.65s)
			(At the pump end): PE = 1500×9.8×35sin26°	**M1**			
			Work done against resistance = 40×6.2×3600	**B1**		Or rate = $40 \times 6.2 (= 248)$	
			½×1500×6.2^2 + 3600P + 40×6.2×3600 = 1500×9.8×35sin26° + ½×1500×(14.3^2) oe	**M1**			Must be dimensionally correct
			P = 345W	**A1**			
				[5]			

	(c)	**(i)**	450×3600 – (124537.5 + 225541.955...) = 1270kJ to 3sf	**M1** **A1**	3.4 1.1	Correct calculation with their values 1620000 – 350079… = 1269921… NB 1620000 – 351479… is M0 1269920…	Must not include resistance, e.g. 345 × 3600 accounted for (see alternative method) A0 for 1268520…
			Alternative Method (450 – 345 + 40 × 6.2) × 3600 = 1270kJ	**M1** **A1**		Use of excess power output × 3600	
				[2]			
		(ii)	eg work must be done against other resistance forces (eg at the nozzle) or a blockage (e.g. at the nozzle) or the pump would heat up (or heat up the air around it or heat up the chemical or the tube(s)) which requires energy, e.g. due to friction between the fluid and the pump blades (exclude internal resistance) or the total resistance to motion may be more than 40N and so more energy is required The model ignores other resistances to motion Resistance to motion of the fluid soi, e.g. the liquid would not all be moving with the same velocity (turbulent flow) or may be relatively viscous and so there would be internal resistance to overcome, which requires energy or some energy may be required to change the direction of the velocity of the liquid at the intake and so the pump will need to provide more energy to get the intake liquid to a velocity of $6.2ms^{-1}$ up the tube	**B1**	3.5b	An explanation which looks at one of the modelling assumptions and shows that a higher power output or more energy may be required if it does not hold. Ignore anything that refers to internal losses in the pump as the question is about the difference between the power output and the gain in mechanical energy, rather than the power input. Candidates need to give a valid reason or example not covered by the question text rather than non-specific statements, e.g. not just that there would be more resistance or that there might be other (unstated) resistances. At the very least, reference to the 40N mentioned in the question as being inadequate is required, or reference to the fact that all other resistances to motion have been ignored.	B0 for considering internal resistance of the motor/electrical energy Exclude statements such as: “energy will not always be constant in the system” “velocity is not always constant” “the model only considers mechanical energy, not electrical energy” “the resistance to motion is not constant” “there would be more resistance” “power output of the motor is not constant” “It doesn’t consider resistance inside the pump” “the fluid cannot be modelled as a particle” “energy loss due to inefficiency in the delivery of power” “there will be friction” “no liquid escapes the tube” “no thermal or sound energy escapes” “The flow of liquid is laminar” References to heat or noise, unless clearly associated with the movement of the fluid
				[1]			

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