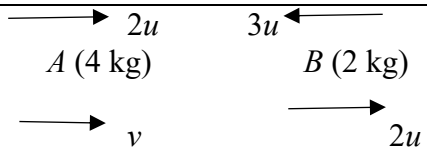
Mark Scheme (Results)

Summer 2023

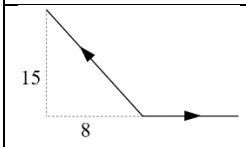
Pearson Edexcel International Advanced Level

In Mechanics M1 (WME01)

Paper 01

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)

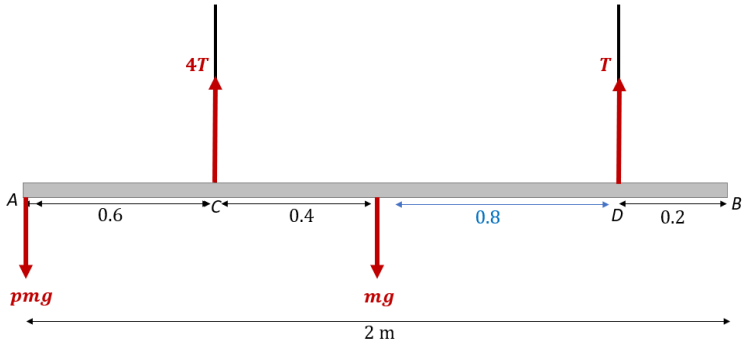
Notes		
(a)		
M1	Dimensionally correct CLM equation or equating of impulses equation. Allow consistent extra g's. Ignore sign errors. May be $+v$ or $-v$	
A1	Correct unsimplified equation	
A1	Cao. Must be **positive.**	
(b)		
B1	Accept *opposite direction.* Do not accept *changed* or *to the left or 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	

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)

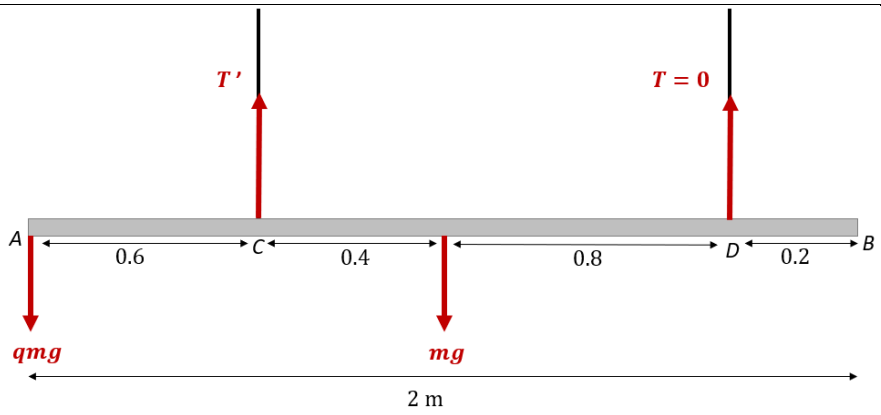
Notes	
	Accept column vectors throughout apart from answer for (a)
(a)	
M1	Uses the vector **sum** of all 3 forces being equal to zero oe **N.B.** $\mathbf{F_3} = \mathbf{F}_1 + \mathbf{F}_2$ is M0
A1	cao Must be in terms of c, **i** and **j** but allow uncollected **i**'s and **j**'s and apply isw if 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

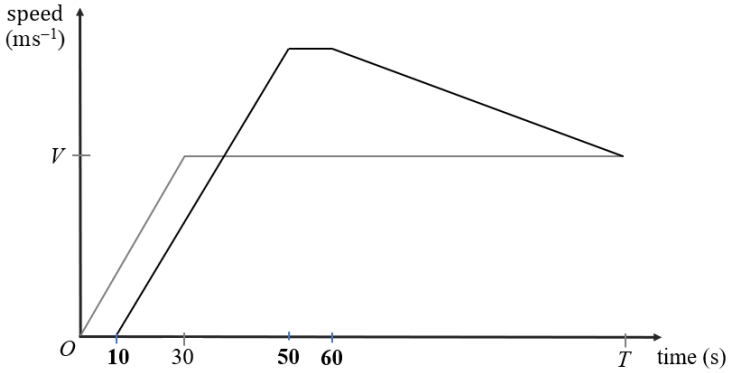
Question Number	Scheme	Marks
3(a)	$1.5 = 0 + \frac{1}{2} g t^2$	M1 A1
	$t = 0.55$ or 0.553(s)	A1
		(3)
3(b)	$1.5 = 0 + \frac{1}{2} a \left(0.6\right)^2$	M1 A1
	$0.2g - R = 0.2a$	M1 A1
	$R = 0.293$, 0.29	A1
		(5)
		(8)

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.

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.

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: $\text{vert}: \quad T' = qmg + mg$ $\text{M}(A): \ (T' \times 0.6) = (mg \times 1)$ $\text{M}(G): \ (qmg \times 1) = (T' \times 0.4)$ $\text{M}(D): \ (qmg \times 1.8) + (mg \times 0.8) = (T' \times 1.2)$ $\text{M}(B): \ (qmg \times 2) + (mg \times 1) = (T' \times 1.4)$
(c)	
B1	Any appropriate comment

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)

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

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

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.	

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.