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Mark Scheme (Results)

Summer 2023

Pearson Edexcel International Advanced Level

In Mechanics M2 (WME02)

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	Scheme	Marks	Notes
1a	$\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	Must be subtracting but condone subtraction in wrong order
	$= 0.3\left(\left(7\mathbf{i} + 7\mathbf{j}\right) - 5\mathbf{i}\right) \quad \left(= 0.6\mathbf{i} + 2.1\mathbf{j}\right)$	A1	correct unsimplified equation Allow $\pm$
	$\left\|\mathbf{I}\right\| = \sqrt{0.6^2 + 2.1^2}$	M1	Use of Pythagoras
	$= \frac{3\sqrt{53}}{10}$	A1	2.2 or better (2.18403…)
		(4)	
1b	Correct method for a relevant angle	M1	e.g. use of trigonometry or scalar product for their **I** θ or 90 - θ
	Correct trig ratio for the required angle and no other angle involved.	A1	From correct **I** e.g. $\tan\theta = \frac{7}{2}$ or $\cos\theta = \frac{10}{\sqrt{53}\times 5}$
	$\theta = 74.1°$	A1	$74°$ or better $\left(74.0546..°\right)$ or 360 – 74 (286) (1.29… radians)
		(3)	

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Question	Scheme	Marks	Notes
Accept column vectors throughout			
2a	Use of $\mathbf{r} = \int \mathbf{v}\,\mathrm{d}t$	M1	Powers going up by 1. Allow one slip in the powers
	$\mathbf{r} = \left(\frac{4}{3}t^3 - \frac{5}{2}t^2 + A\right)\mathbf{i} + \left(-5t^2 - 12t + B\right)\mathbf{j}$	A1	Allow without constant of integration
	Use $t = 2$ and $\mathbf{r} = 2\mathbf{i} + 6\mathbf{j}$ when $t = 0$: $\mathbf{r} = \left(\frac{4}{3}\times 8 - \frac{5}{2}\times 4 + 2\right)\mathbf{i} + \left(-5\times 4 - 12\times 2 + 6\right)\mathbf{j}$	M1	Correct use of given value to obtain **r**
	$= \frac{8}{3}\mathbf{i} - 38\mathbf{j}$	A1	Correct answer only Allow 2.7 or better ISW if they go on to find the magnitude.
		(4)	
2b	**v** in direction of **i** - 2**j**	M1	Use velocity and direction to form an equation in T Condone if they have (-)2 on the wrong side of their equation
	$\Rightarrow -2\left(4T^2 - 5T\right) = \left(-10T - 12\right)$ $\left(8T^2 - 20T - 12 = 0\right)$	A1	Correct unsimplified equation in T (or t) only
	$\Rightarrow T = 3$	A1	Only. Allow $t = 3$.
		(3)	
2c	Use of $\mathbf{a} = \frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$ $\left(\mathbf{a} = \left(8t - 5\right)\mathbf{i} - 10\mathbf{j}\right)$	M1	Powers going down by 1 Allow one slip in the powers
	Use of Pythagoras and $t = 2.5$	M1	Correct use of their derivative to obtain acceleration
	$\lvert a\rvert = \sqrt{\left(20-5\right)^2 + 10^2} = \sqrt{325}\left(= 5\sqrt{13}\right)\mathrm{m\,s^{-2}}$	A1	Any equivalent simplified exact form. Ignore decimals after exact answer seen.
		(3)	

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<table>
<tr><th>Question</th><th>Scheme</th><th>Marks</th><th>Notes</th></tr>
<tr><td colspan="4">They must have a dissection for which they should know or find the position of the centre of mass (e.g. triangles and rectangles). A false assumption about the position of the centre of mass of a trapezium results in 0/5.</td></tr>
<tr><td rowspan="4">3a</td><td><table>
<tr><td></td><td>Large tri</td><td>Small tri</td><td>Small tri</td><td>Whole</td></tr>
<tr><td>Dist PQ</td><td>0</td><td>-2y</td><td>2y</td><td>d</td></tr>
<tr><td>Mass ratio</td><td>27xy</td><td>12xy</td><td>12xy</td><td>27xy</td></tr>
</table></td><td>B1

B1</td><td>Correct distances from PQ or a parallel axis for their complete dissection
Correct mass ratios for a complete dissection</td></tr>
<tr><td>Moments about PQ:</td><td>M1</td><td>Or a parallel axis. Dimensionally correct. Need all non-zero terms and no extras. Condone sign error(s). Allow for $\pm d$
Check the logic carefully.</td></tr>
<tr><td>$(27xy\times 0)-12xy\times(-2y)+12xy\times 2y=27xyd$</td><td>A1</td><td>Correct unsimplified equation. Allow for $\pm d$
Allow for correct distance from a parallel axis</td></tr>
<tr><td>$d=\frac{48}{27}y=\frac{16}{9}y$ *</td><td>A1*</td><td>Obtain given result from fully correct working.</td></tr>
<tr><td colspan="4">There are many different approaches to this.
NB If they are using a trapezium they must show method for the distance. For PQBC the correct value for distance centre of mass from PQ is $\frac{8y}{5}$
Possible alternative moments equations include:
$15xy\times\frac{8y}{5}+9xy\times\frac{4y}{3}+3xy\times 4y=27xyd$ using PQBC, PQDE and DEA
$12xy\times 2y+15xy\times\frac{8y}{5}=27xyd$ using PQA and PQBC
$2\times 3xy\times y-3xy\times y+2\times 6xy\times 1.5y+2\times 3xy\times 2y=27xyd$ working from BC for the folded figure.
$2\times 3xy\times 2y+4\times\frac{1}{2}3xy\times y+2\times 6xy\times 1.5y+3xy\times 4y=27xyd$ working down from PQ</td></tr>
<tr><td></td><td></td><td>(5)</td><td></td></tr>
</table>

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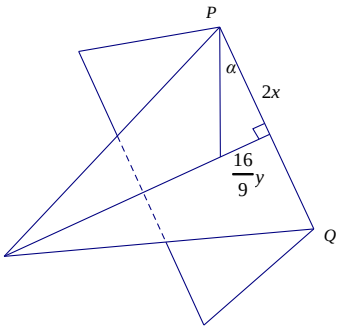
Question	Scheme	Marks	Notes
3b			
	Use of trigonometry	M1	Trig ratio for a relevant angle In their working they need a valid attempt to find α or $90° - \alpha$.
	$\tan\alpha = \frac{\frac{16}{9}y}{2x} = \frac{64}{81}$	A1	Correct unsimplified equation in x and y
	$\Rightarrow x = \frac{9}{8}y$	A1	Correct only. $(x = 1.125y)$ (Accept $x = 1.1y$ or better)
		(3)	

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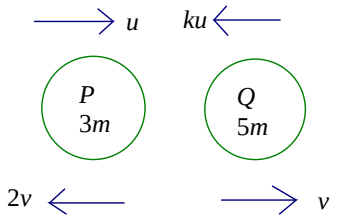
4a			
	Impulse-momentum equation for P:	M1	Correct use of $I = mv - mu$: Evidence of subtraction (can go straight to + you do not need to see $-(-)$) and dimensionally correct. Use of $3m$
	$15mv = 3m(2v-(-u))$	A1	Correct unsimplified equation
	$9mv = 3mu \Rightarrow u = 3v$ *	A1*	Obtain **given answer** from correct working
4a alt	Impulse-momentum equation for Q and CLM:	M1	CLM dimensionally consistent, all 4 terms, condone sign error(s). Correct use of $I = mv - mu$: Evidence of subtraction and dimensionally correct. Use of $5m$
	$15mv = 5m(v+ku)$, $k = 2\frac{v}{u}$ and substitute into CLM: $3mu - 5m\frac{2v}{u}u = 5mv - 6mv$	A1	Correct unsimplified equation in u and v
	$\Rightarrow u = 3v$ *	A1*	Obtain **given answer** from correct working
		(3)	
4b	Impulse-momentum equation for Q or use of CLM:	M1	Dimensionally consistent. All relevant terms.
	$15mv = 5m(v-(-ku))$ or $3mu - 5mku = 5mv - 6mv$	A1	Correct unsimplified equation
	$10v = 5ku = 15kv \Rightarrow k = \frac{2}{3}$	A1	Correct only. Accept 0.67 or better
		(3)	
4c	Use of impact law:	M1	Must be used the right way round. Condone sign error(s)
	$2v + v = e(u+ku)$ $\left(= e \times 3v \times \frac{5}{3}\right)$	A1ft	Correct unsimplified equation. Follow their k.
	$\Rightarrow e = \frac{3}{5}$	A1	Correct only
		(3)	

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4d	Change in KE	M1	Allow for gain rather than loss. Dimensionally correct. Need to use all 4 terms and to be using the correct values for mass.
	$\frac{1}{2}\times 3m\left(u^2-(2v)^2\right)+\frac{1}{2}\times 5m\left((ku)^2-v^2\right)$	A1	Correct unsimplified equation. Allow for gain rather than loss. A0 if an error occurs before they form a single expression
	$\left(\frac{1}{2}\times 3m\left(5v^2\right)+\frac{1}{2}\times 5m\left(3v^2\right)=15mv^2\right)$		NB: $15mv^2=\frac{5}{3}mu^2$
	$\lambda=15$	A1	Correct only. Accept $15mv^2$
		(3)	

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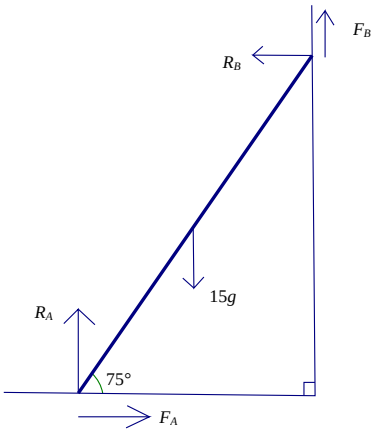
Question	Scheme	Marks	Notes
5a			
	Moments about A:	M1	Dimensionally correct. Include all relevant terms. Condone sign error(s) and sin/cos confusion.
	$15g \times 3\cos 75°$ $= F_B \times 6\cos 75° + R_B \times 6\sin 75°$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation
	$15g \times 3\cos 75°$ $= R_B \times 1.2\cos 75° + R_B \times 6\sin 75°$	M1	Use of $F_B = 0.2R_B$ in their attempt at the moments equation. Seen in part (a), not just on the diagram.
	$R_B = 19$(N) or $R_B = 18.7$(N)	A1	2 sf or 3 sf Ignore if go on to find the total force at A
		(5)	
5b	They need to form 2 equations. Mark them in the order seen. M1A1 for each correct equation		
	Resolve horizontally:	M1	First equation. Include all relevant terms. Dimensionally correct. Condone sign error(s) and sin/cos confusion
	$F_A = R_B (= 18.6925.....)$	A1	Correct unsimplified equation
	Resolve vertically:	M1	Second equation. Include all relevant terms. Dimensionally correct. Condone sign error(s) and sin/cos confusion
	$R_A + F_B = 15g \quad (R_A = 143.26...)$	A1	Correct unsimplified equation
	M1A1 for alternatives e.g. moments about B		$15g \times 3\cos 75°$ $= R_A \times 6\cos 75° - F_A \times 6\sin 75°$
	Use $F_A = \mu R_A$ to solve for μ	D M1	Dependent on the 2 preceding M marks
	$\mu = 0.13$ or better	A1	g cancels (0.1304784…)
		(6)	

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Question	Scheme	Marks	Notes
6a	Equation of motion	M1	Need all terms and dimensionally correct
	$F-600=900\times 2$	A1	Correct unsimplified equation
	$\frac{24000}{V}-600=1800$	M1	Use of $24000=FV$ Allow with 24 for 24000 or with a 0 missing
	$V=10$	A1	Correct only
		(4)	
6b	Equation of motion	M1	Need all terms and dimensionally correct. Mark omission of g as an accuracy error, not a dimension error. Condone sign error(s) and sin/cos confusion If they form separate equations for each vehicle they need both equations and to eliminate T to score the M1
	$F-(700+900)g\sin\theta-(550+600)=1600a$ $\left(\frac{24000}{8}-(1600)g\sin\theta-1150=1600a\right)$	A1 A1	Unsimplified combined equation with at most one error – allow with F Correct combined unsimplified equation with correct substitution for F
	$a=0.456\quad(0.46)\left(\text{ms}^{-2}\right)$	A1	2 sf or 3 sf not $\frac{73}{160}$
		(4)	
6c	Work-energy equation	M1	Must be work-energy. Must be using the mass of the trailer only and the resistance for the trailer only. Dimensionally correct. All relevant terms, no duplication of terms and no extras. Condone sign error(s) and sin/cos confusion.
	$\frac{1}{2}\times 700\times 9^2=550d+700gd\sin\theta$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation
	$d=27\quad(27.3)$	A1	2 sf or 3 sf
		(4)	

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Question	Scheme	Marks	Notes
7a	Energy equation	M1	Q requires energy. Need all terms and dimensionally correct. Condone sign error.
	$\frac{1}{2}mv^2 = \frac{1}{2}m(9+4) + mg \times 20$	A1	Correct unsimplified equation
	$v = 20\,(20.1)\,(\text{ms}^{-1})$	A1	2 sf or 3 sf only. Not $9\sqrt{5}$
		(3)	
7b	Complete method to find the direction as an angle	M1	Complete method to find trig ratio for a relevant angle
	$\cos\alpha = \frac{3}{\text{their (a)}}$	A1ft	Correct unsimplified equation for a relevant angle. Follow their part (a)
	$\alpha = 81°\,(81.4°)$ below the horizontal	A1	Or equivalent. 2 sf or 3 sf. Needs to be clear on a diagram or in words where the angle is measured. Accept "to the horizontal"
		(3)	
7b alt	Complete method to find the direction as a vector in **i** and **j** or as a column vector	M1	
	Component = $\sqrt{(a)^2 - 9}$	A1ft	Correct unsimplified equation. Follow their part (a)
	Direction $3\mathbf{i} - 19.9\mathbf{j}$	A1	2 sf or 3 sf. ISW after correct vector seen
		(3)	
7c	Form an equation in t	M1	Complete method using *suvat* Condone sign errors.
	e.g. $-20 = 2t - \frac{1}{2}gt^2$ or $(-20.1...)\sin\alpha = 2 - gt$	A1	Correct unsimplified equation
	$t = 2.2\,(2.23)\,(\text{s})$	A1	2 sf or 3 sf only
		(3)	
7d	Perpendicular velocity $= 3\mathbf{i} - \lambda\mathbf{j}$	B1	Horizontal component unchanged and vertical not equal to ± 2. Seen or implied
	$(3\mathbf{i} + 2\mathbf{j}).(3\mathbf{i} - \lambda\mathbf{j}) = 0$	M1	Complete method to solve for vertical component If using angles, they should be using $56.3°$ for the perpendicular direction.
	$\Rightarrow \mathbf{v} = \left((3\mathbf{i}) - \frac{9}{2}\mathbf{j}\right)(\text{ms}^{-1})$	A1	Correct vertical component seen or implied
	Use of *suvat* or use of energy to find relevant distance	dM1	Complete method to find the vertical component of perpendicular velocity. Dependent on the previous M1 Working with $3\mathbf{i} - 2\mathbf{j}$ is not equivalent work
	$\left(\frac{9}{2}\right)^2 = 2^2 + 2gs$ or $\frac{1}{2}m(13) + mgs = \frac{1}{2}m\left(9 + \frac{81}{4}\right)$	A1	Correct unsimplified equation for their distance
	$h = 20 - s = 19\,(19.2)$	A1	2 sf or 3 sf
		(6)	

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