Mark Scheme (Results)

October 2021

Pearson Edexcel International A 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.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

PEARSON EDEXCEL IAL MATHEMATICS

General Instructions for Marking

1. The total number of marks for the paper is 75

2. The Edexcel Mathematics mark schemes use the following types of marks:

- **M** marks: Method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
- **A** marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
- **B** marks are unconditional accuracy marks (independent of M marks)
- Marks should not be subdivided.

3. Abbreviations

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

   - bod – benefit of doubt
   - ft – follow through
   - the symbol $\surd$ will be used for correct ft
   - cao – correct answer only
   - cso - correct solution only. There must be no errors in this part of the question to obtain this mark
   - isw – ignore subsequent working
   - awrt – answers which round to
   - SC: special case
   - oe – or equivalent (and appropriate)
   - d… or dep – dependent
   - indep – independent
   - dp decimal places
   - sf significant figures
   - * The answer is printed on the paper or ag- answer given
   - $\sqsubset$ or d… The second mark is dependent on gaining the first mark

4. 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.

5. 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.

6. 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.

7. Ignore wrong working or incorrect statements following a correct answer.

General Principles for Mechanics Marking

(But note that 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.

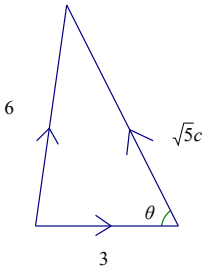
- Misreads – if a misread does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, bearing in mind that after a misread, the subsequent A marks affected are treated as A ft

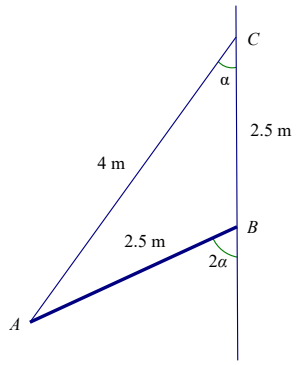
- Mechanics Abbreviations

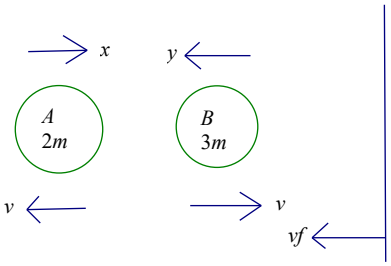
  M(A) Taking moments about A.
  N2L Newton's Second Law (Equation of Motion)
  NEL Newton's Experimental Law (Newton's Law of Impact)
  HL Hooke's Law
  SHM Simple harmonic motion
  PCLM Principle of conservation of linear momentum
  RHS, LHS Right hand side, left hand side.

Q	Solution	Mark	Guidance
1a	$F = \mu R = \frac{1}{5}mg\cos\alpha$	B1	Seen or implied
	Work done = force x distance	M1	Correct method for work done against friction
	$= \frac{1}{5}mg \times \frac{12}{13} \times d = \frac{12}{65}mgd$ *	A1*	Obtain **given answer** from correct working.
		(3)	
1b	Work-energy equation	M1	All terms required and dimensionally correct. Condone sign errors and sin/cos confusion
	$\frac{1}{2}mv^2 = mg \times d \times \frac{5}{13} - \frac{12}{65}mgd \left(= \frac{13}{65}mgd \right)$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation
	$v = \sqrt{\frac{2gd}{5}}$	A1	Or exact equivalent e.g. $\sqrt{\frac{26}{65}gd}$, $\frac{1}{5}\sqrt{10gd}$ Accept $0.63\sqrt{gd}$ or better
		(4)	
		[7]	
2	Equation of motion down the slope	M1	First equation (either direction). Condone sign errors and sin/cos confusion
	$F_1 + 450g \times \frac{1}{15} - R = 450 \times 0.5$ $\left(\frac{P}{12} + 30g - R = 225 \right)$ $\left(\frac{P}{12} - R = -69 \right)$	A1 A1	Unsimplified equation with at most one error. Correct unsimplified equation in P or F_1
	Equation of motion up the slope	M1	Second equation. Condone sin/cos confusion. Signs consistent with first equation and change in direction of motion
	$F_2 - 450g \times \frac{1}{15} - R = 450 \times -0.5$ $\left(\frac{P}{6} - 30g - R = -225 \right)$ $\left(\frac{P}{6} - R = 69 \right)$	A1	Correct unsimplified equation in P or F_2
	$F_1 = \frac{P}{12}$ or $F_2 = \frac{P}{6}\left(= \frac{2P}{12} \right)$	M1	Use of $P = Fv$ at least once
	Solve for P	DM1	Dependent on all previous M marks
	$\left(R = \frac{P}{8} \right)$ $P = 1660$ or $P = 1700$	A1	3 sf or 2 sf (follows use of 9.8) Allow 1.66 kW but not 1.66
		(8)	
		[8]	

3a	Use of $v = \dfrac{\mathrm{d}x}{\mathrm{d}t}$	M1	Recognisable attempt to differentiate the given expression
	$0 = 7t^{\frac{1}{2}}\left(t^2 - 5t + 4\right)$	DM1	Set $v = 0$ and solve for t Dependent on first M1
	$t = 1$ and $t = 4$	A1	Correct solution only
		(3)	
3b	$s = \lvert x_1 - x_0 \rvert + \lvert x_4 - x_1 \rvert$	M1	Correct strategy to find distance for their value(s) of t in $[0,4]$ **Allow M1 if there is no change of direction in the interval**
	$= \left\lvert \dfrac{20}{3} - 0 \right\rvert + \left\lvert -\dfrac{128}{3} - \dfrac{20}{3} \right\rvert$	A1ft	Correct unsimplified expression for their distance (provided there was a change in direction in [0, 4]) **Clearly using $x(4) + 2x(1)$ but $x(4)$ miscalculated so correct combined expression never seen. M1 only**
	$= 56$	A1	Correct solution only
		(3)	
3c	Use of $a = \dfrac{\mathrm{d}v}{\mathrm{d}t}$	M1	Recognisable attempt to differentiate
	$a = \dfrac{35}{2} \times 4^{\frac{3}{2}} - \dfrac{105}{2} \times 4^{\frac{1}{2}} + 14 \times 4^{-\frac{1}{2}}$	M1	Substitute $t = 4$ in their a and simplify
	$= 42$	A1	Correct solution only
		(3)	
		[9]	

4	Use of $\mathbf{I} = m(\mathbf{v} - \mathbf{u})$	M1	As a single vector equation or two separate equations.
	$c\begin{pmatrix}-1\\2\end{pmatrix} = \frac{3}{4}\mathbf{v} - \begin{pmatrix}3\\0\end{pmatrix}$ $\left(\mathbf{v} = \frac{4}{3}\begin{pmatrix}3-c\\2c\end{pmatrix}\right)$	A1	Any equivalent substituted form
	Use of Pythagoras	M1	
	$64 = \frac{16}{9}\left((3-c)^2 + 4c^2\right)$	A1	Correct unsimplified equation in c or a component of $\mathbf{v}$. $\left(5a^2 - 32a = 0 \text{ or } 5b^2 - 16b - 192 = 0\right)$
	Simplify to 3 term quadratic and solve for c	M1	$5c^2 - 6c - 27 = 0$
	$c = 3 \quad \text{or} \quad c = -\frac{9}{5}(-1.8)$	A1	Correct only
		(6)	
4 Alt		M1 A1	Form vector triangle. Dimensionally correct Three correct lengths and $\lvert\cos\theta\rvert = \frac{1}{\sqrt{5}}$ seen or implied
	Use of cosine rule	M1	
	$36 = 9 + 5c^2 - 2\times 3\sqrt{5}c\cos\theta$	A1	Correct unsimplified equation in c with $\cos\theta$ or their $\cos\theta$
	Rearrange as 3 term quadratic and solve for c.	M1	$5c^2 - 6c - 27 = 0$
	$c = 3 \quad \text{or} \quad c = -\frac{9}{5}(-1.8)$	A1	Correct only
		(6)	
		[6]	

5a			
	Moments about B:	M1	Dimensionally correct Condone sin/cos confusion and errors in angles OR: Correct moments equation and resolution Resolving where required
	$T\times 2.5\sin\alpha = 70\times 1.25\sin 2\alpha$ Or $T\times 2.5\sin\alpha = 70\times 2\sin\alpha$ Or use similar triangles $T\times\frac{3}{2} = 70\times\frac{6}{5}$	A1 A1	Unsimplified equation in α with at most one error Correct unsimplified equation in α
	$T = 70\times\frac{4}{5} = 56(\text{N})$ *	A1*	Obtain **given answer** from correct exact working and no errors seen
		(4)	
5b	Resolve horizontally:	M1	First equation
	$H = T\sin\alpha\,(=33.6(\text{N}))$	A1ft	Correct unsimplified equation
	Resolve vertically	M1	Second equation
	$V + T\cos\alpha = 70 \quad (V = 25.2(\text{N}))$	A1ft	Correct unsimplified equation
	$V = \mu H$	M1	Use of $F = \mu R$ with their V, H
	$\mu = \frac{3}{4}$	A1	Correct only (no subst for g required)
		(6)	
5balt	Resolve parallel to the rod:	M1	
	$H\sin 2\alpha + 70\cos 2\alpha = 56\cos\alpha + V\cos 2\alpha$	A1ft	$(24H - 7V = 630)$
	Resolve perpendicular to the rod:	M1	
	$70\sin 2\alpha = 56\sin\alpha + V\sin 2\alpha + H\cos 2\alpha$	A1ft	$(24V + 7H = 840)$
	$V = \mu H$	M1	Use of $F = \mu R$ with their V, H
	$\mu = \frac{3}{4}$	A1	Correct only (no subst for g required)
		(6)	
		[10]	

6a			
	$5mv = 2m\left(v-\left(-x\right)\right)$	M1	Use of $I = mv - mu$
	$x = \frac{3v}{2}$	A1	Seen or implied
	$5mv = 3m\left(v-\left(-y\right)\right)$ or $2mx - 3my = 3mv - 2mv$	M1	Use of $I = mv - mu$ or use of CLM
	$y = \frac{2v}{3}$	A1	Seen or implied
	$2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$	M1	Correct use of impact law (not necessarily with values in terms of v) **Allow $v - v$ on LHS**
	$e = \frac{12}{13}$	A1	0.92 or better
		(6)	
6b	Speed of B after collision with wall $= vf$	B1	Seen or implied
	$2\times\frac{1}{2}\times 3m\left(y^2-\left(vf\right)^2\right) = \frac{1}{2}\times 2m\left(x^2-v^2\right)$	M1	Use KE to form an equation in f. Condone use of change in KE rather than loss **Condone 2 on wrong side**
	$3\left(\frac{4}{9}-f^2\right) = \left(\frac{9}{4}-1\right)$	A1	Correct unsimplified equation for f
	$\left(f^2 = \frac{1}{36}\right)\quad f = \frac{1}{6}$	A1	cao NB: $\frac{\sqrt{31}}{6}$ comes from inconsistent subtraction.
		(4)	
		[10]	

7a	Use of $\dfrac{2a\times\frac{1}{2}}{3\times\frac{\pi}{6}}\left(=\dfrac{2a}{\pi}\right)$	B1	Seen or implied
	Moments about *EC*:	M1	Dimensionally correct Condone use of a parallel axis
	$ad\times\dfrac{d}{2}=\dfrac{1}{6}\pi a^2\times\dfrac{2a}{\pi}\times\sin\dfrac{\pi}{6}$	A1	Correct unsimplified equation
	$\Rightarrow\left(d^2=\dfrac{a^2}{3}\right)\quad a=\sqrt{3}d$ *	A1*	Obtain **given answer** from correct working
		(4)	
7b	Mass ratios $\dfrac{a^2}{\sqrt{3}}:\dfrac{\pi a^2}{6}:\dfrac{a^2}{\sqrt{3}}+\dfrac{\pi a^2}{6}$	B1	Or equivalent. Seen or implied
	Moments about *BC*	M1	Dimensionally correct Condone use of a parallel axis
	$\dfrac{1}{\sqrt{3}}\times\dfrac{a}{2}+\dfrac{\pi}{6}\times\dfrac{2a}{\pi}\times\dfrac{\sqrt{3}}{2}=\left(\dfrac{1}{\sqrt{3}}+\dfrac{\pi}{6}\right)y$	A1ft	Correct unsimplified. Follow their $\dfrac{2a}{\pi}$
	Distance from *BC* = $y=\dfrac{6a}{6+\sqrt{3}\pi}$	A1	Or equivalent $\left(y=\dfrac{6d}{2\sqrt{3}+\pi}\right)$
	Use of trig to find a relevant angle	M1	
	$\tan\beta^{\mathrm{C}}=\dfrac{6}{6+\sqrt{3}\pi}\times\sqrt{3}\qquad\left(\dfrac{\bar{y}}{d}\right)$	A1ft	Or equivalent correct unsimplified equation for the required angle
	$\beta=0.737\quad(0.74)$	A1	0.74 or better $42.2°$ implies correct method
		(7)	
		[11]	

8a	Conservation of energy	M1	Need all three terms and dimensionally correct. Condone sign errors.
	$\frac{1}{2}m\times10^2+mgh=\frac{1}{2}m\times18^2$	A1	Correct unsimplified equation
	$h=11.4 \quad (11)$	A1	3 sf or 2 sf only $\left(\text{not } \frac{80}{7}\right)$
		(3)	
8b	Vertical distance	M1	Complete method using *suvat* to find angle of projection
	$10\sin\alpha\times2.5-\frac{1}{2}g\times2.5^2=-11.4$	A1ft	Follow their h
	$\alpha=50.2°$ or $10\sin\alpha=v_V=7.7678....$	A1	$50°$ or better (50.1618…) Accept $50.3°$ from11.4 Seen or implied Might see $\sin\alpha=\frac{43}{56}$ or $v_V=\frac{215}{28}$
	Horizontal distance $=10\cos\alpha\times2.5$ or $\sqrt{100-v_V{}^2}\times2.5$	M1	
	$=16.0 \quad (16)\,(\text{m})$	A1	3 sf or 2 sf only
		(5)	
8c	Using energy: $\frac{1}{2}m\times64+mgs=\frac{1}{2}m\times100$	M1	Complete method to find height above A
	$s=1.8367...$	A1	1.8 or better
	Use of suvat to form equation in t	M1	
	$1.84=10\sin50.2\times t-4.9t^2$	A1	Correct unsimplified equation
	Solve for t and find difference between roots	DM1	Complete method to find the required time Dependent on 2 previous M marks
	$T=0.98$ or 0.978	A1	2 sf or 3 sf
		(6)	
8c alt	Use of Pythagoras	M1	Complete method to find vertical component of speed
	Vertical speed $\sqrt{64-(10\cos\alpha)^2}=4.8...$	A1	Awrt 4.8 or better
	Use of $10\sin\alpha-gt=\pm v$ to find t	M1	
	$\begin{cases}10\sin50.2°-gt_1=4.8\\10\sin50.2-gt_2=-4.8\end{cases}$	A1	Correct unsimplified equations Could also find time to top
	$T=t_2-t_1=1.27..-0.29..$	DM1	Complete method to find the required time Dependent on 2 previous M marks
	$=0.98$ or 0.978	A1	Final answer. 2 sf or 3 sf
		(6)	
8calt	Use of Pythagoras to form quadratic in t	M1	
	$(10\sin\theta-gt)^2+(10\cos\theta)^2=64$	A1	

	Simplify and substitute for trig	M1	
	$36+9.8^2t^2-150.5t=0$	A1	
	$T=t_2-t_1=1.27..-0.29..$	DM1	Complete method to find the required time Dependent on 2 previous M marks
	$=0.98$ or 0.978	A1	Final answer. 2 sf or 3 sf
		[14]	

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