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Mark Scheme (Results)

January 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.
- 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.

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PEARSON EDEXCEL IAL MATHEMATICS

General Instructions for Marking

1. The total number of marks for this 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.

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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
- ⎿ – 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 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.

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General Principles for Mechanics Marking

(But note that specific mark schemes may sometimes override these general priniciples)

- 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 penalized *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 conversation of linear momentum
RHS, LHS	Right hand side, left hand side

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1a	Equation of motion	M1	Dimensionally correct. Condone sign error.
	$F - R = 1500a$	A1	Correct unsimplified equation in F or P
	Use of $P = Fv$: $\left(\frac{30\,000}{20} - R = 1500 \times 0.6\right)$	M1	Must be trying to use 30 kW but condone error in zeros
	$R = 600$	A1	Correct answer only
		4	
1b	Equation of motion	M1	Dimensionally correct. Need all relevant terms. Condone sign errors and sin/cos confusion. Allow with F.
	$\frac{30\,000}{V} - 1500g \times \frac{1}{8} - 500 = -1500 \times 0.2$	A1 A1	Unsimplified equation with F substituted and at most one error Correct unsimplified equation with F substituted. If F is never substituted, A0A0
	$V = 14.7 \quad (15)$	A1	3 sf or 2 sf
		4	
		(8)	
2	1st equation e.g. Equation for change in KE	M1	Dimensionally correct. Must be subtracting but condone sign error.
	$\frac{1}{2} \times 0.5\left(x^2 + y^2 - \left(5^2 + 3^2\right)\right) = 22$ $\left(x^2 + y^2 = 122\right) \ \left(1^2 + (2\lambda + 3)^2 = 122\right)$	A1	Correct unsimplified equation seen or implied (They might have used impulse-momentum first and done some work before substituting x and y.)
	2nd equation e.g. Impulse-momentum equation	M1	Dimensionally correct. Must be subtracting but condone sign error.
	$0.5(x\mathbf{i} + y\mathbf{j}) - 0.5(5\mathbf{i} + 3\mathbf{j}) = (-2\mathbf{i} + \lambda\mathbf{j})$ $\left((x-5)\mathbf{i} + (y-3)\mathbf{j} = -4\mathbf{i} + 2\lambda\mathbf{j}\right)$	A1	Correct unsimplified equation
	NB: epen has M1A1A1 for the final 3 marks but this should be marked DM1DM1A1		
	Form a quadratic equation in λ	DM1	e.g. $1^2 + (3 + 2\lambda)^2 = 122$ Dependent on the 2 preceding M marks
	Solve for 2 values of λ	DM1	e.g. solve $4\lambda^2 + 12\lambda - 112 = 0$ or $(3 + 2\lambda)^2 = 121$ Dependent on the preceding M1
	$\Rightarrow \lambda = 4 \quad \text{or} \quad \lambda = -7$	A1	Correct only and no errors seen (watch out for $x = -1$ used)
alt	Form a quadratic in y	DM1	e.g. $1 + y^2 = 122 \quad \left(y^2 = 121\right)$ Dependent on the 2 preceding M marks
	Solve for 2 values of y and use these to obtain 2 values of λ	DM1	Dependent on the preceding M1
	$\Rightarrow \lambda = 4 \quad \text{or} \quad \lambda = -7$	A1	
		7	

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3a	<table><tr><td></td><td>area</td><td>distance from *AE*</td></tr><tr><td>rectangle</td><td>$48a^2$</td><td>$4a$</td></tr><tr><td>triangle</td><td>$18a^2$</td><td>$8a-2a\left(=6a\right)$</td></tr><tr><td>lamina</td><td>$30a^2$</td><td></td></tr></table>	B1 B1	Mass ratio correct Distances from *AE* (or parallel axis) correct
	M(*AE*)	M1	Allow use of a parallel axis. The moments equation should include *a* but condone if the mass ratio does not include a factor of a^2. Dimensionally correct.
	$48a^2\times 4a-18a^2\times 6a=30a^2\bar{x}$	A1	Correct unsimplified equation for their axis. Accept as part of a vector equation.
	$\bar{x}=\frac{84}{30}a=\frac{14}{5}a$ *	A1*	Obtain **given answer** from correct working (including correct use of *a*)
			If they take moments about *BD* they get $d=5.2a$ Allow B1B1M1A1A0 if they get this far.
		5	
3b	Find trig ratio of a relevant angle	M1	Correct use of trig.
	$\tan\theta^\circ=\frac{3a}{2.8a}$	A1	Correct equation for the required angle. (DO NOT ISW: If they obtain 47 and then use 90 – 47 = 43 they score M1A0A0)
	$\theta=47$	A1	The Q asks for a whole number of degrees. 0.82 radians scores M1A1A0
		3	
		(8)	

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4a	Use $t = 2$ and $3t^2 + 2t = t^3 + kt$ $(12 + 4 = 8 + 2k)$	M1	Allow verification.
	$k = 4$ *	A1*	Obtain given answer from correct working. Verification requires a clear conclusion.
		2	
4b	Use of $\mathbf{a} = \frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$	M1	Differentiate the vector **v** Majority of powers going down
	$\mathbf{a} = (6t + 2)\mathbf{i} + (3t^2 + 4)\mathbf{j}$	A1	Correct only
	Use $\lvert\mathbf{F}\rvert = m\lvert\mathbf{a}\rvert$	DM1	Correct use of Pythagoras and N2L Dependent on the preceding M1
	$\lvert\mathbf{F}\rvert = 1.5 \times \sqrt{14^2 + 16^2} = 3\sqrt{113}$	A1	Or $\frac{3}{2}\sqrt{452}$ or 32 or better (31.89….)
		4	
4c	Use of $\mathbf{r} = \int \mathbf{v}\,\mathrm{d}t$	M1	Majority of powers going up
	$\mathbf{r} = \left(t^3 + t^2(+A)\right)\mathbf{i} + \left(\frac{1}{4}t^4 + \frac{4}{2}t^2(+B)\right)\mathbf{j}$	A1	Allow without constant of integration
	Correct use of $\mathbf{r} = 3\mathbf{i} + 4\mathbf{j}$ when $t = 0$ to find r when $t = 2$	DM1	$\left(\mathbf{r} = \left(t^3 + t^2 + 3\right)\mathbf{i} + \left(\frac{1}{4}t^4 + \frac{4}{2}t^2 + 4\right)\mathbf{j}\right)$ Dependent on the preceding M1 Use of $\mathbf{r} = -3\mathbf{i} - 4\mathbf{j}$ is M0
	$\mathbf{r} = 15\mathbf{i} + 16\mathbf{j}$	A1	Correct answer only. Accept column vector
		4	
		(10)	

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5a	Use of $F_{\max} = \mu R$: $F_{\max} = \frac{2}{7} \times 1.5g\cos\theta$	M1	$(3.87...)$ Condone trig confusion. Trig substitution not required. Allow M1 if there is a clear statement for $F_{\max}$ "correct" and then used in a calculation including the gain in GPE
	Use of $\text{WD} = 2.5F_{\max}$	M1	Trig substitution not required. M0 if they have included the gain in GPE
			If the method for F is incorrect but involves the use of μ to obtain F and then they use the "work done" formula correctly allow M0M1
	$\text{WD} = 9.69 \quad (9.7)\,(\text{J})$	A1	3 sf or 2 sf not $\frac{126}{13}$
		3	
5b	Work-energy equation	M1	The Q asks for work-energy. Need all terms and dimensionally correct. Condone sign errors and sin / cos confusion
	If their answer to (a) included the GPE then it must be used for the total work done here to score the M1		
	$\frac{1}{2} \times 1.5U^2 = WD + 1.5 \times 9.8 \times 2.5 \times \sin\theta$	A1ft A1ft	Unsimplified equation with at most one error. Correct unsimplified equation Follow their WD against friction
	$U = 5.64 \quad (5.6)$	A1	3 sf or 2 sf
		4	
5c	Work-energy equation for A to A	M1	The Q asks for work-energy. Need all terms and dimensionally correct.
	$\frac{1}{2} \times 1.5v^2 = \frac{1}{2} \times 1.5U^2 - 2WD$	A1ft	Correct unsimplified equation. Follow their WD against friction and their U
	$v = 2.43\,(2.4)\,(\text{m s}^{-1})$	A1	3 sf or 2 sf
		3	
5c alt	Work-energy equation for B to A	M1	The Q asks for work-energy. Need all terms and dimensionally correct.
	$\frac{1}{2} \times 1.5v^2 = 1.5 \times 9.8 \times 2.5 \times \sin\theta - WD$	A1ft	Correct unsimplified equation. Follow their WD
	$v = 2.43\,(2.4)\,(\text{m s}^{-1})$	A1	3 sf or 2 sf
		3	
		(10)	

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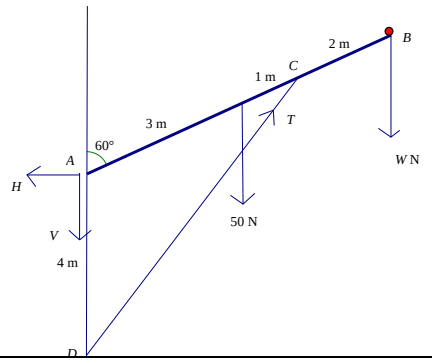
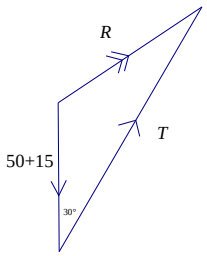
6a			
	M(*A*)	M1	Or equivalent method to form an equation in *W* only. Equation(s) must be dimensionally correct and contain all relevant terms. Condone sin / cos confusion and sign error(s)
	$50\times3\cos30°+W\times6\cos30°=60\sqrt{3}\times4\sin30°$	A1 A1	Unsimplified equation with at most one error. Correct unsimplified equation
	$W=15$ *	A1*	Correct answer only
		4	
6b	First equation e.g. Resolve vertically	M1	Or resolve parallel to pole
	$(\pm)V+50+15=T\cos30°$ $(V=25)$	A1	Or: $P+50\cos60°+15\cos60°=60\sqrt{3}\times\frac{\sqrt{3}}{2}$
	Second equation e.g. Resolve horizontally	M1	Or resolve perpendicular to the pole
	$(\pm)H=T\cos60°\left(=30\sqrt{3}=51.96.....\right)$	A1	Or: $50\cos30°+15\cos30°=60\sqrt{3}\cos60°+Q$
	NB: One of the equations could be a second moments equation		
	$\lvert R\rvert=\sqrt{25^2+\left(30\sqrt{3}\right)^2}$	DM 1	Dependent on the 2 preceding M marks $\left(\sqrt{57.5^2+3\times6.25}\right)$
	$=5\sqrt{133}\left(57.662.....\right)$ (N)	A1	58 N or better
		6	Full marks available using $\pm V,\pm H,\pm P,\pm Q$
6b alt	Form vector triangle for the vertical forces, the thrust and the resultant Correct triangle	M1 A1	
	Use cosine rule	M1	
	$R^2=T^2+\left(50+W\right)^2-2T\left(50+W\right)\cos30°$	A1	Correct unsimplified equation
	$R^2=\left(60\sqrt{3}\right)^2+\left(65\right)^2-2\times60\sqrt{3}\times65\cos30°$	DM 1	Substitute values and solve for $\lvert R\rvert$
	$\lvert R\rvert=5\sqrt{133}\left(57.662.....\right)$ (N)	A1	58 N or better
		6	
		(10)	

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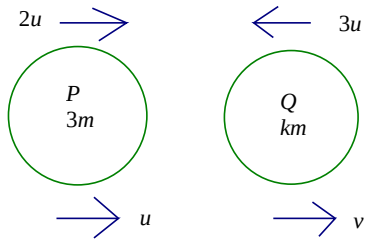
7a			
	Use CLM	M1	Need all terms and dimensionally correct. Condone sign errors. Might see them using equal (and opposite) impulses.
	$6mu - 3kmu = 3mu + kmv \quad \left((3-3k)u = kv\right)$	A1	Correct unsimplified equation
	$\Rightarrow v = \dfrac{(3-3k)}{k}u$ *	A1*	Obtain **given answer** from full and correct working
		3	
7b	Use of Impulse = change in momentum	M1	Must be subtracting. Can be for either particle.
	$\lvert I_Q\rvert = \lvert I_P\rvert = \lvert 3mu - 3m.2u\rvert = 3mu$ or $\lvert kmv - (-3mku)\rvert = \left\lvert km.\dfrac{3-3k}{k}u + 3mku\right\rvert = 3mu$	A1	Correct only (Do not need to state that $\lvert I_Q\rvert = \lvert I_P\rvert$ if find $\lvert I_P\rvert$)
		2	
7c	Use impact law:	M1	Seen or implied. If stated in (a) must be used here. Must be used correctly but condone sign errors
	$\dfrac{v-u}{5u} = e$ or $\dfrac{3-3k}{k}u - u = 5ue$	A1	Correct unsimplified equation
	NB: the second and third M mark are not dependent on the first M mark		
	Use $v > u$ or $e > 0$ to form an inequality in k	M1	Could use $e \ldots 0$ followed by $v \neq u$
	Use $e \geq 1$ to form an inequality in k	M1	
	$\dfrac{3-3k}{k} > 1$ and $3-3k \geq 6k \quad \Rightarrow \dfrac{1}{3} \geq k < \dfrac{3}{4}$	A1	Correct answer only.
		5	
		(10)	

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8a	Condone use of θ or a mixture of θ and α throughout but final answer should be in one variable.		
	Equation for horizontal distance	M1	Complete method using *suvat.* Condone sine / cosine confusion
	$x = u\cos\alpha\, t$	A1	Correct only
	Equation for vertical distance	M1	Complete method using *suvat.* Condone sine / cosine confusion and sign error
	$y = u\sin\alpha\, t - \frac{1}{2}gt^2$	A1	Correct only
	$t = \frac{x}{u\cos\alpha} \Rightarrow$ $y = u\sin\alpha.\frac{x}{u\cos\alpha} - \frac{g}{2}\left(\frac{x}{u\cos\alpha}\right)^2$	DM1	Substitute for *t* to obtain *y* in terms of *x* and α Dependent on the 2 preceding M marks
	$\Rightarrow y = x\tan\alpha - \frac{gx^2}{2u^2}\left(1+\tan^2\alpha\right)$ *	A1*	Obtain **given answer** from full and correct working. Need some evidence for the final step. $\frac{1}{\cos^2\alpha} = 1+\tan^2\alpha$ is not sufficient.
		6	
8b	Conservation of energy:	M1	Method specified in the question. Need all terms and dimensionally correct. Condone sign errors
	$\frac{1}{2}m\times 25^2 = \frac{1}{2}mU^2 + mg\times 20$	A1	Correct unsimplified equation
	$U = 15.3\ (15)$	A1	3 sf or 2 sf only
		3	
8c	Use part (a) or work from first principles to form an equation in $\tan\theta$	M1	$\left(-20 = 30\tan\theta - \frac{9.8\times 900}{2U^2}\left(1+\tan^2\theta\right)\right)$
	Obtain $18.9\tan^2\theta - 30\tan\theta - 1.07 = 0$ $\left(\frac{4410}{233}\tan^2\theta - 30\tan\theta - \frac{250}{233} = 0\right)$	A1ft	Or 3 term equivalent Follow their *U* Can be implied by a correct final answer
	$\Rightarrow \theta = 58.3°$ or $58°$	A1	3 sf or 2 sf only
		3	
		(12)	

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