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Mark Scheme (Results)

Summer 2023

Pearson Edexcel International Advanced Level

In Mechanics M1 (WME01)

Paper 01

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.

- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.

- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.

- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.

- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.

- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.

- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

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General Instructions for Marking

The total number of marks for the paper is 75.

Edexcel Mathematics mark schemes use the following types of marks:

'M' marks
These are marks given for a correct method or an attempt at a correct method. In Mechanics they are usually awarded for the application of some mechanical principle to produce an equation, e.g. resolving in a particular direction; taking moments about a point; applying a suvat equation; applying the conservation of momentum principle; etc.

The following criteria are usually applied to the equation.

To earn the M mark, the equation
(i) should have the correct number of terms
(ii) each term needs to be dimensionally correct

For example, in a moments equation, every term must be a 'force x distance' term or 'mass x distance', if we allow them to cancel 'g' s.

For a resolution, all terms that need to be resolved (multiplied by sin or cos) must be resolved to earn the M mark.

'M' marks are sometimes dependent (DM) on previous M marks having been earned, e.g. when two simultaneous equations have been set up by, for example, resolving in two directions and there is then an M mark for solving the equations to find a particular quantity – this M mark is often dependent on the two previous M marks having been earned.

'A' marks
These are dependent accuracy (or sometimes answer) marks and can only be awarded if the previous M mark has been earned. e.g. M0 A1 is impossible.

'B' marks
These are independent accuracy marks where there is no method (e.g. often given for a comment or for a graph).

A and B marks may be f.t. – follow through – marks.

General Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes:

- bod means benefit of doubt
- ft means follow through
    - the symbol $\surd$ will be used for correct ft
- cao means correct answer only
- cso means correct solution only, i.e. there must be no errors in this part of the question to obtain this mark
- isw means ignore subsequent working

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- awrt means answers which round to
- SC means special case
- oe means or equivalent (and appropriate)
- dep means dependent
- indep means independent
- dp means decimal places
- sf means significant figures
- * means the answer is printed on the question paper
- ⌐ means the second mark is dependent on gaining the first mark

All A marks are 'correct answer only' (cao.), unless shown, for example, as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks affected are treated as A ft, but manifestly absurd answers should never be awarded A marks.

For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.

If a candidate makes more than one attempt at any question:

- If all but one attempt is crossed out, mark the attempt which is NOT crossed out.
- If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.

Ignore wrong working or incorrect statements following a correct answer.

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General Principles for Mechanics Marking

(NB specific mark schemes may sometimes override these general principles)

- Rules for M marks:
  - correct no. of terms;
  - dimensionally correct;
  - all terms that need resolving (i.e. multiplied by cos or sin) are resolved.
- Omission or extra g in a resolution is an accuracy error not method error.
- Omission of mass from a resolution is a method error.
- Omission of a length from a moments equation is a method error.
- Omission of units or incorrect units is not (usually) counted as an accuracy error.
- DM indicates a dependent method mark, i.e. one that can only be awarded if a previous specified method mark has been awarded.
- Any numerical answer which comes from use of g = 9.8 should be given to 2 or 3 SF.
- Use of g = 9.81 should be penalised once per (complete) question.
  - N.B. Over-accuracy or under-accuracy of correct answers should only be penalised *once* per complete question. However, premature approximation should be penalised every time it occurs.
- Marks must be entered in the same order as they appear on the mark scheme.
- In all cases, if the candidate clearly labels their working under a particular part of a question i.e. (a) or (b) or (c)…then that working can only score marks for that part of the question.
- Accept column vectors in all cases.
- Misreads – if a misread does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, bearing in mind that after a misread, the subsequent A marks affected are treated as A ft

Mechanics Abbreviations

M(A)	Taking moments about A.
N2L	Newton's Second Law (Equation of Motion)
NEL	Newton's Experimental Law (Newton's Law of Impact)
HL	Hooke's Law
SHM	Simple harmonic motion
PCLM	Principle of conservation of linear momentum
RHS	Right hand side
LHS	Left hand side

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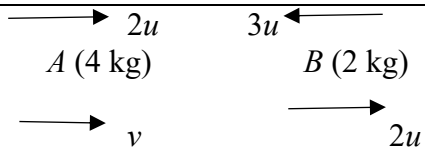
Question Number	Scheme	Marks
1(a)	 CLM: $(4\times 2u)+(-3u\times 2)=4v+(2\times 2u)$ **OR** Equating impulses: $2(2u--3u)=4(-v--2u)$	M1 A1
	$\frac{1}{2}u\left(\text{m s}^{-1}\right)$	A1
		(3)
1(b)	The direction of motion is reversed.	B1
		(1)
1(c)	For B: $I=\pm 2(2u--3u)$ **OR** For A: $I=\pm 4\left(\frac{u}{2}--2u\right)$	M1 A1
	$I=10u$ Ns or $10u$ kgms^{-1}	A1
		(3)
		(7)

Notes		
(a)		
M1	Dimensionally correct CLM equation or equating of impulses equation. Allow consistent extra g's. Ignore sign errors. May be $+v$ or $-v$	
A1	Correct unsimplified equation	
A1	Cao. Must be **positive.**	
(b)		
B1	Accept *opposite direction.* Do not accept *changed* or *to the left or backwards*, away from B **N.B.** This mark is **dependent** on **correctly** obtaining $\frac{1}{2}u$ or $-\frac{1}{2}u$ in (a)	
(c)		
M1	Dimensionally correct impulse-momentum equation using A or B. Condone sign errors with appropriate velocities. M0 if g is included	
A1	Correct unsimplified equation	
A1	Cao **with** units. Accept kg m/s	

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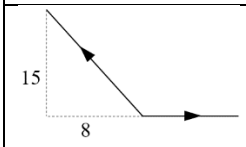
Question Number	Scheme	Marks
2(a)	$\mathbf{F}_3 + (3c\mathbf{i} + 4c\mathbf{j}) + (-14\mathbf{i} + 7\mathbf{j}) = \mathbf{0}$ oe	M1
	$\mathbf{F}_3 = (14 - 3c)\mathbf{i} + (-7 - 4c)\mathbf{j}$	A1
		(2)
2(b)	Resultant force $\mathbf{F}_1 + \mathbf{F}_2 = (6-14)\mathbf{i} + (8+7)\mathbf{j}$ $(= -8\mathbf{i} + 15\mathbf{j})$	M1
	 Find any relevant angle for **their (even if they've subtracted)** resultant (need not be acute nor positive)	M1
	any of $\tan^{-1}\left(\pm\frac{8}{15}\right), \tan^{-1}\left(\pm\frac{15}{8}\right), \sin^{-1}\left(\pm\frac{8}{17}\right), \cos^{-1}\left(\pm\frac{8}{17}\right), \ldots$	A1**ft**
	120° or better (118.0724…) **OR** 240° or better (241.9276..) In radians 2.1 or better (2.0607..) **OR** 4.2 or better (4.2224…)	A1
		(4)
2(c)	Use of Pythagoras on their resultant : $\sqrt{(-8)^2 + 15^2}$ **or** their acceleration: $\sqrt{(\frac{-8}{m})^2 + (\frac{15}{m})^2}$	M1
	Use of $\lvert\text{their } \mathbf{R}\rvert = 8.5m$ **or** their Resultant = $m\mathbf{a}$	M1
	A correct equation in m only eg $17 = m \times 8.5$	A1**ft**
	$m = 2$	A1
	N. B. $\sqrt{\left(\frac{-8}{8.5}\right)^2 + \left(\frac{15}{8.5}\right)^2}$ M1 $-8\mathbf{i} + 15\mathbf{j} = 8.5m$ M1 $\sqrt{\left(\frac{-8}{8.5}\right)^2 + \left(\frac{15}{8.5}\right)^2} = m$ A1ft $2 = m$ A1	
		(4)
		(10)

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Notes	
	Accept column vectors throughout apart from answer for (a)
(a)	
M1	Uses the vector **sum** of all 3 forces being equal to zero oe **N.B.** $\mathbf{F_3} = \mathbf{F}_1 + \mathbf{F}_2$ is M0
A1	cao Must be in terms of c, **i** and **j** but allow uncollected **i**'s and **j**'s and apply isw if necessary.
(b)	
M1	Finds the resultant using $\mathbf{F}_1 + \mathbf{F}_2$ or $-$ their $\mathbf{F}_3$
M1	Uses trig to find a relevant angle **for their resultant**
A1ft	Any **correct** relevant angle (does not need to be acute), ft on their resultant
A1	Cso.
(c)	
M1	Use of Pythagoras to find the magnitude of their resultant force **or** their acceleration
M1	Allow their **R** = 8.5 m
A1ft	A correct scalar equation in m only eg $17 = m \times 8.5$, ft on their resultant
A1	cso

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Question Number	Scheme	Marks
3(a)	$1.5 = 0 + \frac{1}{2} g t^2$	M1 A1
	$t = 0.55$ or 0.553(s)	A1
		(3)
3(b)	$1.5 = 0 + \frac{1}{2} a \left(0.6\right)^2$	M1 A1
	$0.2g - R = 0.2a$	M1 A1
	$R = 0.293$, 0.29	A1
		(5)
		(8)

Notes for Question 3	
(a)	
M1	Complete method to find the time taken using $a = g$
A1	Correct unsimplified equation in t only
A1	Cao
(b)	
M1	Complete method to form an equation in a only, $a \neq g$, using $t = 0.6$
A1	Correct unsimplified equation in a only
M1	Use $F = ma$ to form an equation of motion with correct terms, condone sign errors, $a \neq g$
A1	Correct unsimplified equation
A1	Cao
	N.B. Allow **consistent** use of ($-a$) instead of a and penalise in the second equation if inconsistent. **N.B.** Penalise use of $g = 9.81$ once for the whole question. Also penalise once for the whole question, answers as fractions, penalise the first one, if both answers are fractions.

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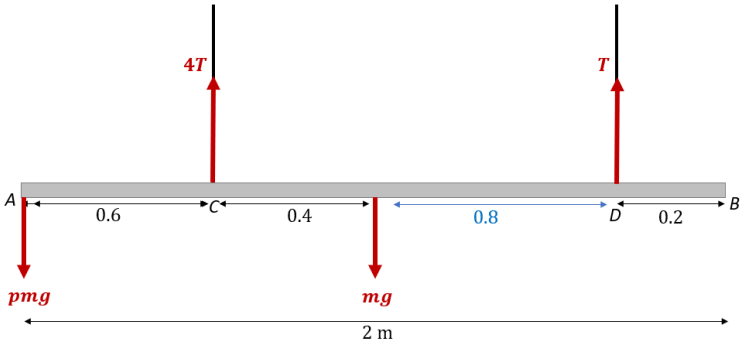
Question Number	Scheme	Marks
4(a)	T and $4T$ correctly placed	B1
	Vertical resolution $T+4T=pmg+mg$ **OR** a moments equation, see below.	M1 A1
	$\mathrm{M}(A):\ (4T\times0.6)+(T\times1.8)=(mg\times1)$  Other moments equations: $\mathrm{M}(C):\ (pmg\times0.6)+(T\times1.2)=(mg\times0.4)$ $\mathrm{M}(G):\ (pmg\times1)+(T\times0.8)=(4T\times0.4)$ $\mathrm{M}(D):\ (pmg\times1.8)+(mg\times0.8)=(4T\times1.2)$ $\mathrm{M}(B):\ (4T\times1.4)+(T\times0.2)=(pmg\times2)+(mg\times1)$	M1 A1
	Eliminate T $5\left(\frac{5mg}{21}\right)=pmg+mg$	M1
	$p=\frac{4}{21}$ (exact ratio of 2 positive integers)	A1
		(7)
4(b)	Tension at D is zero, seen or implied.	B1
	$\mathrm{M}(C):\ (qmg\times0.6)=(mg\times0.4)$	M1 A1
	$q=\frac{2}{3}$ (exact ratio of 2 positive integers), accept 0.666….. or $0.\dot{6}$	A1
		(4)
4(c)	The centre of mass (or gravity) of the beam is in the middle; the mass (weight) of the beam acts at the middle, mass at centre, centre of mass at the centre. Penalise incorrect extras.	B1
		(1)
		(12)

Notes for Question 4

(a)	**N.B.** Full marks can be scored if consistent omission of g's in a **complete solution,** but otherwise penalise omission of g's
B1	Correct relationship between the tensions and placed correctly, seen or implied.
M1	Vertical resolution. Condone forces at C and D the wrong way round or written as T_C and T_D. This equation may be replaced with a moments equation.

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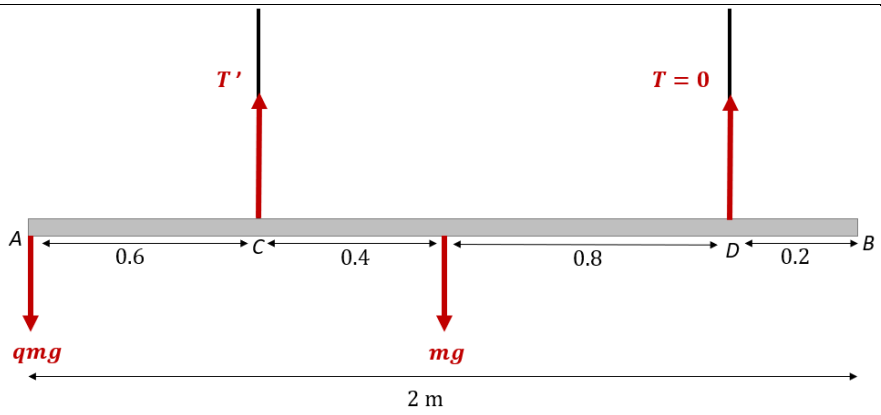
A1	Correct unsimplified equation (even if T and $4T$ are the wrong way round on their diagram)
M1	Moments equation. Correct forces multiplied by a length. Condone consistent forces at C and D the wrong way round or written as T_C and T_D
A1	Correct unsimplified equation, **in a variable consistent with their first equation.**
M1	Eliminate T to give an equation in p only allow extra m's or g's or both
A1	Cao. Must be exact.
	N.B. If they write down more than two equations, award the marks for those equations which they use to solve the problem.
(b)	
B1	Recognise tension at D is 0, seen or implied
M1	Complete method to obtain an equation q only. e.g. Moments about C equation.
A1	Correct unsimplified equation in q only.
A1	Cao. Must be exact.
ALT (b)	
M1	Two other equations could be used and solved to find q. M0 if tension at D is never zero.
A1	Correct unsimplified equation in q only.
A1	Cao. Must be exact.
	 Alternative equations: vert : $T' = qmg + mg$ M(A): $(T' \times 0.6) = (mg \times 1)$ M(G): $(qmg \times 1) = (T' \times 0.4)$ M(D): $(qmg \times 1.8) + (mg \times 0.8) = (T' \times 1.2)$ M(B): $(qmg \times 2) + (mg \times 1) = (T' \times 1.4)$
(c)	
B1	Any appropriate comment

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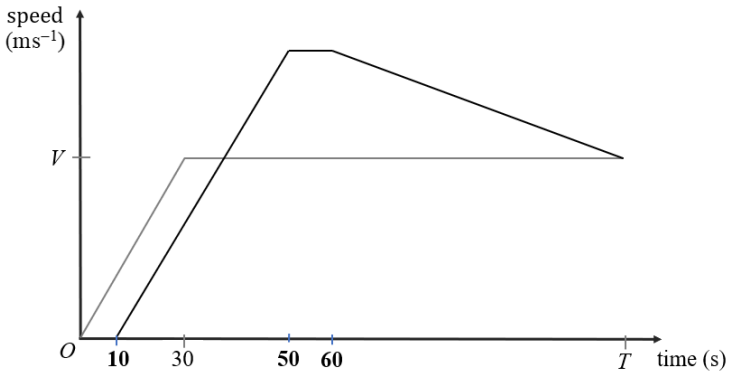
Question number	Scheme	Marks
5(a)	For car: $\left(\frac{T+T-30}{2}\right)V$	M1
	$V(T-15)$ (metres) * Allow $(T-15)V$	A1*
		(2)
5(b)		B1 shape B1 Horiz labels (10,50,60)
		(2)
5(c)	$\frac{speed}{40}=\frac{V}{30}$	M1
	$(\text{speed})=\frac{4V}{3}$ (m s^{-1})*	A1*
		(2)
5(d)	For motorbike **OR:** $\frac{1}{2}\left(\frac{4V}{3}\times 40\right)+\left(\frac{4V}{3}\times 10\right)+\frac{1}{2}\left(\frac{4V}{3}+V\right)(T-60)$ **OR:** $\frac{1}{2}\left(\frac{4V}{3}\times 40\right)+\left(\frac{4V}{3}\times 10\right)+\frac{1}{2}\left(\frac{4V}{3}-V\right)(T-60)+V(T-60)$ **OR:** $\frac{1}{2}\times\frac{4V}{3}\times(10+50)+\frac{1}{2}\left(\frac{4V}{3}+V\right)(T-60)$ (Simplified: $\frac{7VT}{6}-30V$)	M1 A1 A1
	Equate their motorbike distance to $V(T-15)$ to give an equation in T only	M1
	$T=90$	A1
	ALT: Find area of upper trapezium **and** parallelogram (differences in areas) $\frac{1}{2}\left(\frac{V}{3}\right)(T-40+10)$ **and** $10V$	M1 A1 A1
	Equate to give an equation in T only (V cancels)	M1
	$T=90$	A1
		(5)
		(11)

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Notes for Question 5	
(a)	
M1	Uses total area under graph to find an expression for the distance in terms of V and T only May use: Trapezium: $\left(\frac{T+T-30}{2}\right)V$ triangle + rectangle : $\frac{1}{2}(30V)+V(T-30)$ a triangle subtracted from a rectangle: $VT-\frac{1}{2}(30\times V)$ **OR** use of *suvat*: $\frac{1}{2}(30V)+V(T-30)$
A1*	Given answer correctly obtained (allow omission of 'metres'.
(b)	
	N.B. If graph is not done on either of the given graphs on the question paper, they score B0B0 .
B1	Correct shape with acceleration lines parallel and meeting at (T, V) B0 if continuous vertical line at $t = T$
B1	Correct horizontal labels. Accept appropriately labelled delineators. **N.B.** This mark is independent of the first B1.
(c)	
M1	Correct method using gradients or *suvat* to obtain an equation in V only
A1*	Given answer correctly obtained
(d)	
M1	For motorbike: find an expression for the **TOTAL** area under the graph (or use *suvat*) to find the total distance travelled in terms of V and T only. **N.B.** $\frac{1}{2}\left(\frac{4V}{3}\times 40\right)+\left(\frac{4V}{3}\times 10\right)+\frac{1}{2}\left(\frac{4V}{3}-V\right)(T-60)$ is M0 as it omits a part of the area.
A1	Correct unsimplified expression with at most one error/slip
A1	Correct unsimplified expression
M1	Clear attempt to equate their distance to the given distance in part (a) to give an equation in T only i.e. the V's **must** cancel but they do not need to be cancelled for this mark. **N.B.** This is an independent mark.
A1	cao

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Question Number	Scheme	Marks
6	Vertical $R - P\sin\alpha = W$	M1 A1
	Horizontal $F = P\cos\alpha$ **OR** $F_{MAX} \geqslant P\cos\alpha$	M1 A1
	$F \leqslant \frac{1}{4}R$ **or** $F = \frac{1}{4}R$ seen or implied	M1
	Produce a dimensionally correct inequality or equation in P and W only, trig does not need to be substituted	M1
	Reach the **given** answer, with exact working. $P \leqslant \frac{5W}{8}$* or $\frac{5W}{8} \geqslant P$	A1* cso
		(7)
		(7)

Notes for Question 6	
M1	Equation for vertical equilibrium. Correct number of terms, forces resolved where appropriate, condone sign errors and sin/cos confusion. M0 for an inequality
A1	Correct unsimplified equation.
M1	Equation for horizontal equilibrium. Correct number of terms, forces resolved where appropriate, condone sign errors and sin/cos confusion. **N.B.** Allow $F \geqslant P\cos\alpha$
A1	Either $F = P\cos\alpha$ or $F_{MAX} \geqslant P\cos\alpha$ where F_{MAX} may be implied by use of $\frac{1}{4}R$
M1	M0 for $F < \frac{1}{4}R$ or $F > \frac{1}{4}R$ or $F \geqslant \frac{1}{4}R$
M1	Eliminate F and R to form an inequality or equation in P and W only but allow trig to be unsubstituted. e.g. $\frac{1}{4}(W + P\sin\alpha) \geqslant P\cos\alpha$ or $\frac{1}{4}(W + P\sin\alpha) = P\cos\alpha$ M0 for use of $F < \frac{1}{4}R$ or $F > \frac{1}{4}R$ or $F \geqslant \frac{1}{4}R$ to form their inequality
A1* cso	Reach the **given** answer with at least one line of working. Must come from exact working and correct use of the inequality

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Question Number	Scheme	Marks
7(a)	Whole system: $3000-1200g\sin\alpha-600g\sin\alpha-2R-R=1800(0.75)$	M1 A1 A1
	From exact working $R=60$ *	A1* cso
		(4)
7(b)	Trailer: $T-600g\sin\alpha-60=600(0.75)$ **OR** Car: $3000-1200g\sin\alpha-2(60)-T=1200(0.75)$ (T could be replaced by ($-T$) in either equation, leading to $T=-1000$, so tension is 1000)	M1 A1
	$T=1000(\text{N})$	A1
		(3)
7(c)	Equation of motion $-60-600g\sin\alpha=600a$ (or $-600a$) $\left[a=-\frac{11}{12}=-0.9166\ldots\right]$	M1 A1
	$0=12^2+2\left(-\frac{11}{12}\right)d$	M1
	$d=78.5,79$ (m)	A1
		(4)
		(11)

Notes for question 7

(a) **M1**	Equation of motion for the whole system (**or** for car AND trailer with T eliminated) to give an equation in R only. $\sin\alpha$ does not need to be substituted Correct number of terms, forces resolved where appropriate, condone sign errors and sin/cos confusion.
A1	Correct equation with at most one error. $\sin\alpha$ does not need to be substituted
A1	Correct equation. $\sin\alpha$ does not need to be substituted
A1*	Reach the GIVEN answer with at least one intermediate line of working and must come from exact working.
(b) **M1**	Equation of motion for the trailer or for the car. Correct number of terms, forces resolved where appropriate, condone sign errors and sin/cos confusion. $\sin\alpha$ does not need to be substituted but $R = 60$ does
A1	Correct unsimplified equation. $\sin\alpha$ does not need to be substituted
A1	Correct answer for T
(c) **M1**	Form an equation of motion for the trailer to find the new acceleration. Correct number of terms, forces resolved where appropriate, condone sign errors and sin/cos confusion. $\sin\alpha$ does not need to be substituted but $R = 60$ does
A1	Correct unsimplified equation. $\sin\alpha$ does not need to be substituted
M1	Complete method, with a calculated acceleration that is not g, to find the distance travelled.
A1	Cao 2 or 3sf Must be positive. **N.B.** Allow a negative value of d and made positive for the distance.

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Question Number	Scheme	Marks
	Allow working in column vectors and penalise answers to (a) and (b) in column vector form ONCE at the first time it occurs.	
8(a)	$\mathbf{v} = \dfrac{(9\mathbf{i} + 23\mathbf{j}) - (-2\mathbf{i} + \mathbf{j})}{11}$	M1
	Expression for $\mathbf{r}$ with correct structure	M1
	$\mathbf{r} = (-2\mathbf{i} + \mathbf{j}) + t(\mathbf{i} + 2\mathbf{j})$ or $\mathbf{r} = (t-2)\mathbf{i} + (2t+1)\mathbf{j}$	A1 cao
		(3)
8(b)	$\mathbf{s} = (25\mathbf{i} + 25\mathbf{j}) + t(-\mathbf{i} - \mathbf{j})$ **Or** $\mathbf{s} = (25-t)\mathbf{i} + (25-t)\mathbf{j}$	B1
		(1)
8(c)	**Either** $\mathbf{r} - \mathbf{s}$ **Or** $\mathbf{s} - \mathbf{r}$ with their $\mathbf{r}$ and $\mathbf{s}$ substituted	M1
	$\overrightarrow{SR} = \left[(2t-27)\mathbf{i} + (3t-24)\mathbf{j}\right]$m *	A1*
		(2)
8(d)	Distance $(d) = \sqrt{(2t-27)^2 + (3t-24)^2}$ $(d^2) = (2t-27)^2 + (3t-24)^2$	M1
	$(d^2) = 13t^2 - 252t + 1305$	A1
	$t = \dfrac{126}{13} = 9.7$ (s) or better	A1
		(3)
		(9)

Notes for Question 8	
(a)	
M1	Use of displacement/time to find velocity. Allow the difference either way round.
M1	Expression for $\mathbf{r}$ with correct structure using *their* $\mathbf{v}$ and the correct initial position vector.
A1	Correct expression in terms of t, $\mathbf{i}$ and $\mathbf{j}$
(b)	
B1	Any correct expression for $\mathbf{s}$ in terms of t, $\mathbf{i}$ and $\mathbf{j}$
(c)	
M1	(Their $\mathbf{r}$ – their $\mathbf{s}$) or vice versa, unsimplified
A1*	Correct answer correctly obtained. Allow missing square brackets and m, but rest must be identical to given answer.
(d)	
M1	Use of Pythagoras to find an expression for distance (or distance squared)
A1	Correct 3 term quadratic expression **N.B.** If no 3 term quadratic expression is seen but a correct derivative is, award this mark.
A1	9.7 or better. **N.B.** If a fraction is given as the answer, it must be the ratio of two positive integers or a mixed fraction.

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