Mark Scheme (Results)

October 2023

Pearson Edexcel International Advanced Level in Mechanics (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.

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

- 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.

General Principles for Mechanics Marking

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

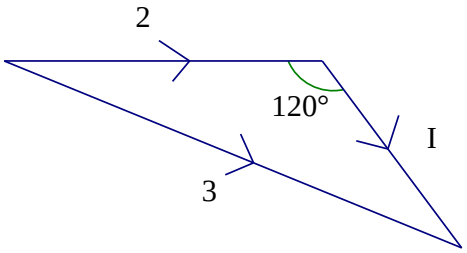
- Rules for M marks:
  - correct no. of terms;
  - dimensionally correct;
  - all terms that need resolving (i.e. multiplied by cos or sin) are resolved.
- Omission or extra g in a resolution is an accuracy error not method error.
- Omission of mass from a resolution is a method error.
- Omission of 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

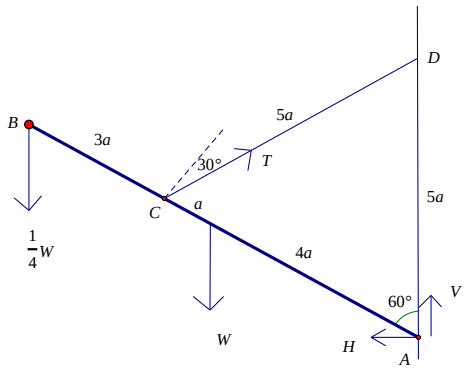
Question	Scheme	Mark	Notes
1	Accept column vectors throughout this question		
1a	Differentiate **r** (both components)	M1	In each component at least one power going down by 1
	$\mathbf{v}=\left(4t^3-16t\right)\mathbf{i}+\left(12t-3\sqrt{t}\right)\mathbf{j}$	A1	Accept as two separate components
	Equate **i** component of **v** to zero and solve for *t*	DM1	Dependent on the first M1. Must start with a component of the vector for **v** Can have more than one value at this stage.
	Obtain $\left(24-3\sqrt{2}\right)\mathbf{j}\ \left(\text{m s}^{-1}\right)$	A1	Accept $20\mathbf{j}\left(\text{m s}^{-1}\right)$ or better. (19.757359…) Correct answer only Answer must be a vector
		[4]	
1b	Differentiate **v** (both components)	M1	For differentiating their **v**, even if the method for obtaining it was incorrect. Their **v** must be a vector. In each component at least one power going down by 1
	Obtain $\mathbf{a}=\left(12t^2-16\right)\mathbf{i}+\left(12-\frac{3}{2}t^{-\frac{1}{2}}\right)\mathbf{j}$	A1	Any equivalent form for acceleration
	Obtain $176\mathbf{i}+\frac{45}{4}\mathbf{j}\left(\text{m s}^{-2}\right)$	A1	Accept $180\mathbf{i}+11\mathbf{j}\left(\text{m s}^{-2}\right)$ or better ISW
		[3]	
		(7)	

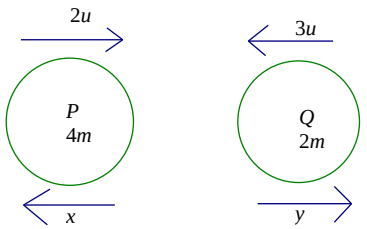
Question	Scheme	Mark	Notes
2a	<table><tr><td></td><td>*PQUY*</td><td>*RSTU*</td><td>*VWXY*</td></tr><tr><td>Mass</td><td>$16a^2$</td><td>$2\times4a^2$</td><td>$2\times4a^2$</td></tr><tr><td>From *PX*</td><td>$2a$</td><td>$5a$</td><td>a</td></tr></table>	B1 B1	Correct mass ratios (accept 2:1:1) Correct vertical distances
	Moments about *PX* or a parallel axis	M1	Dimensionally correct equation. All terms required Allow for an equation within a vector equation.
	$16a^2\times2a+8a^2\times5a+8a^2\times a=32a^2d$ $\left(=(16+8+8)a^2\times d\right)$ or equivalent for a parallel axis	A1	Correct unsimplified equation Allow for an equation within a vector equation. Could have *y* for *d* here o.e.
	$80a=32d\Rightarrow d=\frac{5}{2}a$ *	A1*	Obtain given answer from correct working. At least one stage of simplifying the moments equation is required. e.g. $32a^3+40a^3+8a^3$ seen, or they might have simplified the mass ratios at the start. Must get to $d=\ldots$ in the final line
		[5]	
2b	Moments about *PQ* or a parallel axis	M1	Dimensionally correct equation. All terms required
	$16a^2\times2a+8a^2\times3a+8a^2\times5a$ $=(16+8+8)a^2\times h$ or equivalent for a parallel axis	A1ft A1	Unsimplified equation with at most one error. Follow their mass ratios. Correct unsimplified equation
	$\Rightarrow h=3a$ from *PQ*	A1	a from *YT*, $3a$ from *XW*
	The working for the first 4 marks must be seen or used in part (b)		
	Correct use of trig. to find the tangent of a relevant angle.	M1	With *their* $3a$ e.g. $\tan\theta=\frac{3}{4-\frac{5}{2}}$
	$\tan\theta=2$	A1	Correct only
		[6]	
2c	Complete method to obtain an equation in *M* and *F*	M1	e.g. *M*oments about *Q* Dimensionally correct equation.
	$3a\times Mg=4a\times F$	A1	Correct unsimplified equation Condone if *a* missing throughout
	$F=\frac{3}{4}Mg$	A1	Correct only
		[3]	
		(14)	

Question	Scheme	Mark	Notes
3	Form impulse-momentum equation	M1	Dimensionally correct. Accept answers in "vector" form, or as separate components. Condone sine / cosine confusion.
	One correct equation	A1	e.g. one correct component of $\begin{pmatrix} I\cos 60° \\ I\sin 60° \end{pmatrix} = \frac{1}{4}\left[\begin{pmatrix} 12\cos\alpha \\ 12\sin\alpha \end{pmatrix} - \begin{pmatrix} 8 \\ 0 \end{pmatrix}\right]$ or $\left(= \begin{pmatrix} 3\cos\alpha - 2 \\ 3\sin\alpha \end{pmatrix}\right)$ $\begin{pmatrix} I\cos 60° \\ I\sin 60° \end{pmatrix} = \frac{1}{4}\left[\begin{pmatrix} v_x \\ v_y \end{pmatrix} - \begin{pmatrix} 8 \\ 0 \end{pmatrix}\right]$ $\left(= \begin{pmatrix} 3\cos\alpha - 2 \\ 3\sin\alpha \end{pmatrix}\right)$ if working parallel and perpendicular to the initial direction or one of $8\sin 60° = 12\cos(30° + \alpha)$ or $I = 0.25(12\sin(30° + \alpha) - 8\cos 60°)$ if working parallel and perpendicular to the impulse
	Form a second impulse-momentum equation	M1	
	correct second equation	A1	
	Complete method to solve for I	DM1	Dependent on the two preceding M marks. e.g. from $36 = (I+4)^2 + 3I^2 \quad (4I^2 + 8I - 20 = 0)$
	$I = \sqrt{6} - 1$ (or 1.45 or 1.4)	A1	
		[6]	
3 alt		**M1**	Use of $I = mv - mu$ to draw a vector triangle. Dimensionally consistent.
		A1	Correct diagram
	Form an equation in I	**M1**	e.g. by using cosine rule
	$4 + I^2 - 4I\cos 120° = 9$	**A1**	Correct unsimplified equation A correct cosine rule equation can imply the first M1A1 if no diagram seen
	Solve for I	**DM1**	Dependent on the 2 preceding M marks $I^2 + 2I - 5 = 0$
	$I = \sqrt{6} - 1$ (or 1.45 or 1.4)	**A1**	
		(6)	

Question	Scheme	Mark	Notes
4a	$4 - gT_1 = 0$ or $T_1 = \dfrac{\sqrt{32}\sin 45°}{g}$	M1	Complete method using *suvat*
	$T_1 = 0.408\,(0.41)$	A1	3 sf or 2 sf only. Not $\frac{20}{49}$
		[2]	
4b	Height of Q above P:	M1	Complete method using *suvat* and 7 and 4 for the initial vertical components
	$h = \left(7T_1 - \frac{1}{2}gT_1^2\right) - \left(4T_1 - \frac{1}{2}gT_1^2\right) \quad (= 3T_1)$	A1	Correct unsimplified expression in T_1 or their T_1 They do not need to have substituted for T_1 (2.0408… - 0.8163…)
	$h = 1.2$ (m)	A1ft	2 sf only $(3 \times \textit{their}\ T_1)$
		[3]	
4c	Correct time for P to reach B. ($\frac{40}{49}$, 0.816, or $\frac{8}{g}$ or better)	B1	Seen or implied.
	Vertical component of speed $= 7 - g \times 2T_1 \quad (= -1)$	M1	Complete method using *suvat* with $2T_1$ or their t for the time at B M0 if not using 7
	$\tan\alpha = \pm\dfrac{\textit{their}\ 1}{5}$	M1	Correct use of *their* 1 and 5 to find an equation in a relevant angle (e.g. 90 – α)
	$\alpha = 11$	A1	11 or better (e.g. 11.3)
	If they use T_1 in place of $2T_1$ can score B0M0M1A0		
		[4]	
4d	Form an equation in T_2 only	M1	Complete method using *suvat* and perpendicular gradients. e.g. $\begin{pmatrix}5\\7\end{pmatrix}\cdot\begin{pmatrix}5\\7-gT_2\end{pmatrix} = 0$ Condone sign errors (Vertical component of speed $= \pm\frac{25}{7}$) (perpendicular direction is downwards at 35.5° to the horizontal)
	$-\dfrac{25}{7} = 7 - gT_2$	A1	Correct unsimplified equation
	$T_2 = 1.08$ or $T_2 = 1.1$	A1	3 sf or 2 sf only
		[3]	
		(12)	

Question	Scheme	Mark	Notes
5a	Use of $P = Fv$ $\left(F = \frac{500}{6}\right)$	M1	
	Equation of motion	M1	Dimensionally correct. Required terms and no extras
	$F - 60 = 80a$	A1	Correct unsimplified equation in F
	$a = \frac{7}{24}\left(\text{m s}^{-2}\right)$	A1	0.29 or better (0.291666666..)
		[4]	
5b	Gain in KE = $\frac{1}{2} \times 80 \times 8^2 \text{(J)} \left(= 2560\text{(J)}\right)$ Gain in GPE = $80 \times 9.8 \times 300 \text{ (J)} \left(= 235200\text{(J)}\right)$ Work done against resistance $= 20\,000 \times 60$	B1 B1	Any one correct (seen or implied) A second term correct (seen or implied) (KE gain + GPE gain = 237760 J)
	Use of *suvat* and $F = ma$ is M0A0A0		
	expression for combined work and energy	M1	All terms required and no double counting. Mass replaced with 80. Condone sign errors. Dimensionally correct. Condone error in zeros in $20\,000$
	Total work done $= 40 \times 64 + 80 \times 9.8 \times 300 + 20\,000 \times 60$	A1	Correct unsimplified expression for the work done
	$1440\left(\text{kJ}\right)$ or $1400\left(\text{kJ}\right)$	A1	Accept answers in joules. 3 sf or 2 sf (1437760)
		[5]	
5c	Equation of motion	M1	Dimensionally correct. Required terms and no extras
	$F - 60 - 80g \times \sin\alpha = 0$ $\frac{P}{7} - 60 - 80g \times \frac{1}{20} = 0$	A1 A1	Unsimplified equation in P or F with at most one error Correct unsimplified equation in P
	$P = 694$ or $P = 690$	A1	3sf or 2 sf only
		[4]	
		(13)	

Question	Scheme	Mark	Notes
6a			
	Moments about A: **M0 if there is no resolving**	M1	Need all terms and no extras. Dimensionally consistent. Condone sign errors and sine/cosine confusion.
	$4a\cos 30°\times W+8a\cos 30°\times\frac{W}{4}$ $=5a\cos 30°\times T$	A1	Correct unsimplified equation
	$6W=5T\Rightarrow T=\frac{6}{5}W$ *	A1*	Obtain **given answer** from correct working, e.g. show cancelling of the common factors or some simplification of the moments equation
		[3]	
6b	They need 2 equations. Award M1A1 for the first correct equation seen and M1A1 for the second correct equation. Common alternatives: $M(B)$: $T\cos 30°\times 3a+V\cos 30°\times 8a=W\cos 30°\times 4a+H\cos 60°\times 8a$ $M(C)$: $W\cos 30°\times a+H\cos 60°\times 5a=\frac{1}{4}W\cos 30°\times 3a+V\cos 30°\times 5a$ Perpendicular to rod: $\frac{1}{4}W\cos 30°+W\cos 30°+H\cos 60°=T\cos 30°+V\cos 30°$ Parallel to rod: $\frac{1}{4}W\cos 60°+T\cos 60°+W\cos 60°=V\cos 60°+H\cos 30°$		
	First equation dimensionally correct. Condone sine/cosine confusion and sign errors	M1	e.g. Resolve horizontally
	Correct unsimplified equation	A1	$H=T\cos 30°\quad\left(H=\frac{3\sqrt{3}}{5}W\right)$
	Second equation dimensionally correct. Condone sine/cosine confusion and sign errors	M1	e.g. resolve vertically
	Correct unsimplified equation	A1	$V+T\cos 60°=W+\frac{W}{4}\quad\left(V=\frac{13}{20}W\right)$
	$\lvert R\rvert=\sqrt{V^2+H^2}$ or $\lvert R\rvert^2=V^2+H^2$	DM1	Correct use of Pythagoras Dependent on two preceding M marks.
	$\lvert R\rvert=\frac{W}{20}\sqrt{3\times 144+169}=\frac{\sqrt{601}}{20}W$	A1	$1.2W$ or better (1.22576…)
		[6]	
		(9)	

Question	Scheme	Mark	Notes
7a			
	Equation for CLM	M1	Dimensionally correct. All terms required. Condone sign errors.
	$8mu-6mu=2my-4mx$ $(u=y-2x)$	A1	Correct unsimplified equation
	Equation for kinetic energy ($\frac{1}{2}$ or 2 must be used)	M1	Dimensionally correct. Correct masses paired with correct velocities. All terms required. No sign errors. Condone 2 on the wrong side.
	$2mx^2+my^2=\frac{1}{2}(2m\times4u^2+m\times9u^2)$ $(17u^2=4x^2+2y^2)$	A1	Correct unsimplified equation
	Solve for y: $17u^2=2y^2+(y-u)^2$ $\Rightarrow 3y^2-2yu-16u^2=0$	DM1	Some working must be shown to obtain the quadratic in y (and u). Dependent on the preceding M marks $((3y-8u)(y+2u)=0)$
	$\Rightarrow y=\frac{8}{3}u$ *	A1*	Obtain given answer from correct working
		[6]	
7b	Use of Impact Law: $x+y=e\times5u$	M1	Condone sign errors but must be used the right way round.
	$e=\dfrac{\frac{1}{2}\left(\frac{8}{3}u-u\right)+\frac{8}{3}u}{5u}$	A1	Correct unsimplified equation. $\left(x=\dfrac{5u}{6}\right)$
	$=\dfrac{7}{10}$	A1	Correct only
		[3]	
7c	Velocity of Q after impact $=f\times\dfrac{8}{3}u$	B1	Allow $\pm$
	No collision if $f\times\frac{8}{3}u\le\frac{5}{6}u$ i.e. speed of $P\ge$ speed of Q	M1	Correct inequality with their values Accept strict inequality. Dimensionally correct.
	$\Rightarrow 0<f\le\frac{5}{16}$	A1	Both ends required. $(0<f\le0.3125)$
		[3]	
7d	Use of $I=\pm2m\left(y-\left(-\dfrac{1}{4}y\right)\right)$	M1	Subtraction seen or implied with *their* $\frac{1}{4}y$ Requires correct mass Requires correct impact law
	$\lvert I\rvert=\dfrac{20}{3}mu$	A1	Or equivalent. Must be positive $6.7mu$ or better Condone $-\dfrac{20}{3}mu\rightarrow\dfrac{20}{3}mu$ with no explanation
		[2]	
		(14)	

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