Cambridge Assessment International Education

Cambridge International AS & A Level

MATHEMATICS **9709/42**

Paper 4 Mechanics **February/March 2023**

MARK SCHEME

Maximum Mark: 50

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge International will not enter into discussions about these mark schemes.

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Generic Marking Principles

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptors for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:
Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:
Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:
Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:
Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:
Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:
Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

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Mathematics Specific Marking Principles	
1	Unless a particular method has been specified in the question, full marks may be awarded for any correct method. However, if a calculation is required then no marks will be awarded for a scale drawing.
2	Unless specified in the question, answers may be given as fractions, decimals or in standard form. Ignore superfluous zeros, provided that the degree of accuracy is not affected.
3	Allow alternative conventions for notation if used consistently throughout the paper, e.g. commas being used as decimal points.
4	Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. wrong working following a correct form of answer is ignored (isw).
5	Where a candidate has misread a number in the question and used that value consistently throughout, provided that number does not alter the difficulty or the method required, award all marks earned and deduct just 1 mark for the misread.
6	Recovery within working is allowed, e.g. a notation error in the working where the following line of working makes the candidate’s intent clear.

Mark Scheme Notes

The following notes are intended to aid interpretation of mark schemes in general, but individual mark schemes may include marks awarded for specific reasons outside the scope of these notes.

Types of mark

M Method mark, awarded for a valid method applied to the problem. Method marks are not 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. Correct application of a formula without the formula being quoted obviously earns the M mark and in some cases an M mark can be implied from a correct answer.

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).

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

DM or **DB** When a part of a question has two or more 'method' steps, the M marks are generally independent unless the scheme specifically says otherwise; and similarly, when there are several B marks allocated. The notation DM or DB is used to indicate that a particular M or B mark is dependent on an earlier M or B (asterisked) mark in the scheme. When two or more steps are run together by the candidate, the earlier marks are implied and full credit is given.

FT Implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A or B marks are given for correct work only.

- A or B marks are given for correct work only (not for results obtained from incorrect working) unless follow through is allowed (see abbreviation FT above).
- For a numerical answer, allow the A or B mark if the answer is correct to 3 significant figures or would be correct to 3 significant figures if rounded (1 decimal place for angles in degrees).
- The total number of marks available for each question is shown at the bottom of the Marks column.
- Wrong or missing units in an answer should not result in loss of marks unless the guidance indicates otherwise.
- Square brackets [ ] around text or numbers show extra information not needed for the mark to be awarded.

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Abbreviations

AEF/OE	Any Equivalent Form (of answer is equally acceptable) / Or Equivalent
AG	Answer Given on the question paper (so extra checking is needed to ensure that the detailed working leading to the result is valid)
CAO	Correct Answer Only (emphasising that no ‘follow through’ from a previous error is allowed)
CWO	Correct Working Only
ISW	Ignore Subsequent Working
SOI	Seen Or Implied
SC	Special Case (detailing the mark to be given for a specific wrong solution, or a case where some standard marking practice is to be varied in the light of a particular circumstance)
WWW	Without Wrong Working
AWRT	Answer Which Rounds To

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Question	Answer	Marks	Guidance
1(a)	$4500 = \frac{600 \times 15}{t}$	M1	Use of power = ΔW / Δt to get an equation in t. May see $600v = 4500 \Rightarrow v = 7.5$ followed by $7.5t = 15$.
	$t = 2$ s	A1	
		2	
1(b)	$\pm 600 = 200a [\Rightarrow a = \pm 3]$	*M1	Use of Newton's second law; 2 terms only.
	$0 = \frac{15}{their\,2} + (their - 3)t$	DM1	Use of constant acceleration to set up an equation that would lead to a positive t, e.g. $v = u + at$ with *their* $t = 2$ and *their* negative a (and possibly *their* 7.5 from **(a)**).
	$t = 2.5$s	A1	
		3	

Question	Answer	Marks	Guidance
2(a)	Use constant acceleration in an attempt to find v or v^2 $[v^2 = 15^2 - 2g \times 10]$	M1	e.g. $v^2 = u^2 + 2as$ with $a = \pm g$.
	Speed = 5 m s^{-1}	A1	
		2	

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Question	Answer	Marks	Guidance
2(b)	$(s_P =) \pm\left(15t - \frac{1}{2}gt^2\right)$, $(s_Q =) \pm \frac{1}{2}gt^2$	*B1	Use of $s = ut + \frac{1}{2}at^2$ for either. Allow if a not substituted, need both expressions with opposite sign of t^2 term and the same a.
	Use $s_P + s_Q = 18$ and solve for t	DM1	Allow $s_P + s_Q = \pm 18$. Must have s_P and s_Q of the correct form.
	So height = 10.8 m	A1	
	Alternative method for Question 2(b): Using relative velocity		
	$\pm 15t$	*B1	Use of relative velocity (no acceleration).
	Use $15t = 18$ and solve for t	DM1	Allow $15t = \pm 18$.
	So height = 10.8 m	A1	Not from $t = -1.2$ made positive without justification.
		3	

Question	Answer	Marks	Guidance
3(a)	Attempt to integrate $\left[(v =) \frac{4}{1.5}t^{\frac{3}{2}} = \frac{8}{3}t^{\frac{3}{2}} (+c)\right]$	M1	Increasing power by 1 and a change in coefficient in at least one term; may be unsimplified. $v = at$ M0.
	Substitute $t = 9$ to get speed = 72 m s^{-1}	A1	Or use limits $t = 0$ and $t = 9$.
		2	

Question	Answer	Marks	Guidance
3(b)	Attempt at integration of *their* v $\left[(s=)=\frac{8/3}{2.5}t^{2}=\frac{16}{15}t^{\frac{5}{2}}(+c')\right]$	*M1	Increasing power by 1 and a change in coefficient in at least one term; may be unsimplified. $s=vt$ M0 *Their* v, which has come from integration in part **(a)**.
	Equate *their* v and *their* s and attempt to solve for t $\left[\frac{16}{15}t^{\frac{5}{2}}=\frac{8}{3}t^{\frac{3}{2}}\Rightarrow\frac{16}{15}t-\frac{8}{3}=0\right]$	DM1	*Their* v must have come from integration. Allow if *their* c from **(a)** is not 0.
	time $=\frac{5}{2}$ s	A1	Must discard $t=0$ and $t=-\frac{5}{2}$.
		3	

Question	Answer	Marks	Guidance
4(a)	Tension = 0 N	B1	May be implied.
		1	
4(b)	Power $[=0.2\times 2]=0.4$ W	B1	Use of power = Fv. Allow without units.
		1	

Question	Answer	Marks	Guidance
4(c)	Driving force = 1.2/2 [= 0.6 N]	**B1**	
	Use of Newton's second law for locomotive or truck or system	**M1**	Correct number of relevant terms.
	For locomotive: $\text{DF} - 0.2 - T = 0.8a$ For truck: $T = 0.4a$ For system: $\text{DF} - 0.2 = 1.2a$	**A1**	For any two correct.
	For attempt to solve for T	**M1**	From equations with correct number of relevant terms. Using *their* dimensionally correct DF. May see $a = \frac{1}{3}$.
	$T = \frac{2}{15}\text{N}$	**A1**	Allow awrt 0.133 .
		5	

Question	Answer	Marks	Guidance
5(a)	Attempt to resolve vertically	**M1**	4 terms; allow with T_A and T_B; allow sign errors; allow g missing.
	$500 + T\cos 45 + T\cos 45 - 100g = 0$ OR $500 + T_A\cos 45 + T_B\cos 45 - 100g = 0$ AND $T_A(\sin 45) = T_B(\sin 45)$	**A1**	Must have $T_A = T_B = T$. Allow if $500 - 2T\cos 45 - 100g = 0$. Allow $500 - T_A\cos 45 - T_B\cos 45 - 100g = 0$ AND $T_A(\sin 45) = T_B(\sin 45)$.
	$T = 354\text{N}$	**A1**	Allow $250\sqrt{2}$, $\frac{500}{\sqrt{2}}$. Allow if $500 - 2T\cos 45 - 100g = 0$ to obtain $T = -354$ and then state magnitude is 354. If T_A and T_B are different values then A0.
	Alternative Method 1 for Question 5(a): Resolving perpendicular to a strut		
	Resolve perpendicular to T_A or T_B	**M1**	3 terms; allow sign errors; allow g missing.
	$T_A(\text{or } T_B) + 500\cos 45 = 100g\cos 45$	**A1**	Allow $T_A(\text{or } T_B) + 100g\cos 45 = 500\cos 45$.
	$T_A = T_B = 354$	**A1**	Allow $250\sqrt{2}$, $\frac{500}{\sqrt{2}}$.

Question	Answer	Marks	Guidance
5(a)	**Alternative Method 2 for Question 5(a): Using triangle of forces**		
	Attempt Pythagoras on a right-angled triangle of forces or use of trigonometry $\left[\begin{array}{c} T_A{}^2 + T_B{}^2 = (100g - 500)^2 \\ \text{OR } \sin 45 \, or \cos 45 = \dfrac{100g - 500}{T_A} \, or \, \dfrac{100g - 500}{T_B} \end{array}\right]$	M1	4 terms; allow with T_A and T_B; allow sign errors; allow g missing.
	$T^2 + T^2 = (100g - 500)^2$ OR $T_A{}^2 + T_B{}^2 = (100g - 500)^2$ AND $T_A(\sin 45) = T_B(\sin 45)$ OR $\sin 45 = \dfrac{T_A(\text{or } T_B)}{100g - 500}$ OR $\cos 45 = \dfrac{T_A(\text{or } T_B)}{100g - 500}$	A1	Allow $\sin 45 = \dfrac{T_A(\text{or } T_B)}{500 - 100g}$ OR $\cos 45 = \dfrac{T_A(\text{or } T_B)}{500 - 100g}$.
	$T_A = T_B = 354$	A1	Allow $250\sqrt{2}$, $\dfrac{500}{\sqrt{2}}$.
	Alternative Method 3 for Question 5(a): Using Lami's Theorem		
	Attempt at Lami	M1	Allow with T_A and T_B; allow sign errors; allow g missing.
	$\dfrac{100g - 500}{\sin 90} = \dfrac{T_A(\text{or } T_B)}{\sin 135}$	A1	Allow $\dfrac{500 - 100g}{\sin 90} = \dfrac{T_A(\text{or } T_B)}{\sin 135}$. Allow $\dfrac{100g - 500}{\sin 270} = \dfrac{T_A(\text{or } T_B)}{\sin 45}$.
	$T_A = T_B = 354$	A1	Allow $250\sqrt{2}$, $\dfrac{500}{\sqrt{2}}$.
		3	

Question	Answer	Marks	Guidance
5(b)	Attempt to resolve vertically **and** horizontally	**M1**	3 terms vertically and 2 terms horizontally; allow sign errors; allow g missing. Must have $T_A = 0$.
	$T_B \cos 45 + 500 - 100g = 0$ and $F - T_B \sin 45 = 0$	**A1**	Allow $-T_B \cos 45 + 500 - 100g = 0$ and $F + T_B \sin 45 = 0$ OR $T_B \cos 45 + 500 - 100g = 0$ and $F + T_B \sin 45 = 0$ OR $-T_B \cos 45 + 500 - 100g = 0$ and $F - T_B \sin 45 = 0$. For both equations correct.
	$F = 500$	**A1**	awrt 500 to 3sf.
	Alternative Method 1 for Question 5(b): Resolving perpendicular to T_B		
	Attempt to resolve perpendicular to T_B	**M1**	3 terms; allow sign errors; allow g missing. Must have $T_A = 0$.
	$F \cos 45 + 500 \cos 45 = 100g \cos 45$	**A1**	Allow $-F \cos 45 + 500 \cos 45 = 100g \cos 45$.
	$F = 500$	**A1**	awrt 500 to 3sf.

Question	Answer	Marks	Guidance
5(b)	**Alternative Method 2 for Question 5(b): Using Lami's Theorem**		
	Attempt at Lami	**M1**	Allow sign errors.
	$\frac{100g-500}{\sin 135}=\frac{F}{\sin 135}\left(=\frac{T_B}{\sin 90}\right)$	**A1**	Allow $\frac{500-100g}{\sin 135}=\frac{F}{\sin 135}$ or $\frac{100g-500}{\sin 45}=\frac{F}{\sin 45}$ or $\frac{100g-500}{\sin 45}=\frac{F}{\sin 225}$ or $\frac{100g-500}{\sin 225}=\frac{F}{\sin 45}$.
	$F=500$	**A1**	awrt 500 to 3sf.
	Alternative Method 3 for Question 5(b): Using triangle of forces		
	Attempt use of trigonometry on right angled triangle	**M1**	Allow sign errors; allow g missing.
	$\tan 45=\frac{F}{100g-500}$	**A1**	Allow $\tan 45=\frac{F}{500-100g}$
	$F=500$	**A1**	awrt 500 to 3sf.
		3	

Question	Answer	Marks	Guidance
6(a)(i)	Attempt to resolve parallel to the plane	**M1**	4 terms; allow sin/cos mix; allow sign errors; allow g missing.
	$T\cos 20-5-2g\sin 30=2\times 1.2$	**A1**	Correct equation.
	$T=18.5$	**A1**	awrt 18.5 .
		3	

Question	Answer	Marks	Guidance
6(a)(ii)	Attempt resolve perpendicular to the plane $R = 2g\cos 30 - T\sin 20$	M1	3 terms; allow sin/cos mix: allow sign errors; allow with T or their T; allow g missing.
	Use of $5 = \mu R$ to get an equation in μ only $\left[5 = \mu \times (2g\cos 30 - T\sin 20)\right]$	M1	Where R is a two term expression with a component of $2g$ and a component of *their* T; allow g missing.
	$\mu = 0.455$	A1	awrt 0.455; allow 0.46 or 0.45; do not allow $\frac{5}{11}$.
		3	
6(b)	Max $F = 0.8 \times (2g\cos 30 - 15\sin 20)$ $\left[= 0.8 \times 12.1902\ldots\ldots = 9.7521\ldots\ldots\right]$	*B1	
	Net force up the plane $= 15\cos 20 - 2g\sin 30 \left[= 4.0953\ldots\ldots\right]$	*B1	OR $15\cos 20 - 2g\sin 30 - 0.8 \times (2g\cos 30 - 15\sin 20)$ $[= 2a] \Rightarrow -5.6567\ldots\ldots[= 2a] \Rightarrow a = -2.8283\ldots\ldots$ If max F incorrect and use $F = ma$ then allow B1 for $15\cos 20 - 2g\sin 30 -$ *their* max F.
	[State $4.0953\ldots\ldots < 9.7521\ldots\ldots$,] hence the block does not move [up the plane]	DB1	Must have correct values (to at least 1 sf) to compare for this mark. No incorrect statement seen.
	Alternative Method 1 for Question 6(b)		
	Max force down plane $= 0.8 \times (2g\cos 30 - 15\sin 20) + 2g\sin 30$ $\left[= 0.8 \times 12.1902 + 10\ldots\ldots = 19.7521\ldots\ldots\right]$	*B1	
	Force up plane $= 15\cos 20 \left[= 14.0953\ldots\ldots\right]$	*B1	i.e. using it to compare with their max force down the plane.
	[State 1 $4.0953\ldots\ldots < 19.7521\ldots\ldots$,] hence the block does not move [up the plane]	DB1	Must have correct values (to at least 1 sf) to compare for this mark. No incorrect statement seen.

Question	Answer	Marks	Guidance
6(b)	**Alternative Method 2 for Question 6(b)**		
	$F = 15\cos 20 - 2g\sin 30 [= 4.9053......]$ Or $R = 2g\cos 30 - 15\sin 20 [= 12.1902......]$	***B1**	
	Get $\mu = \dfrac{15\cos 20 - 2g\sin 30}{2g\cos 30 - 15\sin 20} [= 0.3359......]$	***B1**	
	[State $0.3359...... < 0.8$,] hence the block does not move [up the plane]	**DB1**	Must have correct value of μ (to at least 1 sf) to compare for this mark. No incorrect statement seen.
		3	

Question	Answer	Marks	Guidance
7(a)	Attempt to use conservation of energy $\left[\frac{1}{2}\times 0.5v^2 = 0.5g\times 1.8\right]$ or $\left[\frac{1}{2}\times mv^2 = mg\times 1.8\right]$	**M1**	2 terms, dimensionally correct. Do not allow from use of constant acceleration.
	$v=6$	**A1**	Do not allow from use of constant acceleration.
	Attempt at conservation of momentum $\left[0.5\times 6(+0) = 0.5\times 4 + 0.1w\right]$	**M1**	3 terms; allow sign errors; allow *their* $v=6$ or just v; allow if using mgv (consistently in all terms).
	Speed of Q $(=w)$=10 m s^{-1}	**A1**	AG Do not allow from use of constant acceleration. Do not allow if using mgv. Use of constant acceleration gets M0 A0 M1 A0 maximum.
		4	**SC Assuming elastic collision** **M1A1** $0.5g\times 1.8 = \frac{1}{2}\times 0.1w^2 + \frac{1}{2}\times 0.5\times 4^2$ **M1** For attempt at conservation of energy, 3 terms; allow sign errors. **B1** Speed of Q $(=w)$=10 m s^{-1}

Question	Answer	Marks	Guidance
7(b)	Attempt at conservation of momentum $\left[0.1\times10=(0.1+0.4)\times z\ (\Rightarrow z=2)\right]$	*M1	3 terms, allow sign errors, allow if using mgv.
	Attempt to use conservation of energy $\left[\frac{1}{2}\times(0.1+0.4)\times(their\ 2)^2=(0.1+0.4)gh\ \ (\Rightarrow h=0.2)\right]$	*DM1	Dependent on previous M mark. 4 terms, dimensionally correct. Do not allow from use of constant acceleration. $their\ 2\neq10$.
	Use trigonometry to get an equation in θ and solve for θ $\left[\theta=\sin^{-1}\left(\frac{their\ 0.2}{0.4}\right)\right]$	DM1	Dependent on previous 2 M marks. Using *their* h and 0.4 . Allow sin/cos mix.
	$\theta=30$	A1	Do not allow if using mgv.
	Alternative method for Question 7(b): Using constant acceleration		
	Attempt at conservation of momentum $\left[0.1\times10=0.5\times z\ (\Rightarrow z=2)\right]$	*M1	2 terms, allow sign errors, allow if using mgv.
	Attempt at use of constant acceleration $\left[0^2=(their\ 2)^2\pm2\times a\times0.4\ \ (\Rightarrow a=\mp5)\right]$	*DM1	Dependent on previous M mark. Uses constant acceleration with $u=their\ 2$ and $s=0.4$ to get an equation in a ; $their\ 2\neq10$.
	Use N2L to get an equation in θ leading to a positive value of θ and solve for θ $\left[(0.5)\lvert their\ a\rvert=(0.5)g\sin\theta\right]$	DM1	Dependent on previous 2 M marks. Using *their* a ; May have m for 0.5 . Allow sin/cos mix.
	$\theta=30$	A1	Do not allow if using mgv.
		4	

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Question	Answer	Marks	Guidance
7(c)	Q takes 0.7 s to travel from B to C	**B1**	
	$0.4 = \frac{(their\,2)+0}{2}t \Rightarrow t = 0.4$	**B1FT**	SOI FT *their* 2 from (b), $t = \frac{0.8}{their\,2}$. For use of $s = \left(\frac{u+v}{2}\right)t$ to get a time up the slope. Allow for total time on slope from $0 = (their\,2)t - \frac{1}{2}(their\,a)t^2 \Rightarrow t = 0.8$.
	Distance between P moved is $(0.7+0.8)\times 4(=6)$	**B1**	Allow 1 m from point *C*.
	Set up equation in t using $4t$, $(their\,2)t$ and *their* 6 and solve for t $[4t + (their\,2)t = (their\,1) \text{OR} (their\,6) + 4t + (their\,2)t = 7]$	**M1**	Must have considered all parts of motion to find times from relevant equations.
	Distance from $B = 6\frac{2}{3}$ m	**A1**	

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Question	Answer	Marks	Guidance
7(c)	**Alternative method for last 3 marks of Question 7(c)**		
	[Time for P =]$\frac{b}{4}$ **and** [Time for QR =]$\frac{7-b}{2}$ OR [Time for P =]$\frac{7-c}{4}$ **and** [Time for QR =]$\frac{c}{2}$	**B1**	Where b is distance from B OR Where c is distance from C.
	Attempt to form an equation from use of total time and solve for b (or c) $\left[\begin{array}{l}\frac{7-b}{2}+0.7+0.4+0.4=\frac{b}{4}\left[\Rightarrow b=6\frac{2}{3}\right]\\ OR\ \frac{c}{2}+0.7+0.4+0.4=\frac{7-c}{4}\left[\Rightarrow c=\frac{1}{3}\right]\end{array}\right]$	**M1**	Where b is distance from B OR Where c is distance from C. Must have considered all parts of motion to find times from relevant equations.
	Distance from B = $6\frac{2}{3}$ m	**A1**	
		5	