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MATHEMATICS **9709/45**

Paper 4 Mechanics **October/November 2025**

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 alon g side the specific content of the mark scheme or generic level descriptions 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, non-integer 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 or sign 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 A or B 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.

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Annotations guidance for centres

Examiners use a system of annotations as a shorthand for communicating their marking decisions to one another. Examiners are trained during the standardisation process on how and when to use annotations. The purpose of annotations is to inform the standardisation and monitoring processes and guide the supervising examiners when they are checking the work of examiners within their team. The meaning of annotations and how they are used is specific to each component and is understood by all examiners who mark the component.

We publish annotations in our mark schemes to help centres understand the annotations they may see on copies of scripts. Note that there may not be a direct correlation between the number of annotations on a script and the mark awarded. Similarly, the use of an annotation may not be an indication of the quality of the response.

The annotations listed below were available to examiners marking this component in this series.

Annotations

Annotation	Meaning
	More information required
	Accuracy mark awarded zero
	Accuracy mark awarded one
	Independent accuracy mark awarded zero
	Independent accuracy mark awarded one
	Independent accuracy mark awarded two
	Benefit of the doubt
	Blank Page
	Incorrect
Dep	Used to indicate DM0 or DM1

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Annotation	Meaning
DM1	Dependent on the previous M1 mark(s)
FT	Follow through
~~	Indicate working that is right or wrong
Highlighter	Highlight a key point in the working
ISW	Ignore subsequent work
J	Judgement
JU	Judgement
M0	Method mark awarded zero
M1	Method mark awarded one
M2	Method mark awarded two
MR	Misread
O	Omission or Other solution
Off-page comment	Allows comments to be entered at the bottom of the RM marking window and then displayed when the associated question item is navigated to.
On-page comment	Allows comments to be entered in speech bubbles on the candidate response.
PE	Judgment made by the PE
Pre	Premature approximation
SC	Special case
SEEN	Indicates that work/page has been seen

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Annotation	Meaning
SF	Error in number of significant figures
✓	Correct
TE	Transcription error
XP	Correct answer from incorrect working

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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	Resolving in any direction to get an equation	*M1	Correct number of relevant terms; allow sign errors; allow consistent or inconsistent sin/cos mix.
	$P+21\cos 47-Q\cos 65-32\cos 35=0$ $P+14.321\ldots-Q\cos 65-26.212\ldots=0$	A1	This could be with their Q.
	$21\sin 47+32\sin 35-Q\sin 65=0$ $15.358\ldots+18.354\ldots-Q\sin 65=0$ $33.712\ldots-Q\sin 65=0$	A1	
	Attempt to solve for $P=-21\cos 47+(37.198...)\cos 65+32\cos 35$	DM1	From equation(s) with correct number of relevant terms. Using their Q. Must be a numerical expression for P. All forces resolved as appropriate but allow consistent or inconsistent sin/cos mix. If no intermediate working to solve their two original equations, can still earn **DM1** if answers correct for their equations but **DM0** if answers wrong for their equations.
	P = 27.6 AND Q = 37.2	A1	27.61147… and 37.19804… **DM1** may be earned here.
		5	

Question	Answer	Marks	Guidance
2(a)	Correct velocity-time graph	B1	Trapezium starting and finishing on the horizontal axis. V and 246 labelled but ignore gradients. Ignore any other labelling. Condone label o6 rather than V.
		1	

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Question	Answer	Marks	Guidance
2(b)	Method using total time first		
	Time accelerating is $\frac{V}{0.5}$ $[= 2V]$ **or** time decelerating is $\frac{V}{0.2}[= 5V]$	***B1**	For one correct time in terms of V.
	$[T =]246 - \frac{V}{0.5} - \frac{V}{0.2}[= 246 - 7V]$	**B1**	OE Allow correct un-simplified expression.
	$\frac{1}{2}\left(\frac{V}{0.5} \times V\right) + V(246 - 7V) + \frac{1}{2}\left(\frac{V}{0.2} \times V\right) = 1350$ or $\frac{1}{2}(246 + 246 - 7V)(V) = 1350$ or $0 + \frac{1}{2} \times 0.5 \times (2V)^2 + V(246 - 7V) + V \times 5V - \frac{1}{2} \times 0.2 \times (5V)^2 = 1350$ or $\frac{V^2}{2(0.5)} + V(246 - 7V) + \frac{V^2}{2(0.2)} = 1350$ or $0 = V - 0.2\left(246 - 246 + 7V - \frac{V}{0.5}\right)$ or e.g. $246 - 7V = \frac{2700 - 246V}{V}$	**DM1**	Set up an equation in V only with the correct number of relevant terms to find total distance. Dependent on $\frac{V}{0.5}$ and $\frac{V}{0.2}$ seen, possibly embedded. e.g. triangle/rectangle/triangle to get first equation or trapezium to get second equation or use $s = ut + \frac{1}{2}at^2$ to get the third equation or use $v^2 = u^2 + 2as$ to get the fourth equation or use $v = u + at$ to get the fifth equation or two expressions for T can be equated to form an equation for V to get the sixth equation OE.

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Question	Answer	Marks	Guidance
2(b)	$7V^2 - 492V + 2700 = 0$	**A1**	AG. No need to see intermediate steps after a correct equation seen but must check that any intermediate steps seen are correct. If any errors seen anywhere then **A0.**
	Alternative using total displacement first (trapezium OE)		
	Distance accelerating is $\frac{V^2}{2\times 0.5}\left[=V^2\right]$ **or** distance decelerating is $\frac{V^2}{2\times 0.2}\ \left[=2.5V^2\right]$ $\frac{1}{2}(246+T)V = 1350$ or $\frac{246-T}{2}V + VT = 1350$ or alternatively $\frac{1}{2}\left(\frac{V}{0.5}\times V\right) + VT + \frac{1}{2}\left(\frac{V}{0.2}\times V\right) = 1350$	***B1**	For distance accelerating/decelerating. or for trapezium area or could use 2 triangles and rectangle.
	$\left[T=\right]\frac{2700}{V} - 246\ \left[=\frac{2700-246V}{V}\right]$ or alternatively (from above alternative) $\left[T=\right]\frac{1350-\frac{7}{2}V^2}{V}$	**B1**	OE. Allow correct un-simplified expression.
	$t_1 + T + t_2 = 246 \Rightarrow \frac{V}{0.5} + \frac{2700}{V} - 246 + \frac{V}{0.2} = 246$ or $2V + \frac{2700}{V} - 246 + 5V = 246$ oe or alternatively (from above alternative) $7v + \frac{1350-\frac{7}{2}V^2}{V} = 246$	**DM1**	Set up an equation in V only with the correct number of relevant terms but all terms present. Some candidates are getting to the correct equation for T and then substituting this back into the trapezium equation which simply gets 1350 = 1350, so does not show the required equation and gets **B1B1M0A0.**

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Question	Answer	Marks	Guidance
2(b)	$7V^2 - 492V + 2700 = 0$	**A1**	AG. No need to see intermediate steps after a correct equation seen but must check that any intermediate steps seen are correct. If any errors seen anywhere then **A0.**
	Alternative where *T* is not found		
	Time accelerating is $\frac{V}{0.5}$ $[= 2V]$ **or** time decelerating is $\frac{V}{0.2}[= 5V]$ or Distance accelerating is $\frac{V^2}{2\times 0.5}\left[= V^2\right]$ **or** distance decelerating is $\frac{V^2}{2\times 0.2}$ $\left[= 2.5V^2\right]$	***B1**	For one correct time or distance in terms of V.
	Total distance = $246V - \frac{V^2}{2\times 0.5} - \frac{V^2}{2\times 0.2}$	**B1**	OE.
	$246V - \frac{V^2}{2\times 0.5} - \frac{V^2}{2\times 0.2} = 1350$	**DM1**	Set up an equation in V only with the correct number of relevant terms but all terms present.
	$7V^2 - 492V + 2700 = 0$	**A1**	AG. No need to see intermediate steps after a correct equation seen, but must check that any intermediate steps seen are correct. If any errors seen anywhere then **A0.**
		4	

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Question	Answer	Marks	Guidance
2(c)	$V = 6$ ONLY	*B1	**B0B0** if both solutions stated and do not discard $\frac{450}{7}$
	$V \neq \frac{450}{7}$ as e.g. this would lead to the athlete running at a constant speed for a negative time $\left[= \frac{2700 - 246\left(\frac{450}{7}\right)}{\left(\frac{450}{7}\right)} or\ 246 - 7\left(\frac{450}{7}\right) = -204 \right]$ OR the athlete would take longer than 246 seconds to decelerate $\left[t_{decelerate} = \frac{450}{7} \div 0.2 = \frac{2250}{7} = 321.4 > 246 \right]$ OR $\left[t_{acc+dec} = \frac{450}{7} \times 7 = 450 > 246 \right]$	DB1	Any acceptable reason for rejecting greater root e.g. not feasible for an athlete to be running at 64.3 metres per second. Other root must be seen, not e.g. just state $T > 0$ without mention of other root but if they state $\frac{450}{7}$, then say $T > 0$, so not suitable then award **B1**. Calculations not necessary but if calculations are shown they must be correct.
		2	

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Question	Answer	Marks	Guidance
3(a)	Either driving force: $\frac{P}{12}$ or $\frac{P}{20}$	*B1	OE. $P=12F$ or $P=20F$ but **B0** if erroneous value of F.
	$\frac{P}{20}-R=0$ or $20F_1=12F_2$	*B1	OE. $P=20R$ or $F_1=\frac{3}{5}F_2$.
	$\frac{P}{12}-R-800g\times0.15=0$ or $F_2-R-800g\times0.15=0$ where F_2 is the larger of the two forces or $\frac{P}{12}-R-800g\times\sin8.6=0$ or $P=12\left(R+800g\times0.15\right)$ or $P=12\left(R+800g\times\sin8.6\right)$	*M1	Attempt at N2L on inclined section of the road; correct number of relevant terms, allow sign errors and sin/cos mix with components only where needed. Must have more than simply $\sin\alpha$ or $\cos\alpha$. g must be present. Resistance term here must be same as that in second **B1**.
	$\frac{P}{12}-\frac{P}{20}-800g\times0.15=0\Rightarrow P=$ or $F_2-F_1-800g\times0.15=0\Rightarrow P=$ or $\frac{P}{12}-\frac{P}{20}-800g\times\sin8.6=0\Rightarrow P=$ or $20R-12\left(R+800g\times0.15\right)=0\Rightarrow R=$ or $20R-12\left(R+800g\times\sin8.6\right)=0\Rightarrow R=$	DM1	Eliminate and solve for either P or R. Correct number of relevant terms, allow sign errors and sin/cos mix. Must have more than simply $\sin\alpha$ or $\cos\alpha$. If no solving seen, answer must be correct for their equations to be awarded **DM1.** Dependent on **B1B1M1**
	$P=36000$ and $R=1800$	A1	Using angle of 8.63 gives $P=36012\left(36000\right)$ and $R=1800.6$ (1800) which scores **A1**. Using an angle of 8.6 does not give answers correct to 3sf so gets **A0**.
		5	

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Question	Answer	Marks	Guidance
3(b)	Attempt at N2L to form an equation on inclined section of the road	**M1**	Correct number of relevant terms, allow sign errors and sin/cos mix with components only where needed. Must have more than simply $\sin\alpha$ or $\cos\alpha$. Allow D for driving force. g must be present.
	$\frac{32000}{10} - 800g \times 0.15 - 1800 = 800a$ or $\frac{32000}{10} - 800g \times \sin 8.6 - 1800 = 800a$	**A1FT**	Correct equation following through their R.
	0.25 [m s^{-2}]	**A1**	Condone answer of 0.249 from using an angle of 8.63. Using an angle of 8.6 does not give answer correct to 3sf so gets **A0**.
		3	

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Question	Answer	Marks	Guidance
4(a)	$a = kt - 3 \Rightarrow v = \frac{1}{2}kt^2 - 3t \Rightarrow [+c]$	*M1	Increase power by 1 and a change in coefficient in at least one term (which must be the same term). Use of $v = at$ scores **M0**.
	$t = 0, v = 1 \Rightarrow v = \frac{1}{2}kt^2 - 3t + 1$	A1	Correct expression for v. $v = \frac{1}{2}kt^2 - 3t[+c]$ followed by $c = 1$ scores **A1**.
	Discriminant $9 - 4 \times \frac{1}{2}k < 0$ or Discriminant $36 - 4(k)(2) < 0$	DM1	Set the discriminant of their 3-term quadratic in t to less than zero (or other complete method). NB: attempt at quadratic formula to find roots can score **M1** only if they find $b^2 - 4ac$ and consider its sign OE.
	$[9 - 2k < 0$ or $36 - 8k < 0 \Rightarrow]$ $k > 4.5$	A1	AG. If any errors seen anywhere then **A0**.
	Alternative for final 2 marks using completing the square		
	$\left[k\left(t - \frac{3}{k}\right)^2 - \frac{9}{k} + 2 > 0 \Rightarrow\right]$ $-\frac{9}{k} + 2 > 0$	DM1	Attempt to complete the square and then use fact that the last two terms > 0. Must get to $-\frac{their\ 3^2}{k} + 2 \times their\ 1 > 0$. Must be from 3 term quadratic.
	$k > 4.5$	A1	AG If any errors seen anywhere then **A0**.

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Question	Answer	Marks	Guidance
4(a)	**Alternative for final 2 marks using fact that $a=0$ gives minimum velocity**		
	[When $a=0$] $\left[\text{or } t=\frac{-b}{2a}\right], t=\frac{3}{k} \Rightarrow v=\frac{1}{2}k\left(\frac{3}{k}\right)^2-3\times\frac{3}{k}+1=-\frac{9}{2k}+1$ so minimum value of v is $v=-\frac{9}{2k}+1 \Rightarrow -\frac{9}{2k}+1>0$	**DM1**	Complete method to find minimum velocity and set greater than zero. If state maximum rather than minimum, then **M1A0**. Allow their 3 and their 1.
	$k>4.5$	**A1**	AG. If any errors seen anywhere then **A0**.
		4	

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Question	Answer	Marks	Guidance
4(b)	$\frac{1}{2}\times 2.5t^2-3t+1=0$ or $5t^2-12t+4=0$ oe $\Rightarrow t=...$	*M1	Substitute $k=2.5$ and attempt to solve 3-term quadratic in t to get at least one t-value. If working shown must be using correct formula or if factorising two terms must be correct for their three-term quadratic when expanding brackets. If no working shown they must have at least one answer for their 3-term quadratic and if two answers, both must be correct. Dep on first **M1** in **4(a)**.
	$t=2$ (and 0.4)	A1	If 2 used below as the middle limit without any working allow **M1A1**.
	Attempt at integration of a 3-term quadratic for v	*M1	Increase power of their v by 1 and a change in coefficient in at least one term (which must be the same term) Use of $s=vt$ scores **M0**. Allow with value of k not substituted Dep on first **M1** in **4(a)**.
	$s=\frac{5}{12}t^3-\frac{3}{2}t^2+t[+c]$	A1	Allow un-simplified. Must have k substituted.
	$\left[\frac{5}{12}t^3-\frac{3}{2}t^2+t\right]_1^2=\left(\frac{5}{12}(2)^3-\frac{3}{2}(2)^2+2\right)-\left(\frac{5}{12}(1)^3-\frac{3}{2}(1)^2+1\right)$ $\left[-\frac{2}{3}-\left(-\frac{1}{12}\right)=-\frac{7}{12}\right]$ $\left[\frac{5}{12}t^3-\frac{3}{2}t^2+t\right]_2^3=\left(\frac{5}{12}(3)^3-\frac{3}{2}(3)^2+3\right)-\left(\frac{5}{12}(2)^3-\frac{3}{2}(2)^2+2\right)$ $\left[\frac{3}{4}-\left(-\frac{2}{3}\right)=\frac{17}{12}\right]$	DM1	Use both limits correctly between 1 and their 2 **and** between their 2 and 3 provided 1 < their 2 < 3. No other phases should be included e.g. 0 to 0.4 Dependent on **M1M1**.

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Question	Answer	Marks	Guidance
4(b)	Total distance is 2 m	**A1**	**SCB1** for correct answer with no attempt at integration seen following on from first **M1A1**. NB answer of $\frac{5}{6}$ from not finding t when $v = 0$ usually gets max **M0A0M1A1M0A0**. However if they find t when $v = 0$ and make an error in the sign e.g. $\frac{7}{12}$ rather than $-\frac{7}{12}$ can score max **M1A1M1A1M1A0**. Do not ISW. Accept AWRT 2.00 to 3sf.
		6	

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Question	Answer	Marks	Guidance
5(a)	Attempt N2L for Q **and** R to form two equations	***M1**	Correct number of relevant terms in each, allow sign errors and T for both tensions. Masses must be correct. Condone different accelerations. Ignore anything relating to P. For first 4 marks condone substituted value of g.
	$5g - T_{PQ} = 5a$ or $5g - 2T_{[PR]} = 5a$ $T_{PR} - 2g = 2a$ or $T_{[PR]} - 2g = 2a$ or $\frac{5g - T_{PQ}}{5} = \frac{T_{PR} - 2g}{2}\left[= a\right]$	**A1**	Must be using different T's – possibly with the result that $T_{PQ} = 2T_{PR}$. Condone use of $2T_{PQ} = T_{PR}$ for this **A1**. Accelerations must be the same. Allow $T_{PQ} - 5g = 5a$ and $2g - T_{PR} = 2a$.
	$5g - 4g = 5a + 4a$ or $5g - 2(2a + 2g) = 5a$ oe Or $\frac{5g - 2T_{PR}}{5} = \frac{T_{PR} - 2g}{2}$ oe	**DM1**	Use $T_{PQ} = 2T_{PR}$ to obtain an equation in a only or in T only. Can be implied by correct value of a or T_{PQ} or T_{PR} if no solving seen.
	$a = \frac{1}{9}g$ Condone $\frac{10}{9}$ or $\frac{9.8}{9}$ or $\frac{9.81}{9}$ or 1.11. $T_{PR} = \frac{20}{9}g$, $T_{PQ} = \frac{40}{9}g$	**A1**	**A1** for any one of the three answers. Second **A1** for all three.
	Allow $T_{PR} = 2.22g$ **and** $T_{PQ} = 4.44g$	**A1**	You may see $a = -\frac{1}{9}g$ if equations 'backwards' but must get to $a = \frac{1}{9}g$ OE for **A1**. Tensions must be in terms of g but ISW. Do not allow e.g. $T_{PQ} = 5g - \frac{5}{9}g$ as final answer. Allow **A1** if tensions not labelled.
		5	

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Question	Answer	Marks	Guidance
5(b)	$[R_P =]6g\cos 30$	**B1**	Seen or implied by $\frac{60\sqrt{3}}{2}$ or $30\sqrt{3}$ or $3g\sqrt{3}$ but must be the normal reaction.
	Attempt N2L for P or whole system to form an equation	***M1**	Correct number of relevant terms (5) (or 4 terms if tensions combined), allow sign errors, allow F for friction but must be using two different expressions for tensions. Must be component of weight (and weights, not masses, if using whole system). Must substitute their tension and acceleration. Must use correct mass(es). You may see an equation such as $5g - F = 4a$, which comes from combining equations for P and N2L for Q or R, and this may be shown in **5(a)** rather than **5(b)**, so in this case link the two parts.
	For P: $6g\sin 30 + their\frac{40}{9}g - their\frac{20}{9}g - F = 6\times their\frac{1}{9}g$ For system: $5g + 6g\sin 30 - 2g - F = 13\times their\frac{1}{9}g$	**A1FT**	Correct equation following through their two different values of T and their a. Do not need a value for F and allow with wrong F. Note: $their\frac{40}{9}g - their\frac{20}{9}g$ may be combined into $their\frac{20}{9}g$ Note: $F = \frac{410}{9} = 45.5555\ldots$ Check very carefully for **FT** of their a, T_{PR}, T_{PQ}.
	$6g\sin 30 + their\frac{40}{9}g - their\frac{20}{9}g - \mu\times 6g\cos 30 = 6\times their\frac{1}{9}g$	**DM1**	Use of $F = \mu R$ to obtain an equation in μ only where R is a component of $6g$.

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Question	Answer	Marks	Guidance
5(b)	$\mu = 0.877$	**A1**	$0.876717\ldots$; $\frac{41\sqrt{3}}{81}$.
		5	

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Question	Answer	Marks	Guidance
5(c)	$d = \frac{1}{2} \times \frac{1}{9} g \times 1.5^2 \quad [\Rightarrow d = 1.25]$	**M1**	OE. Use of $s = ut + \frac{1}{2}at^2$ with $u = 0$, $t = 1.5$ and their a from part **(a)** or other complete method to get an equation in d only. May use $\frac{1}{2}x$ rather than d. Must not use $a = 10$ unless this is their a from **5(a)**.
	2.5 [m]	**A1FT**	FT 2.25a.
	Alternative using work-energy		
	For 6kg particle $\frac{1}{2} \times 6 \times \left(their \frac{g}{9} \times 1.5 \right)^2 - 6g \sin 30 \times d = their \frac{40g}{9} \times d - their \frac{20g}{9} \times d - their \mu \times 6g \cos 30 \times d$ $[\Rightarrow d = 1.25]$ for whole system $\frac{1}{2} \times 13 \times \left(their \frac{g}{9} \times 1.5 \right)^2 - 6g \sin 30 \times d = 5gd - 2gd - their \mu \times 6g \cos 30 \times d$ $[\Rightarrow d = 1.25]$	**M1**	Use of work-energy with all dimensionally correct terms present. Terms should have components as required and allow consistent sin/cos mix May use $\frac{1}{2}x$ rather than d.
	2.5 [m]	**A1FT**	
		2	

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Question	Answer	Marks	Guidance
6	$km\times 2u - m\times u = km\times u + m\times v_B$	***M1**	Attempt at CLM; correct number of terms and correct masses with relevant velocities but allow sign errors. v_B is the speed of B after impact. If g included with the masses then **M1A0**.
	$v_B = (k-1)u$ or $ku = v_B + u$ or $k = \frac{v_B+u}{u}$ or $k = \frac{v_B}{u}+1$	**A1**	Any correct equation linking v_B, k and u but with m eliminated.
	$KE_{before} = \frac{1}{2}\times km\times(2u)^2 + \frac{1}{2}\times m\times(\pm u)^2 \left[= 2kmu^2 + \frac{1}{2}mu^2\right]$	***B1**	KE before impact.
	$KE_{after} = \frac{1}{2}\times km\times u^2 + \frac{1}{2}\times m{v_B}^2$ Or $KE_{after} = \frac{1}{2}\times km\times u^2 + \frac{1}{2}\times mu^2(k-1)^2$	***B1FT**	KE after impact. Allow if their expression for v_B is wrong. Allow B1B1 for the change in KE = $\pm\left(\frac{3}{2}kmu^2 + \frac{1}{2}mu^2 - \frac{1}{2}m{v_B}^2\right)$
	$0.65\times\left(2kmu^2 + \frac{1}{2}mu^2\right) = \frac{1}{2}mu^2\left(k + (k-1)^2\right)$ Or $\left(2kmu^2 + \frac{1}{2}mu^2\right) - \frac{1}{2}mu^2\left(k+(k-1)^2\right) = 0.35\times\left(2kmu^2 + \frac{1}{2}mu^2\right)$ Or $0.8ku^2 + 0.325u^2 = \frac{1}{2}(k-1)^2u^2$	***DM1**	Setting up the equation $0.65\times KE_{before} = KE_{after}$ OE with their expression for v_B in terms of k substituted. Must be correct way around and must use 0.65 OE. Dependent on **M1B1B1**. May see $1.6ku^2 + 0.65u^2 = v_B^2$ leading to $1.6ku^2 + 0.65u^2 = (k-1)^2u^2$.
	$2.6k + 0.65 = k + k^2 - 2k + 1 \Rightarrow k^2 - 3.6k + 0.35 = 0$ or $20k^2 - 72k + 7 = 0$	**DM1**	Re-arrange to a 3-term quadratic in k only – Dependent on **M1B1B1M1**.

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Question	Answer	Marks	Guidance
6	$k = 3.5$ only	**A1**	If $k = 0.1$ seen must be rejected. Reason not required but if a reason given it must be valid e.g. as $k - 1 > 0$ **or** reject later e.g. if $k = 0.1 \Rightarrow v_B = -0.9u$ but not possible as $v_B > 0$.
	$v_B = 2.5u$ Ignore the other solution if shown ($v_B = -0.9u$)	**A1**	Not dependent on previous **A** mark. If g included in momentum equation then max **M1A0B1B1M1M1A1A0**.
	ALTERNATIVE (eliminating k)		
	$km \times 2u - m \times u = km \times u + m \times v_B$	***M1**	Attempt at CLM; correct number of terms and correct masses with relevant velocities but allow sign errors - v_B is the speed of B after impact. If g included with the masses then **M1A0**.
	$v_B = (k-1)u$ or $ku = v_B + u$ or $k = \dfrac{v_B + u}{u}$ or $k = \dfrac{v_B}{u} + 1$	**A1**	Any correct equation linking v_B, k and u but with m eliminated.
	$KE_{before} = \dfrac{1}{2} \times km \times (2u)^2 + \dfrac{1}{2} \times m(\pm u)^2 \left[= 2kmu^2 + \dfrac{1}{2}mu^2 \right]$ Or $KE_{before} = \dfrac{1}{2} \times \left(\dfrac{v_B + u}{u} \right) m \times (2u)^2 + \dfrac{1}{2} \times mu^2$	***B1FT**	KE before impact. Allow if their expression for k is wrong.
	$KE_{after} = \dfrac{1}{2} \times km \times u^2 + \dfrac{1}{2} \times m{v_B}^2$ or $KE_{after} = \dfrac{1}{2} \times \left(\dfrac{v_B + u}{u} \right) m \times u^2 + \dfrac{1}{2} \times m{v_B}^2$	***B1FT**	KE after impact. Allow if their expression for k is wrong. Allow **B1B1** for the change in KE $\pm\left(\dfrac{3}{2}kmu^2 + \dfrac{1}{2}mu^2 - \dfrac{1}{2} \times m{v_B}^2 \right)$.

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Question	Answer	Marks	Guidance
6	$0.65\times\left(\frac{1}{2}\times\left(\frac{v_B+u}{u}\right)m\times(2u)^2+\frac{1}{2}\times mu^2\right)=\frac{1}{2}\times\left(\frac{v_B+u}{u}\right)m\times u^2+\frac{1}{2}\times m{v_B}^2$ or $\left(\frac{1}{2}\times\left(\frac{v_B+u}{u}\right)m\times(2u)^2+\frac{1}{2}\times mu^2\right)-\left(\frac{1}{2}\times\left(\frac{v_B+u}{u}\right)m\times u^2+\frac{1}{2}\times m{v_B}^2\right)=0.35\left(\frac{1}{2}\times\left(\frac{v_B+u}{u}\right)m\times(2u)^2+\frac{1}{2}\times mu^2\right)$ or $0.65\times\left(2mu(v_B+u)+\frac{1}{2}mu^2\right)=\frac{1}{2}mu(v_B+u)+\frac{1}{2}m{v_B}^2$	***DM1**	Setting up the equation $0.65\times KE_{before}=KE_{after}$. OE with expression for k in terms of v_B substituted. Must be correct way around and must use 0.65 OE. Dependent on **M1B1B1**. May see $1.6ku^2+0.65u^2={v_B}^2$ oe leading to $1.6\left(\frac{v_B+u}{u}\right)u^2+0.65u^2={v_B}^2$.
	$1.3uv_B+1.625u^2=0.5u^2+0.5uv_B+0.5{v_B}^2$ $\Rightarrow {v_B}^2-1.6uv_B-2.25u^2=0$ $\Rightarrow 20{v_B}^2-32uv_B-45u^2=0$	**DM1**	Re-arrange to a 3-term quadratic in terms of v_B and u only. Dependent on **M1B1B1M1**.
	$v_B\neq -0.9u$	**A1**	Explicitly seen and rejected.
	$v_B=2.5u$ Ignore the other solution if shown $(v_B=-0.9u)$	**A1**	Not dependent on previous **A** mark. If g included in momentum equation, then max **M1A0B1B1M1M1A1A0**.
		8	

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