Mark Scheme (Results)

Summer 2022

Pearson Edexcel International Advanced Level In Mechanics 2 (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.

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
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) be dimensionally correct i.e. all the terms need to be dimensionally correct
e.g. 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 few of the A and B marks may be f.t. – follow through – marks.

3. General 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 √ 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)
- dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- * The answer is printed on the paper
- ⎿ 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

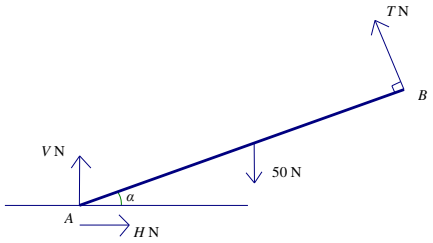
M(A)	Taking moments about A.
N2L	Newton's Second Law (Equation of Motion)
NEL	Newton's Experimental Law (Newton's Law of Impact)
HL	Hooke's Law
SHM	Simple harmonic motion
PCLM	Principle of conservation of linear momentum
RHS, LHS	Right hand side, left hand side

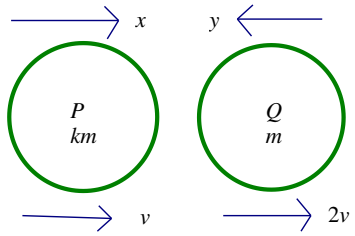
Q	Solution	Mark	Guidance
1a			**Allow column vectors.**
	Use of $\mathbf{v}=\dfrac{\mathrm{d}\mathbf{r}}{\mathrm{d}t}$	M1	Powers going down by 1. At least 2 powers going down .
	$\mathbf{v}=\left(3t^2-8\right)\mathbf{i}+\left(t^2-2t+2\right)\mathbf{j}$	A1	Any equivalent form
	Use of $\mathbf{a}=\dfrac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$	M1	Powers going down by 1. At least 2 powers going down .
	$\mathbf{a}=6t\mathbf{i}+\left(2t-2\right)\mathbf{j}$	A1	Any equivalent form
	$=24\mathbf{i}+6\mathbf{j}\left(\mathrm{m\,s^{-2}}\right)$	A1	Must see acceleration stated as a correct simplified vector. ISW
		[5]	
1b	Direction $2\mathbf{i}+\mathbf{j}$	M1	Form equation in t or T only using direction. Condone use of 2 on the wrong side. Using their **v**
	$\Rightarrow\left(3T^2-8\right)=2\left(T^2-2T+2\right)$ $\left(T^2+4T-12=0\right)$	A1ft	Correct unsimplified **equation** in t or T. **Solving not required for the M1** Follow their **v**: **i** component = 2(**j** component)
	$T=2$	A1	Only Do not need to see method of solution.
		[3]	
		(8)	

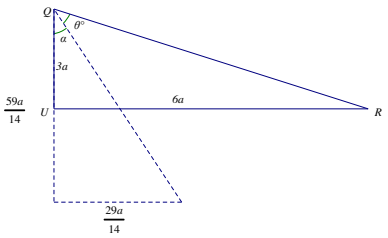
2a	Speed after first collision $=\frac{2}{3}u$	B1	Seen or implied (possibly on diagram)
	Speed after second collision $=\frac{4}{9}u$	B1	Seen or implied (possibly on diagram)
	Correct method for total time	M1	Correct formula, dimensionally correct and including all 3 elements.
	$T_1=\frac{d}{u}+\frac{3d}{\frac{2}{3}u}+\frac{2d}{\frac{4}{9}u}\quad\left(=\frac{d}{u}+\frac{9d}{2u}+\frac{18d}{4u}\right)$	A1	Correct unsimplified expression for T_1
	$T_1=\frac{10d}{u}$	A1	Correct single term. Allow unsimplified fraction e.g. $T_1=\frac{40d}{4u}$
		[5]	
2b	$T_2=\frac{10d}{\frac{4}{9}u}=\frac{45d}{2u}\quad\left(T_2=\frac{9}{4}T_1\right)$	B1ft	Follow through is on their T_1 and / or their $\frac{4}{9}u$ Any equivalent form e.g $\frac{90d}{4u}$.
		[1]	
		(6)	

3			**Allow column vectors**
	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	Must be subtracting
	$(\mathbf{I} =) \pm 0.5\left((4-\lambda)\mathbf{i} + (-\lambda)\mathbf{j}\right)$	A1	Accept $\pm$ correct unsimplified expression on right hand side. (Ignore the left hand side) Allow $2\mathbf{i} - \frac{\lambda}{2}(\mathbf{i}+\mathbf{j})$ or equivalent
	Use of magnitude to form an equation in one variable	M1	Correct use of Pythagoras
	$\frac{5}{2} = \frac{1}{4}\left((4-\lambda)^2 + (-\lambda)^2\right)$	A1ft	Follow their **I**
	$0 = 2\lambda^2 - 8\lambda + 6 \quad (= (2\lambda - 6)(\lambda - 1))$	DM1	Form a 3 term quadratic (seen or implied). Not necessarily stated "= 0" From $\mathbf{I} = a\mathbf{i} + b\mathbf{j}$ can obtain $4a^2 - 8a + 3 = 0$ or $4b^2 + 8b + 3 = 0$ Dependent on the preceding M1 **Solving not required for the M1.**
	$\lambda = 3$ and $\lambda = 1$	A1cso	**From correct solution only.** Do not need to see method of solution.
		[6]	
3alt	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$ to form a vector triangle	M1	
	Triangle with sides of length $\sqrt{\frac{5}{2}}$, $\lvert 2\mathbf{i}\rvert$ and $\left\lvert \frac{\lambda}{2}(\mathbf{i}+\mathbf{j}) \right\rvert$	A1	
	Use of cosine rule with $45°\left(\frac{\pi}{4}\right)$	M1	
	$\frac{5}{2} = 2^2 + \left(\frac{\lambda}{2}\right)^2 \times 2 - 2 \times 2 \times \frac{\lambda}{2}\sqrt{2}\cos 45°$	A1ft	Correct unsimplified equation Follow their magnitudes
	$0 = \lambda^2 - 4\lambda + 3 \quad (= (\lambda - 3)(\lambda - 1))$	DM1	Form a 3 term quadratic (seen or implied) Dependent on the preceding M1
	$\lambda = 3$ and $\lambda = 1$	A1	Correct solution only
		[6]	
		(6)	

4	Use of $F = \frac{P}{v}$	M1	Formula with a speed substituted correctly At least once.
	Equation for horizontal motion	M1	Dimensionally correct in P or F. Condone sign errors. Need all terms
	$\frac{P}{15} - R = -0.2 \times 900 \quad \left(\frac{P}{15} - R = -180\right)$	A1	Correct unsimplified equation in P and R
	Equation for motion down hill	M1	Dimensionally correct in P or F_D. Condone sign errors. Condone sin / cos confusion. Need all terms. M0 if using F(down) = F(horizontal)
	$F_D + 900g \times \sin\theta - R = 900 \times 0.4$ $\left(\frac{P}{12} + 30g - R = 360\right) \quad \left(\frac{P}{12} = R + 66\right)$	A1	Unsimplified equation in F_D or P and R with at most one error.
		A1	Correct unsimplified equation in (P and) R with trig substituted. e.g. $\frac{5}{4}(R - 180) = 360 - 30g + R$
	Solve for R	DM1	Dependent on the 3 preceding M marks. Condone slips in the algebra.
	$R = 1160 \quad \text{or} \quad R = 1200$	A1	3 sf or 2 sf only NB the answer follows the use of 9.8, so a final answer 1164 is A0. Clear use of 9.81 is a rubric infringement. It gives $(P = 14742 \text{ and}) \; R = 1162.8$ and scores a maximum of 7/8 (final A0)
		[8]	
		(8)	
	Some candidates work through with the two driving forces. They score M1M1 as above A1 for 4 x F(down) = 5 x F(horizontal) or equivalent M1A1 as above A1 for Correct unsimplified equation in R e.g. $\frac{5}{4}(R - 180) = 360 - 30g + R$ M1A1 as above		

5a			
	Moments about A	M1	Dimensionally correct equation i.e. force x distance = force x distance. Condone sin/cos confusion Mark 50g as an accuracy error
	$4T = 2\cos\alpha \times 50$ $\left(= 2\times\frac{4}{5}\times 50\right)$	A1	Correct unsimplified equation. Need to see $\cos\alpha$ **OR** $\frac{4}{5}$ Might see LHS = $T\cos\alpha\times 4\cos\alpha + T\sin\alpha\times 4\sin\alpha$
	$T = 20$ *	A1*	Obtain **given answer** from correct working. Must see $\frac{4}{5}$ used correctly.
		[3]	
5b	Resolve horizontally	M1	Condone sin/cos confusion
	$H = T\sin\alpha$	A1	Correct equation
	Resolve vertically	M1	Need all 3 terms. Condone sign error and sin/cos confusion.
	$T\cos\alpha + V = 50$	A1	Correct equation
	Either or both of the above equations could be replaced by a moments equation e.g. $\mathrm{M}(B): 4\cos\alpha\times V = 4\sin\alpha\times H + 2\cos\alpha\times 50$ or by resolving perpendicular & parallel to the rod: $T + V\cos\alpha = 50\cos\alpha + H\sin\alpha$ & $50\sin\alpha = H\cos\alpha + V\sin\alpha$		
	Use $F = \mu R$ to form an equation in μ	M1	$(H = \mu V)$ Used, not just stated i.e. they must get as far as substituting their values.
	$\mu = \frac{6}{17}$	A1	$\mu = 0.35$ or better Accept $\frac{12}{34}$
		[6]	
		(9)	

6a			
	They need to form three equations, one of which must be the impact law. Mark them as you see them, so the first M1A1 on epen is available for the first equation seen, the second M1A1is for the second equation seen etc. If there are more than 3 equations, mark this as multiple attempts and all the marks for the equations actually used in the solution. **Treat the second and third A marks as follow through marks if they are substituting values they have already found.**		
	Use of $I = mv - mu$ for P or Q	M1	Dimensionally correct. Need all terms. M0 if m is missing on RHS
	$5mv = m\left(2v - \left(-y\right)\right)$ or $-5mv = km\left(v - x\right)$	A1	Correct unsimplified equation
	Use of CLM or second use of $I = mv - mu$	M1	Dimensionally correct. Need all terms. In CLM allow cancelled m and extra common factor (eg g) throughout
	$kmx - my = kmv + 2mv$ $(kx - y = kv + 2v)$ or $-5mv = km\left(v - x\right)$	A1	Correct unsimplified equation
	Use of impact law	M1	Must be used with e on the correct side. Condone sign errors
	$2v - v = \frac{1}{5}\left(x + y\right)$	A1	Correct unsimplified equation
	$y = 3v$	A1	cao
	$x = 2v$	A1	cao
	$k = 5$	A1	cao
		[9]	
6b	KE lost	M1	Dimensionally correct. Accept change in KE. Not scored until they form the complete substituted equation.
	$= \frac{1}{2} \times km\left(x^2 - v^2\right) + \frac{1}{2} \times m\left(y^2 - 4v^2\right)$ $\left(= \frac{15}{2}mv^2 + \frac{5}{2}mv^2\right)$	A1ft	Correct unsimplified expression. Follow their x, y, k Condone sign change without explanation. $\left(\text{KE before} = 14.5mv^2\right.$ $\left.\text{KE after} = 4.5mv^2\right)$
	$= 10mv^2$	A1	Only
		[3]	
		(12)	

7a	<table><tr><td></td><td>*PQUV*</td><td>*URST*</td><td>*QRU*</td><td>total</td></tr><tr><td>Mass ratio</td><td>$9a^2$</td><td>$36a^2$</td><td>$18a^2$</td><td>$63a^2$</td></tr><tr><td>Displacement From *QT*</td><td>$-\frac{3a}{2}$</td><td>$3a$</td><td>$2a$</td><td>d</td></tr></table>	B1 B1	Correct mass ratios (1:4:2:7) Correct displacements from *QT* or a parallel axis seen or implied. Signs consistent
	Equation for moments about *QT* $18\times 2a+36\times 3a-9\times\frac{3a}{2}=63d$ $\left(4a+12a-\frac{3a}{2}=7d\right)$	M1 A1	(or a parallel axis) Dimensionally correct. Condone sign errors Or equivalent Correct unsimplified equation Check consistent in *a*.
	$d=\frac{29a}{2}\Big/7\left(=\frac{261a}{2}\Big/63\right)=\frac{29a}{14}$ *	A1*	Obtain **given answer** from correct working. Need to see at least one interim step with all the *a* terms collected. Check *a* is in final answer.
		[5]	
7b	Condone if "*a*" is missing throughout the working in part (b) because they have not been asked for the distance here.		
	Vertical distances from *Q*: $\frac{3a}{2}, 6a\left(=3a+3a\right), 2a, \left(v\right)$ From *T*: $7.5a, 3a, 7a$	B1	Seen or implied
	Equation for moments about *PQ*	M1	(Or a parallel axis) Dimensionally correct. Condone sign errors
	$9\times\frac{3a}{2}+18\times 2a+36\times 6a=63v$ $\left(\frac{3a}{2}+2\times 2a+4\times 6a=7v\right)$	A1	Correct unsimplified equation
	$v=\frac{59a}{14}$ $\left(\frac{67}{14}a \text{ above } T, \frac{17}{14}a \text{ below } U\right)$	A1	$4.2a$ or better (4.214…)
	The working for (a) and (b) might be combined in a vector equation. The marks for (b) are scored if the work is used in (b).		
			
	$\tan\alpha=\frac{29}{59}$ $\left(=26.175...°\right)$	M1	Use trig and their *v* to find a relevant angle Allow for $90°-26.17...°$

	$\theta° = \tan^{-1} 2 - \tan^{-1}\left(\frac{29}{59}\right)$	M1	Use their v to find the required angle $(63.43..° - 26.175..°)$
	$\theta = 37.3$	A1	37 or better
		[7]	
		(12)	
8a	Normal reaction between P and the ramp $= 3g\cos\alpha \quad \left(= \frac{18g}{\sqrt{37}} = 29.0\right)$	B1	cao ISW
	Use of $F = \frac{3}{4}R$	M1	$\frac{3}{4} \times$ their R (Must have an R)
	Work done $= 4F$	M1	Their F (Must have an F)
	$= 87.0\,(87)\,(\text{J})$	A1	3 sf or 2 sf only (follows 9.8) do not allow $\frac{54}{\sqrt{37}}g$ (this is an acceleration)
		[4]	
8b	Work-energy equation	M1	**M0 if not using work-energy**. All terms required. Condone sign errors Condone sin/cos confusion
	$\frac{1}{2} \times 3U^2 - \text{their(a)} - 3g \times 4\sin\alpha = \frac{1}{2} \times 3 \times 25$	A1ft A1ft	Unsimplified equation with at most one error. Follow their (a) Correct unsimplified equation Follow their (a)
	$U = 9.79$ or $U = 9.8$	A1	3 sf or 2 sf only (follows 9.8)
		[4]	
8c	Time taken:	M1	Complete method using *suvat* and $u = 5$ to form an equation in t only
	$-4\sin\alpha = (5\sin\alpha)t - \frac{1}{2}gt^2$ $\left(4.9\sqrt{37}t^2 - 5t - 4 = 0\right)$	A1	Correct unsimplified equation for t.
	$t = 0.45969....$	A1	Seen or implied
	Horizontal distance	M1	Complete method using *suvat* and $u = 5$
	$= (5\cos\alpha)t \quad \left(= \frac{30}{\sqrt{37}}t\right)$	A1ft	Follow their t
	$= 2.27$ or 2.3 (m)	A1	3 sf or 2 sf only
		[6]	
	Alternative: First M1A1 as above Second M1A1 as above Second A1 correct quadratic in horizontal distance e.g. $\frac{37\times4.9}{35\times25}d^2 - \frac{1}{6}d - \frac{4}{\sqrt{37}} = 0$ Final A1 as above		
		(14)	

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