Cambridge International AS & A Level

MATHEMATICS **9709/41**

Paper 4 Mechanics **October/November 2021**

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.

Cambridge International is publishing the mark schemes for the October/November 2021 series for most Cambridge IGCSE™, Cambridge International A and AS Level components and some Cambridge O Level components.

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.

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.

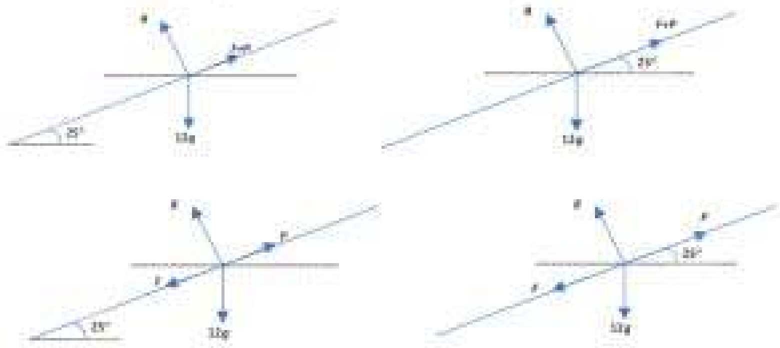
Abbreviations

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

Question	Answer	Marks	Guidance
1(a)	$6V + 30V + 3V = 585$ $0.5(30 + 48)V = 585$	**M1**	Use of constant acceleration equations or a *v*-*t* graph. Complete method to set up an equation in V using constant acceleration equations or correct area formula in *v*-*t* graph.
	Speed of the bus = 15 ms^{-1}	**A1**	Must be positive.
		2	
1(b)	Magnitude of deceleration = 2.5	**B1 FT**	OE. Do not allow $a = -2.5$.
		1	

Question	Answer	Marks	Guidance
2(a)	Attempt at use of conservation of momentum	**M1**	4 terms implied, i.e. *m* and *km* included before and after collision. Velocity after collision is the same for *m* and *km*.
	$km \times 6 - m \times 2 = (km + m) \times 4$	**A1**	
	$k = 3$	**A1**	
		3	
2(b)	KE initial = $\frac{1}{2} \times km \times 6^2 + \frac{1}{2} \times m \times (-2)^2$ KE after = $\frac{1}{2} \times (km + m) \times 4^2$	**M1**	Attempt at any of the three possible KE terms, unsimplified. *k* need not be substituted here.
	Loss of KE = $24m$ J	**A1 FT**	KE loss = $56m - 32m$ FT on *their* k, KE loss $= (10k - 6)m$, $k > 0.6$.
		2	

Question	Answer	Marks	Guidance
3	Attempt at resolving in any direction	M1	Correct number of terms. No substitution for α required.
	$P\cos\theta = (36-24)\cos 36.9$ or $P\cos\theta = (36-24)\times 0.8$	A1	
	$P\sin\theta + 20 = (24+36)\sin 36.9 = 14.4 + 21.6$ or $P\sin\theta + 20 = 60\times 0.6 = 36$	A1	
	$P\cos\theta = 9.6, P\sin\theta = 16 \quad P = \sqrt{16^2 + 9.6^2}$	M1	Correct method for solving equations for *P*. OE
	$\theta = \tan^{-1}\left(\frac{16}{9.6}\right)$	M1	Correct method for solving equations for θ . OE e.g. $\theta = \tan^{-1}\left(\frac{5}{3}\right)$
	$P = 18.7$ $\theta = 59[.0]$	A1	Allow $P = \frac{16\sqrt{34}}{5}$. Allow $P = 18.6$.
		6	

Question	Answer	Marks	Guidance
4(a)	Correct 4 force diagram 	**B1**	Angles shown. F either up/down slope. 
		1	
4(b)	Attempt to resolve forces parallel to the plane	**M1**	Three terms, allow sign errors.
	$P + F = 12g \sin 25 \; [= 50.7]$	**A1**	Must have correct direction of F here.
	$R = 12g \cos 25 \; [= 108.8]$	**B1**	
	$F = 120\cos 25 \times 0.35 \quad [= 38.1]$ $P + 38.1 = 120 \sin 25$	**M1**	Attempt to solve for P using equations with the correct number of terms. R must be a single-term component of $12g$.
	$P = 12.6$	**A1**	$P = 12.64926\ldots$ Allow $P = 12.7$
		5	

Question	Answer	Marks	Guidance
5(a)	$s = 30 \times 20$	**B1**	
	$\text{PE change} = 1600 \times g \times s \times 0.12$ $[\text{PE change} = 1600 \times g \times 20 \times 30 \times 0.12]$	**M1**	Attempt change in PE. May use angle = 6.9º. Allow sin/cos error only.
	Change in PE $= 1152000$ J	**A1**	
		3	
5(b)	$1\,960\,000 = WD_{res} + \textit{their}\,\text{PE}$ $[1\,960\,000 = WD_{res} + 1152\,000]$ $[WD_{res} = 808\,000\text{ J}]$	**M1**	Using work-energy, allow sign error.
	$R = WD_{res} \div 600$	**B1**	Using $WD_{res} = R \times 600$.
	Force resisting motion = $R = 1350\text{ N}$ to 3sf	**A1**	Allow $R = \frac{4040}{3}$ N. Allow R negative.
	Alternative method for question 5(b)		
	$DF - R - 1600g \times 0.12 = 0$	**M1**	R is the resisting force.
	$DF = \frac{196000}{20 \times 30}\ \left[= \frac{9800}{3}\right]$	**B1**	
	Force resisting motion = $R = \frac{4040}{3} = 1350\text{ N}$ to 3sf	**A1**	Allow R negative.
		3	

Question	Answer	Marks	Guidance
5(c)	$P = \left(\frac{4040}{3} + 1600 \times g \times 0.12\right) \times 20$ $\left[= \frac{196\,000}{3}\right]$	M1	For using $P = DF \times v$. Allow use of *their R*.
	$P = 65.3$ kW	A1	
	Alternative method for question 5(c)		
	$P = \frac{1960\,000}{30}$	M1	For using $P = \text{Work done} \div \text{Time}$.
	$P = 65.3$ kW	A1	
	Alternative method for question 5(c)		
	$P = \frac{9800}{3} \times 20$	M1	For using $P = DF \times v$. Allow use of *their DF*.
	$P = 65.3$ kW	A1	
		2	

Question	Answer	Marks	Guidance
5(d)	$0.85\times\frac{196\,000}{3}=DF\times 20$	**B1 FT**	$P=DF\times v$ $\left[DF=\frac{8330}{3}\right]$ FT on *their P*.
	$DF-R-1600g\times 0.12=1600a$ $\left[\frac{8330}{3}-\frac{4040}{3}-1920=1600a\right]$	**M1**	Newton's 2nd law, four terms, allow sin/cos error, *their R* and *their DF*.
	$a=[-]0.306\,\text{ms}^{-2}$	**A1**	$a=[-]\frac{490}{1600}=[-]\frac{49}{160}$
	Alternative method for question 5(d)		
	$9800=DF\times 20$	**B1 FT**	Using the reduction in power as the cause of the deceleration. $9800=0.15\times$ *their* $P=DF\times v$
	$DF=1600d$ $\left[\frac{9800}{20}=1600d\right]$	**M1**	
	$a=[-]0.306\,\text{ms}^{-2}$	**A1**	$a=[-]\frac{490}{1600}=[-]\frac{49}{160}$
		3	

Question	Answer	Marks	Guidance
6(a)	$a = 2pt - q$	*M1	Attempt to differentiate v.
	$36p - 6q = 36$ $4p - q = 0$	DM1	For attempting to set up 2 equations using $a = 0$ at $t = 2$ and matching the velocities at $t = 6$ and solve for p or q.
	$p = 3, q = 12$	A1	Both correct.
		3	
6(b)	Correct quadratic from $t = 0$ to $t = 6$ **or** Correct straight line from 6 to 14	B1	No labelling necessary for this mark.
	Both quadratic and straight line correct	B1	Must join and no labelling needed.
	All correct and key points shown	B1	All correct, labelled at (4, 0), (6, 36) and (14, 0).
		3	
6(c)	Attempt to integrate v	*M1	Allow in terms of p and q.
	$s = t^3 - 6t^2$	A1 FT	FT on *their* p and q values.
	$s(\text{quadratic}) = \left[\left\|t^3 - 6t^2\right\|\right]_0^4 + \left[t^3 - 6t^2\right]_4^6$	DM1	$[= 32 + 32]$ Using limits correctly for $t = 0$ to $t = 6$. Allow in terms of p and q.
	$s(\text{triangle}) = \left[63t - 2.25t^2\right]_6^{14} = 144$ or area of triangle $= 144$	B1	
	Total distance travelled in 14 s = 208 m	A1	
		5	

Question	Answer	Marks	Guidance
7	Particle A: $2g - T = 2a$ Particle B: $T - 3g\sin 18 = T - 9.27 = 3a$ System: $2g - 3g\sin 18 = 2g - 9.27 = (2+3)a$	**M1**	Apply Newton's 2nd law to either particle A, or to particle B or the system. Correct number of terms.
		A1	A and B correct or system correct.
	$a = 2.145898034$ $[5a = 10.72949017]$	**M1**	Attempt to find a using equations with correct number of terms.
	$v^2 = 2 \times a \times 0.45$	**M1**	Use of constant acceleration equations with *their* $a \neq \pm g$ to find v^2 when A reaches the ground.
	$v^2 = 2 \times 2.145898034 \times 0.45 = 1.931308\cdots$ $[v = 1.389715162]$	**A1**	Allow unsimplified.
	$T = 0$, $\pm 3g\sin 18 = 3a$ $[a = \pm 3.0901699]$	**M1**	Attempt to find a for the motion of B when string becomes slack. Allow sin/cos error, no extra terms.
	$[0 = 1.93 - 2 \times 3.09 \times s]$ $[s = 0.312]$	**M1**	Use constant acceleration equations, using a new $a \neq \pm g$, to find the further distance, s, travelled by B before coming to rest.
	Total distance moved by B = 0.45 + 0.312 = 0.762 m	**A1**	
	Alternative method for question 7		
	Attempt PE loss as A reaches the ground	**M1**	Allow sin/cos error.
	PE loss = $2g \times 0.45 - 3g \times 0.45\sin 18$ $[= 4.82827]$	**A1**	Correct unsimplified.
	$2g \times 0.45 - 3g \times 0.45\sin 18 = \frac{1}{2} \times (2+3)v^2$	***M1**	Apply work-energy equation as PE loss = KE gain, allow sign error, sin/cos error, 4 terms implied.

Question	Answer	Marks	Guidance
7	Solve for v^2	**DM1**	
	$v^2 = 1.931308\ldots \quad [v = 1.389715162]$	**A1**	
	PE gain = $3g \times s\sin 18$	**M1**	Attempt PE gain for *B* after string breaks, allow sign error, sin/cos mix, *s* = extra distance travelled by *B* along the plane.
	$3g \times s\sin 18 = \frac{1}{2} \times 3 \times 1.931308 \quad [s = 0.312]$	**M1**	Work energy equation for *B* as PE gain = KE loss, 2 terms.
	Total distance moved by *B* = 0.45 + 0.312 = 0.762 m	**A1**	
		8	