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Mark Scheme (Results)

Summer 2024

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.
- 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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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.

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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 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.

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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 Right hand side
LHS Left hand side

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Q	Scheme	Marks	Notes
1(a)	Expression for total KE before collision	M1	Dimensionally correct. Condone confusion between before and after for A . Allow if vectors seen in the working but the modulus is used correctly. The two parts must be added together Allow confusion of 2 kg and 3 kg
	$\frac{1}{2}\times 2\times 5^2+\frac{1}{2}\times 3\times(3^2+(-1)^2)$	A1	correct unsimplified expression
	= 40 (J)	A1	cao
		(3)	
1(b)	$2((3\mathbf{i}+2\mathbf{j})-5\mathbf{j})$	M1	change in momentum of A, must be a difference but allow subtraction in either order Must be using the correct mass, 2 kg
	$=(6\mathbf{i}-6\mathbf{j})$ (N s)	A1	Cao The final answer should be in terms of **i** and **j** because this is asked for in the question. Accept $2(3\mathbf{i}-3\mathbf{j})$ ISW
		(2)	
1(c)	impulse-momentum equation for B	M1	must use negative of their answer to (b) and the initial velocity of B Must be using the correct mass, 3 kg or CLM with correct terms (allow slip) and plus signs
	$3(\mathbf{v}_B-(3\mathbf{i}-\mathbf{j}))=(-6\mathbf{i}+6\mathbf{j})$ or $2\times 5\mathbf{j}+3(3\mathbf{i}-\mathbf{j})=2(3\mathbf{i}+2\mathbf{j})+3\mathbf{v}_B$	A1ft	correct unsimplified equation ft on their impulse from (b)
	$\mathbf{v}_B=(\mathbf{i}+\mathbf{j})$ (m s^{-1})	A1	Cao Accept column vector ISW
		(3)	
		(8)	

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Q	Scheme	Marks	Notes
2(a)	$\frac{3}{4}t = \sqrt{2t+1}$	M1	Equate the two expressions Allow M1 only if they verify that it works for $k = 4$
	$9t^2 - 32t - 16 = 0$	A1	Correct 3 term quadratic In t or in k. Any equivalent form without the root
	$t = 4$ or $-\frac{4}{9}$, so $k = 4$ $k \geqslant 0$ *	A1*	**Given answer** for k correctly explained The Q asks for an explanation, so they must explain why they reject the negative root.
		(3)	
2(b)	Differentiate v to obtain a	M1	power decreasing by 1, condone incorrect chain rule
	$a = \frac{\mathrm{d}v}{\mathrm{d}t} = \frac{1}{2}(2t+1)^{-\frac{1}{2}} \times 2$	A1	Correct derivative (any equivalent form)
	When $t = 1.5$, $a = 0.5$ ($\mathrm{m\,s^{-2}}$)	A1	cao
		SC	Allow M1A1A0 for correct differentiation seen as part of a vector approach
		(3)	
2(c)	$x = \int \sqrt{2t+1}\ \mathrm{d}t$	M1	Attempt to integrate: power increasing by 1 Must see working – the question excludes calculators for this step
	$= \frac{2}{3}(2t+1)^{\frac{3}{2}} \times \frac{1}{2}$ $(+C)$	A1	Correct indefinite integral
	Correct use of correct limits	M1	Use of $t = 0$, $x = 0$ and $t = 4$ as limits in a definite integral or to obtain the constant of integration and hence x when $t = 4$ $\left(C = -\frac{1}{3}\right)$ "Correct use" means (value when 4 substituted) – (value when 0 substituted)
	$x = \frac{26}{3}$	A1	Accept 8.7 or better
	$\int \frac{3}{4}t\ \mathrm{d}t$	M1	Attempt to integrate: power increasing by 1 Must see working – the question excludes calculators for this step NB It is correct to use *suvat* in place of this second interval, but if they do then M1 includes use of the correct initial speed (3 $\mathrm{ms^{-1}}$)
	$= \left[\frac{3}{8}t^2\right]_4^8$	A1	Correct definite integral. Accept $\frac{3\times 64}{8} - \frac{3\times 16}{8}$ or equivalent unsimplified expression
	Total = $\frac{80}{3}$ (m) (=18 (m))	A1	Accept 27 or better $\left(26.\dot{6}\right)$
		SC	Correct integration seen as part of a vector approach can score M1A1M0A0M1A0A0
		(7)	
		(13)	

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Q	Scheme	Marks	Notes
3(a)	Large disc: πR^2; Small disc: πr^2; Template: $\pi R^2 - \pi r^2$ 0; $R-r$; $\pm kr$	B1	correct area ratios and distances seen or implied Allow + *kr* or -*kr*
	Moments about axis through *X*	M1	Or moments about a parallel axis. Need all terms but condone sign errors Do not need to see the zero term Dimensionally consistent Could be part of a vector equation
	$(0\times\pi R^2)-\pi r^2\times(R-r)=\left(\pi R^2-\pi r^2\right)\times(-kr)$ Moments about the left-hand end of the diameter through *X* and *Y* gives: $\pi R^2.R-\pi r^2\left(2R-r\right)=\pi\left(R^2-r^2\right)\left(R-kr\right)$	A1	Correct unsimplified equation Do not need to see the zero term Must be using – *kr* (unless they have changed the sign on the left-hand side)
	$r=\dfrac{k}{1-k}R$ *	A1*	Obtain **given answer** from correct working e.g. via $\dfrac{r}{R+r}=k$
			If they use $\bar{x}$ in place of $\pm kr$ and never substitute $\pm kr$ they can score B0M1A0A0
		(4)	
3(b)	$0<\dfrac{k}{1-k}R<R$	M1	use of correct inequality
	$(0<)k<(1-k)\Rightarrow(0<)k<\dfrac{1}{2}$	A1	Correct only Only need the right-hand value. A0 with an incorrect left hand value
		(2)	
3(c)	$k=\dfrac{4}{9}\Rightarrow r=\dfrac{4}{5}R$	B1	Seen or implied (this mark could be implied by the correct expression for tanα in terms of *k*)
	$\tan\alpha=\dfrac{R}{kr}\quad\left(=\dfrac{R}{\frac{4}{9}\times\frac{4}{5}R}=\dfrac{45}{16}\right)$ $\left(\tan\alpha=\dfrac{1-k}{k^2}\right)$	M1	Correct use of trig in a correct triangle Available for finding 90 - α
	$\alpha = 70^o$	A1	or better (70.426…) Accept 109.6, 250.4 and 289.6
		(3)	

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Q	Scheme	Marks	Notes
3(d)	Moments about an axis through P	M1	dimensionally consistent, condone sign errors and missing g throughout The equation should be of the form $M_1gR = Mg$ x a distance(in r or R) Moments about any other axis requires use of the forces acting at P
	M(P), $M_1gR = Mg \times \frac{4}{9}r$ Or $M_1gR = Mg \times \frac{16}{45}R$	A1	correct unsimplified equation in r and / or R
	$M_1 = \frac{16}{45}M$	A1	Accept 0.36 M or better
		(3)	
		(12)	

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Q	Scheme	Marks	Notes
4(a)	$F = \frac{1}{7} \times mg\cos\alpha \quad \left(= \frac{1}{7} \times mg \times \frac{4}{5}\right)$	M1	condone sin/cos confusion
	$= \frac{4mg}{35}$ *	A1*	obtain **given answer** from correct working Correct trig value must be seen as it is a given answer – could be against the Q
		(2)	
4(b)	Energy equation: PE gain + WD against Fr = KE lost or equivalent	M1	NB: The question tells them to use work-energy. Need all terms, dimensionally correct but condone sign errors. Condone sine / cosine confusion
	$\frac{4mgd}{35} + mgd\sin\alpha = \frac{1}{2}m \times 10ag$ Or $\frac{4mgd}{35} + mgd \times \frac{3}{5} = \frac{1}{2}m \times 10ag$	A1 A1	unsimplified equation with at most one error correct unsimplified equation
	d (= AB) = $7a$	A1	cao
		(4)	
4(c)	Energy equation	M1	NB: The question tells them to use work-energy. Need all terms, dimensionally correct but condone sign errors
	$\frac{4mg}{35} \times 14a = \frac{1}{2}m \times 10ag - \frac{1}{2}mV^2$ or $\frac{4mg}{35} \times 7a = mg \times 7a \times \frac{3}{5} - \frac{1}{2}mV^2$ or $\frac{4mg}{35} \times d = mg \times d \times \frac{3}{5} - \frac{1}{2}mV^2$	A1ft A1ft	unsimplified equation with at most one error, ft on their AB correct unsimplified equation Allow A1A1 if they have substitued for g
	$V = \sqrt{\frac{34ag}{5}}$	A1	accept $2.6\sqrt{ag}$, $\sqrt{6.8ag}$ or better. Accept $\sqrt{\frac{170ag}{25}}$
		(4)	
		(10)	

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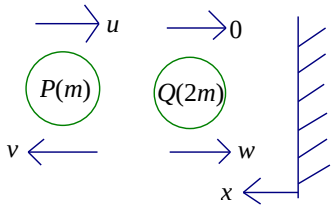
Q	Scheme	Marks	Notes
5(a)			
	Use of CLM (or equal and opposite impulses):	M1	correct no. of terms, dim correct, condone sign errors
	$mu = -mv + 2mw$	A1	Or equivalent
	Use of NEL:	M1	correct way round, condone sign errors
	$eu = v + w$	A1	Or equivalent
	Solve for v	DM1	Dependent on both preceding M marks
	$v = \frac{u(2e-1)}{3}$	A1	Or equivalent
	v consistently in the wrong direction gives $v = \frac{u(1-2e)}{3}$		Mark as a misread and allow M1A0M1A0M1A1, but full marks if they later take account of the change in direction to give the correct final answer
	If the direction of v is correct in one equation and incorrect in the other then mark as seen		
		(6)	
5(b)	NEL at the wall: $x = \frac{1}{3}w$	B1	Allow + / -: they might be working with velocities
	$w = \frac{u(e+1)}{3}$	B1	Or equivalent expression for w
	$\frac{1}{3} \times \frac{u(e+1)}{3} > \frac{u(2e-1)}{3}$	M1	use of *their x* > *their v*
	$e < \frac{4}{5}$	A1	cao
	$\frac{1}{2} < e < \frac{4}{5}$	A1	cao
		(5)	
		(11)	

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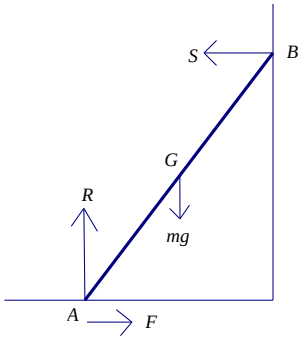
Q	Scheme	Marks	Notes
6(a)			
	$F = \frac{1}{3}R$	B1	For a correct statement seen anywhere e.g. on a diagram
either	Horizontal forces: $S = F\ \left(=\frac{1}{3}mg\right)$	B1	
	Equation for M(A)	M1	need correct terms, condone sign errors and sin/cos confusion. Condone a missing throughout.
	$S \times 2a\cos\alpha = mga\sin\alpha$	A1	Correct unsimplified
or	$R = mg$	B1	
	Equation for M(B)	M1	need correct terms, condone sign errors and sin/cos confusion. Condone a missing throughout.
	$F \times 2a\cos\alpha + mga\sin\alpha = R \times 2a\sin\alpha$	A1	Correct unsimplified
or	$S = F\ \left(=\frac{1}{3}mg\right)$	B1	
	Equation for M(G)	M1	need correct terms, condone sign errors and sin/cos confusion. Condone a missing throughout.
	$Fa\cos\alpha + Sa\cos\alpha = mga\sin\alpha$	A1	Correct unsimplified
SC	$S = F\left(=\frac{1}{3}mg\right)$ or $R = mg$ and no moments equation	B1	And no further marks
	Solve for $\tan\alpha$	M1	
	$\tan\alpha = \frac{2}{3}$ *	A1*	Obtain given answer from correct working
SC	A candidate who never uses g can score B1B0M1A0M1A0		
		(6)	

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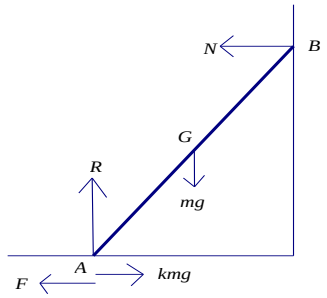
Q	Scheme	Marks	Notes
6(b)			
	A good starting point for marking part (b) is to count the number of terms in the moments equation		
either	Use of $R = mg$ and M(A)	M1	
	$N = S = \frac{1}{3}mg$	A1	Correct only
	Resolve horizontally: $kmg = \frac{1}{3}R + N$ and solve for k	DM1	Dependent on the moments equation need correct terms, condone sign errors
	$k = \frac{2}{3}$	A1	correct equation
		(4)	
or	M(A) and	M1	need correct terms, condone sign errors and sin/cos confusion. Condone a missing throughout.
	$mga\sin\alpha = N \times 2a\cos\alpha$	A1	Correct unsimplified equation
	Resolve horizontally : $kmg = \frac{1}{3}R + N$ and use $R = mg$ and $\tan\alpha = \frac{2}{3}$ to solve for k	DM1	Dependent on the moments equation need correct terms, condone sign errors OR could use a second moments equation
	$k = \frac{2}{3}$	A1	Correct only
or	M(B),	M1	need correct terms, condone sign errors and sin/cos confusion. Condone a missing throughout.
	$mga\sin\alpha + kmg \times 2a\cos\alpha$ $= R \times 2a\sin\alpha + \frac{1}{3}R \times 2a\cos\alpha$	A1	
	Use of $R = mg$ and $\tan\alpha = \frac{2}{3}$ to solve for k	DM1	Dependent on the moments equation OR could use a second moments equation
	$k = \frac{2}{3}$	A1	Correct only
		(4)	
or	M(G),	M1	need correct terms, condone sign errors and sin/cos confusion
	$Na\cos\alpha + kmga\cos\alpha = Ra\sin\alpha + Fa\cos\alpha$	A1	Correct unsimplified equation
	Resolve horizontally : $kmg = \frac{1}{3}R + N$ and use $R = mg$ and $\tan\alpha = \frac{2}{3}$ to solve for k	DM1	Dependent on the moments equation need correct terms, condone sign errors OR could use a second moments equation
	$k = \frac{2}{3}$	A1	Correct only
		(10)	

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Q	Scheme	Marks	Notes
7(a)	Horizontal distance	M1	equation with correct terms, condone sign errors
	$2ut = 80$	A1	correct equation
	Vertical distance or vertical speed	M1	equation with correct terms, condone sign errors
	$0 = ut - \frac{1}{2}gt^2$	A1	correct equation in t Alternatives include $-u = u - gt$ or $0 = u - g\,\frac{1}{2}t$
	Solve for u $\left(\text{e.g. } u \times \frac{80}{2u} = \frac{1}{2}g\frac{80^2}{4u^2}\right)$	DM1	Dependent on the two previous M marks
	$u = 14$*	A1*	obtain **given answer** correctly
	If they consistently have u horizontal and $2u$ vertically, then mark as a misread. M1A0M1A0M1A1 Fortuitously, they do obtain the given answer		
		(6)	
7(b)	$v^2 = (7\sqrt{17})^2 - 28^2$	M1	form an equation in v only (v is vertical component)
	=> $v = 7$ (or -7)	A1	second value not needed
	Use of *suvat* to find the required time Check their logic. Have they found the time speed is $< 7\sqrt{17}$ or the time the speed is $> 7\sqrt{17}$?	DM1	Dependent on the first M mark. Complete method to obtain the required time. condone sign errors
	$7 = 14 - gt \Rightarrow t = \frac{5}{7} = 0.71...$	A1	Obtain a relevant value of t
	Total time = $2 \times \frac{5}{7} = 1.4$ or 1.43 (s)	A1	For the required time to 2 sf or 3 sf A0 for $\frac{10}{7}$; follows the use of an approximate value for g
	The misread from (a) will give $v = \pm\sqrt{637} = \pm 7\sqrt{13}$ (± 25.2), critical value of time $t = 0.282$, required time 0.56 (s)		No further penalty for the misread if the penalty is already applied in (a)
		(5)	

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7(b) alt	$\frac{1}{2}m(28^2+14^2)-\frac{1}{2}m(7\sqrt{17})^2=mgh$	M1	form an equation in *h* only
	$\Rightarrow h = 7.5$	A1	Correct only
	Use of *suvat* to find the required time Check their logic. Have they found the time speed is $< 7\sqrt{17}$ or the time the speed is $> 7\sqrt{17}$?	DM1	Dependent on the first M mark. Complete method to obtain the required time, condone sign errors
	$7.5 = 14t - \frac{1}{2}\times 9.8t^2 \quad \Rightarrow t = \frac{5}{7}, t = \frac{15}{7}$	A1	Obtain at least one relevant value for *t*
	Total time $= \frac{20}{7} - \left(\frac{15}{7} - \frac{5}{7}\right) =$ 1.4 or 1.43(s)	A1	For the required time to 2 sf or 3 sf A0 for $\frac{10}{7}$; follows the use of an approximate value for *g*
	The misread from (a) will give the same value for h (7.5), *t* = 5.43 and *t* = 0.28, so required time 0.56 (s)		
		(5)	
7b alt	Use $7\sqrt{17}$ to form an equation in *t* only	M1	
	$\Rightarrow 7\sqrt{17} = \sqrt{(14-gt)^2+28^2}$	A1	Or equivalent
	Solve to find the required time Check their logic. Have they found the time speed is $< 7\sqrt{17}$ or the time the speed is $> 7\sqrt{17}$?	DM1	Dependent on the first M mark. Complete method to obtain the required time, condone sign errors
	$147 = 2gt - g^2t^2 \quad \Rightarrow t = \frac{5}{7}, t = \frac{15}{7}$	A1	Obtain at least one relevant value for *t*
	Total time $= \frac{20}{7} - \left(\frac{15}{7} - \frac{5}{7}\right) =$ 1.4 or 1.43(s)	A1	For the required time to 2 sf or 3 sf A0 for $\frac{10}{7}$; follows the use of an approximate value for *g*
		(5)	
		(11)	

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