Mark Scheme (Results)

January 2022

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
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 $\surd$ 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)
- dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- $*$ The answer is printed on the paper
- $\underline{}$ 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

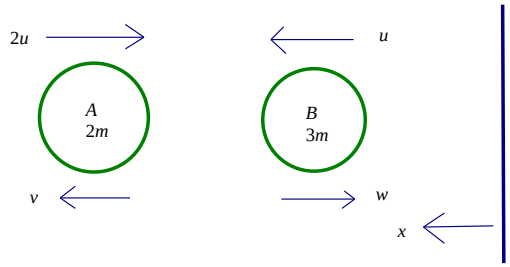
  PCLM Principle of conservation of linear momentum

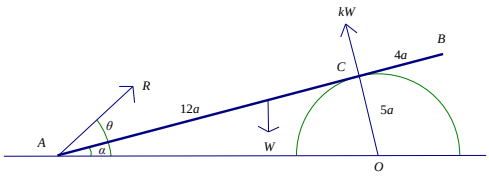
  RHS, LHS Right hand side, left hand side

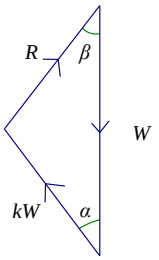
1a	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	Condone subtraction in the wrong order.
	$\begin{pmatrix} -4 \\ 6 \end{pmatrix} = \frac{1}{2}\begin{pmatrix} x-2 \\ y-4 \end{pmatrix}$	A1	Correct unsimplified equation Any equivalent form. Allow with **v**
	$\mathbf{v} = -6\mathbf{i} + 16\mathbf{j}\left(\text{m s}^{-1}\right)$	A1	Correct only. Seen or implied SR: Allow 3/3 if stop at $\mathbf{v} = 6\mathbf{i} - 16\mathbf{j}\left(\text{m s}^{-1}\right)$
	$\lvert\mathbf{v}\rvert = \sqrt{(-6)^2 + 16^2}$	M1	Correct use of Pythagoras with their **v**
	$= \sqrt{292}\ \left(= 2\sqrt{73}\right)\left(\text{m s}^{-1}\right)$	A1	Correct simplified value. 17 or better (17.088……)
			Allow 5/5 if working from the negative of the velocity.
		[5]	
1b	Correct use of trigonometry to find 2 relevant angles - as values or in inverse tangent form	M1	For their **v** e.g. $\pm 69.44..°, 63.43..°$ or $\pm 1.212..., 0.4636..$
	$\theta = \left(180° - \tan^{-1}\frac{16}{6}\right) - \tan^{-1}\frac{4}{2}$	A1ft	Correct unsimplified expression for θ Any equivalent form
	$= 47°$	A1	$47°$ or better (47.121..) $312.9°$ Accept radians (0.8224..)
		[3]	
1b alt	Use of scalar product with two relevant vectors	M1	For their **v**
	$\theta = \cos^{-1}\left(\frac{-12+64}{\sqrt{20}\sqrt{292}}\right)$	A1ft	Correct unsimplified expression for $\cos\theta$ or equivalent
	$= 47°$	A1	$47°$ or better (47.121..) $312.9°$ Accept radians (0.8224..)
		[3]	
		(8)	

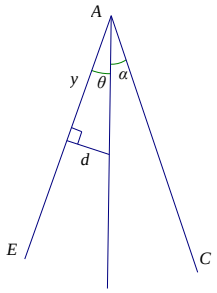
2.a	Equation of motion for car and trailer	M1	Need all terms. Dimensionally correct. Condone sin/cos confusion and sign errors.
	$F-300-150-\frac{200g}{20}-\frac{600g}{20}=0$ $\left(F-842=0\right)$	A1 A1	Unsimplified equation in P or F with at most one error Correct unsimplified equation in P or F Missing g is one accuracy error
	$\frac{1000P}{15}\left(-450-98-294=0\right)$	M1	Use of $P=Fv$ Allow with P or $1000P$
	$P=12.6$ or $P=13$	A1	3 s.f. or 2 s.f. only A final answer of 12600 (13000) scores 4/5 Condone 12600=12.6 (correct thinking without stating the units)
		[5]	
2b	KE lost = gain in GPE + WD against resistance	M1	Must be using work-energy principle for trailer only. Dimensionally correct. Correct terms and no extras. Condone sign errors and sin / cos confusion.
	$\frac{1}{2}\times 200\times 400=\frac{200}{20}gd+300d\left(=398d\right)$	A1 A1	Correct unsimplified equation in one variable with at most one error Correct unsimplified equation in one variable.
	$XY=d=101\ \left(100\right)$ (m)	A1	3 s.f. or 2 s.f. only
		[4]	
		(9)	

3a	Use of $\mathbf{a} = \frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$ $\left(\mathbf{a} = 18\cos 3t\,\mathbf{i} - 2\sin t\,\mathbf{j}\right)$	M1	Differentiate to obtain $\mathbf{a} = \lambda\cos 3t\,\mathbf{i} + \mu\sin t\,\mathbf{j}$
	Use of $\mathbf{F} = m\mathbf{a}$: $\mathbf{F} = \frac{1}{4}\mathbf{a}$	M1	Must be working in vectors
	$\mathbf{F} = \frac{9}{2}\cos 3t\,\mathbf{i} - \frac{1}{2}\sin t\,\mathbf{j}$	A1	Or equivalent. e.g. as a column vector
		[3]	
3b	$2\cos t + 1 = 0$	M1	Set **j** component of **v** = 0 and solve for t
	$\Rightarrow t = \frac{2\pi}{3}$	A1	ISW if correct answer seen. Only answer $120°$ scores A0 here and the final A0
	Use of $\mathbf{v} = \frac{\mathrm{d}\mathbf{r}}{\mathrm{d}t}$ $\left(\mathbf{r} = -2\cos 3t\,\mathbf{i} + \left(t + 2\sin t\right)\mathbf{j}\left(+\mathbf{C}\right)\right)$	M1	Integrate **v** with respect to t to obtain $\mathbf{r} = p\cos 3t\,\mathbf{i} + \left(t + q\sin t\right)\mathbf{j}\left(+\mathbf{C}\right)$ Condone if there is no constant of integration.
	$t = 0,\quad \mathbf{r} = \left(4\mathbf{i} - \sqrt{3}\mathbf{j}\right)\mathrm{m}$ $\mathbf{r} = \left(-2\cos 3t + 6\right)\mathbf{i} + \left(t + 2\sin t - \sqrt{3}\right)\mathbf{j}$	M1	Correct use of boundary condition to find their **C.** Could be part of a definite integral e.g. $4\mathbf{i} - \sqrt{3}\mathbf{j} + \int_0^t 6\sin 3t\mathbf{i} + \left(1 + 2\cos t\right)\mathbf{j}\mathrm{d}t$ for their upper limit
	$= 4\mathbf{i} + \frac{2\pi}{3}\mathbf{j}\quad (\mathrm{m})$	A1 A1	Accept $4\mathbf{i} + 2.1\mathbf{j}$ or better one component correct both components correct ISW if they also offer $4\mathbf{i} + 120\mathbf{j}$ "correct" components after an M0 are fortuitous – A0
		[6]	
		(9)	

4a			
	Use of CLM	M1	Need all terms, dimensionally correct. Condone sign errors.
	$4mu-3mu=3mw-2mv$ $(u=3w-2v)$	A1	Correct unsimplified equation
	Use of impact law	M1	Used correctly. Condone sign errors
	$v+w=3eu$	A1	Correct unsimplified equation. Signs consistent with their CLM equation
	$\begin{cases} u=3w-2v \\ 6eu=2w+2v \end{cases}$	DM1	Dependent on both preceding M marks. Solve to find speed of *B*.
	$\Rightarrow 5w=u+6eu, \quad w=\frac{1}{5}u(1+6e)$ *	A1*	Obtain **given answer** from correct working
		[6]	
4b	$v=3eu-w=\frac{u}{5}(9e-1)$	B1	Check their diagram / directions and allow $v=\frac{u}{5}(1-9e)$ if correct for their working. Any equivalent form. Must be seen or used in (b)
	$x=\frac{u}{7}(1+6e)$	B1	Seen or implied. Accept $\pm$
	Second collision if $\frac{u}{7}(1+6e)>\frac{u}{5}(9e-1)$	M1	Correct inequality to find the upper limit for *e*, using their *v* and *x*
	$(0<)e<\frac{4}{11}$	A1	Final answer. Or equivalent Do not need to mention the lower limit, but if they do it must be stated correctly (strict inequality).
		[4]	

5a			
	Angle ACO is a right angle or state that AB is a tangent hence triangle is $5a$, $12a$, $13a$ *	B1*	Or equivalent **explanation** of **given answer.** They need to say why it is a 5, 12, 13 triangle. If they say nothing, check the diagram to see if there is a right angle marked.
		[1]	
5b	Moments about A:	M1	Dimensionally correct equation Condone sin / cos confusion
	$W \times 8a\cos\alpha = kW \times 12a$ $\left(W \times 8a \times \frac{12}{13} = kW \times 12a\right)$	A1	Correct unsimplified equation
	$k = \frac{8}{13}$ *	A1*	Obtain given answer from correct working. Need to see correct substitution for $\cos\alpha$ and correct final statement.
		[3]	
5c	$\leftrightarrow R_H = kW\sin\alpha$	M1	First equation e.g. resolve horizontally. Condone sin/cos confusion
	$= \frac{8W}{13} \times \frac{5}{13} = \frac{40W}{169}$	A1	Correct unsimplified expression for R_H
	$\updownarrow R_V + kW\cos\alpha = W$	M1	Second equation e.g. resolve vertically. Condone sin/cos confusion and sign errors.
	$R_V = W - \frac{8W}{13} \times \frac{12}{13} = \frac{73W}{169}$	A1	Correct unsimplified expression for R_V
	$\lvert R\rvert^2 = (R_V)^2 + (R_H)^2$	DM1	Dependent on the two preceding M marks. Method to obtain the magnitude, e.g.correct use of Pythagoras
	$\lvert R\rvert = \frac{W}{169}\sqrt{40^2 + 73^2}$ $= \frac{\sqrt{6929}}{169}W = \frac{\sqrt{41}}{13}W$	A1	Accept $0.49W$ or better Allow $\sqrt{\frac{41W^2}{169}}$ or correct unsimplified form. ISW
	$\tan\theta° = \frac{73}{40}$ $(=1.825)$	DM1	Dependent on the first 2 M marks. Method to obtain the angle, e.g.correct use of trigonometry to find a relevant angle $(\theta$ or $90-\theta)$
	$\theta = 61$ (61.3)	A1	61 or better (61.2796…)
		[8]	
	See overleaf for alternatives		
5c Alt 1	$P = W\sin\alpha$	M1	First equation e.g. resolve parallel to the rod. Condone sin/cos confusion.

	$=\frac{5W}{13}$	A1	Correct unsimplified expression for parallel component
	$Q+kW=W\cos\alpha$	M1	Second equation e.g. resolve perpendicular to the rod. Condone sin/cos confusion and sign errors.
	$Q=\frac{12}{13}W-\frac{8}{13}W=\frac{4W}{13}$	A1	Correct unsimplified expression for perpendicular component
	$\lvert R\rvert=\sqrt{P^2+Q^2}$	DM1	Dependent on the first 2 M marks. Correct use of Pythagoras
	$\lvert R\rvert=\frac{W}{13}\sqrt{4^2+5^2}=\frac{\sqrt{41}}{13}W$	A1	Accept 0.49*W* or better Allow correct unsimplified form
	$\theta°=\tan^{-1}\frac{5}{12}+\tan^{-1}\frac{4}{5}$	DM1	Dependent on the first 2 M marks. Correct use of trig to find the required angle
	$\theta=61\quad(61.3)$	A1	61 or better (61.2796…)
		[8]	
5c Alt2		M1 A1	Vector diagram showing the three forces acting Correctly configured
	Use of Cosine Rule:	M1	Correct use of cosine rule for their triangle
	$R^2=W^2+(kW)^2-2W(kW)\cos\alpha$	A1	Correct unsimplified equation.
	$R^2=W^2+\frac{64}{169}W^2-\frac{16}{13}\times\frac{12}{13}W^2\left(=\frac{41}{169}W^2\right)$	DM1	Solve for *R*. Dependent on the first 2 M marks
	$\lvert R\rvert=\frac{\sqrt{41}}{13}W$	A1	Accept 0.49*W* or better
	$\frac{R}{\sin\alpha}=\frac{kW}{\sin\beta}\quad\left(\sin\beta=\frac{8}{13}\times\frac{\sqrt{41}}{13}\times\frac{5}{13}\right)$	DM1	Dependent on the first M mark. Correct method to find a relevant angle e.g. by use of sine rule
	$\theta=90-28.7=61.3$	A1	61 or better (61.2796…)
		[8]	
		(12)	

6a	Mass ratio $24a : 25a : 7\pi a : 7a(7+\pi)$	B1	Correct ratio seen or implied
	Moments about AE	M1	Need all terms, with their masses and horizontal distances Allow use of a parallel axis.
	$25a \times \frac{7}{2}a + 7\pi a \times \frac{14a}{\pi}$ $= 7a(7+\pi)d$	A1	Correct unsimplified equation
	$\frac{371}{2}a^2 = 7a(7+\pi)d$ $\Rightarrow d = \frac{53}{2(7+\pi)}a$ *	A1*	Obtain **given answer** from correct working Condone if they call it $\overline{x}$
		[4]	
6b	Centre of mass of semicircle lies $7a$ "vertically below" A	B1	Seen or implied e.g. $17a$ above E
	Moments about "horizontal" axis through A:	M1	Or a parallel axis. Need all terms, with their masses and distances.
	$24a \times 12a + 25a \times 12a + 7\pi a \times 7a$ $= 7a(7+\pi)y$	A1	Correct unsimplified equation
	$y = \frac{49a(12+\pi)}{7(7+\pi)}\left(= \frac{7a(12+\pi)}{7+\pi}\right)$	A1	Any equivalent form. Accept $\frac{84+17\pi}{7+\pi}a$ from E
	NB: A candidate might have a vector equation in (a) which provides evidence for some or all or the first 4 marks in (b).		
			
	$\theta° = \tan^{-1}\frac{d}{y} = \tan^{-1}\frac{53}{14(12+\pi)}\left(=14.037...°\right)$	DM1	Use trig to find relevant angle $\left(\theta \text{ or } 90-\theta\right)$ in a triangle with d and A (must now be working with vertical distance of C of M from A) Dependent on first M
	$\alpha° = \tan^{-1}\frac{7}{24} - \theta°$	DM1	Dependent on the previous M1. Complete method for the required angle
	$\alpha = 2.2$	A1	2.2 or better (2.22…)
		[7]	
		(11)	

7a	Horizontal distance	M1	Correct use of *suvat*
	$x = u\cos\alpha\, t$	A1	Correct equation
	Vertical distance	M1	Correct use of *suvat*
	$y = u\sin\alpha\, t - \frac{1}{2}gt^2$	A1	Correct equation. Correct signs. Condone if not using "y"
	$t = \frac{x}{u\cos\alpha} \Rightarrow$ $y = u\sin\alpha.\frac{x}{u\cos\alpha} - \frac{g}{2}\left(\frac{x}{u\cos\alpha}\right)^2$ $\left(= x\tan\alpha - \frac{gx^2}{2u^2}\sec^2\alpha\right)$	DM1	Dependent on the first 2 M marks. Substitute for *t* to obtain *y* in terms of *x* and α
	$y = x\tan\alpha - \frac{gx^2}{2u^2}\left(1+\tan^2\alpha\right)$ *	A1*	Obtain **given answer** from correct working (final step needs to be explained). Allow if $\sec^2\alpha$ seen. Must be "y" here
		[6]	
7b	$u = 20,\ x = 10,\ y > 2 \Rightarrow$ $2 = 10\tan\theta - \frac{100g}{800}\left(1+\tan^2\theta\right)$ $\left(\frac{g}{8}\tan^2\theta - 10\tan\theta + \left(2+\frac{g}{8}\right) = 0\right)$	M1	Use given values to form quadratic in $\tan\theta$ or equivalent equation in one trig function. Allow working with =, < or > 2
	Critical values: $\theta° = 18.6°$ or $\theta° = 82.7°$	A1	One correct value to 2 sf or better
	Range: $18.6 < \theta < 82.7$	A1	Accept < or $\leqslant$ $\left(19 \leq \theta \leq 82 \text{ or } 83\right)$ max 3 sf
		[3]	
7c	$y = 10\tan 40° - \frac{9.8\times 100}{2\times 400}\left(1+\tan^2 40°\right)$	M1	Use given formula to find vertical height
	$y = 6.3(03...)\ (\text{m})$	A1	Can be implied by correctly substituted formula
	Conservation of energy	DM1	Dependent on the first M1. Need all 3 terms. Dimensionally correct. Condone sign errors.
	$\frac{1}{2}mv^2 = \frac{1}{2}m\times 400 - mgy$	A1ft	Correct unsimplified equation in *y* or their *y*
	$v = 17 \quad (16.6)\left(\text{m s}^{-1}\right)$	A1	2sf or 3sf only
		[5]	
7c alt	$20\cos 40°\, t = 10\ ,\ t = \frac{1}{2\cos 40°} = 0.653....$ $\updownarrow v_V = 20\sin 40° - gt$	M1	Complete method using *suvat* to vertical component of speed e.g. by finding time taken then use of $v = u - gt$ or finding vertical distance and using *suvat*
	$= 6.5 \quad (6.459...)$	A1	6.5 or better (not final answer so allow > 3sf or a correct unsimplified expression)
	$v^2 = \left(v_H\right)^2 + \left(v_V\right)^2$	DM1	Correct use of Pythagoras

			Dependent on preceding M mark
	$\leftrightarrow v_H = 20\cos 40° \left(=15.3....\right)$	A1	Horizontal component of speed seen or implied
	$v = 17 \quad (16.6)\left(\text{m s}^{-1}\right)$	A1	2sf or 3sf only
		[5]	
7d	$0 = x\tan 40° - \dfrac{9.8x^2}{800}\left(1+\tan^2 40°\right)$	M1	Complete method to solve for x.
	$x = 40\,(40.2)\,(\text{m})$	A1	2sf or 3sf only
		[2]	
7d Alt1	$y = 0 \Rightarrow t = \dfrac{40\sin 40°}{g}\left(=2.623...\right)$ $x = 20\cos 40° \times t$	M1	Complete method to solve for x.
	$x = 40\,(40.2)\,(\text{m})$	A1	2sf or 3sf only
		[2]	
7d Alt2	$\text{Range} = \dfrac{20^2\sin 80°}{g}$	M1	Complete method to solve for x.
	$= 40\,(40.2)\,(\text{m})$	A1	2sf or 3sf only
		[2]	
		(16)	