

Mark Scheme (Results)

Summer 2021

Pearson Edexcel International Advanced Level In Mechanics M2 (WME02/01)

Q	Solution	Mark	Notes
1	Driving force $(F) = \frac{3500}{V}$	B1	Use of $P = Fv$
	Equation of motion: $F - 20V + 480g \sin \theta = 0$	M1	Need all terms. Dimensionally correct. Condone sign errors and sin/cos confusion
	$\frac{3500}{V} - 20V + 40g = 0$	A1	Correct unsimplified equation in <i>V</i> .
	$20V^2 - 392V - 3500 = 0$	M1	Form a 3 term quadratic equation $(=0)$ in V
	V = 26.3 (26)	A1	3 sf or 2 sf Not $\frac{49 + 22\sqrt{14}}{5}$ (follows use of 9.8)
		(5)	
		[5]	

2a			Allow column vectors throughout
	dv	M1	Differentiate – at least 3 powers
	Use $\mathbf{a} = \frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$		going down by 1
	$\mathbf{a} = (10t - 3t^2)\mathbf{i} + (6t^2 - 8)\mathbf{j}$	A1	
	$\mathbf{F} = 1.5 \times ((20-12)\mathbf{i} + (24-8)\mathbf{j})$	DM1	Substitute $t = 2$ and use $\mathbf{F} = m\mathbf{a}$
			Dependent on preceding M1
	$=12\mathbf{i}+24\mathbf{j}$	A1	Ignore magnitude of F if found
		(4)	
2b	$5t^2 - t^3 = 0 \implies t = 5$	B1	(Not moving when $t = 0$ so no
			need to mention $t = 0$)
	Use of $\mathbf{r} = \int \mathbf{v} dt$	M1	Integrate to find r – at least 3
	,		powers going up by 1.
	$\mathbf{r} = \left(\frac{5}{3}t^3 - \frac{1}{4}t^4\right)\mathbf{i} + \left(\frac{1}{2}t^4 - 4t^2\right)\mathbf{j}$	A1	Condone if no constant of
	$\begin{bmatrix} 1 & 3^t & 4^t \end{bmatrix}$		integration seen (since
			$t = 0, \mathbf{r} = 0)$
	$\mathbf{r} = \left(\frac{625}{12}\right)\mathbf{i} + \left(\frac{425}{2}\right)\mathbf{j}$	A1	Final answer $52\mathbf{i} + 210\mathbf{j}$ or better
	$\begin{bmatrix} 12 \end{bmatrix}^{1} \begin{bmatrix} 2 \end{bmatrix}^{3}$		$(52.08\dot{3}i + 212.5j)$
		(4)	,
		[8]	
		[°]	

3a		square	triangle	circle	T			
	mass	36	8	π	$28-\pi$			
	c		7		_			
	from AD	3 <i>a</i>	$\frac{7}{3}a$	4 <i>a</i>	d			
	Mass r	atio					B1	
	Distan	ces fron	n AD or a	a parall	el axis		B1	
	M(AD	or para	llel axis)				M1	Moments equation. Need all terms and dimensionally correct. Condone sign errors.
	36×3a	$a-8\times\frac{7}{3}$	$a-\pi\times 4$	a = (28	$(-\pi)d$		A1	Correct unsimplified equation for their parallel axis
			$-4\pi a = ($					
	$d = \frac{32}{3}$	$\frac{24-56-}{3(28-3)}$	$\frac{-12\pi}{\pi}a =$	$\frac{4(67-3)}{3(28-3)}$	$\left(\frac{3\pi}{\pi}\right)a$		A1*	Obtain given answer from correct working
								Distance from BC is $ \frac{(236-6\pi)a}{3(28-\pi)} $ Allow 4/5 if seen.
							(5)	
36	Or reso	- ($f \times 6a$ $M(G)$, wh	ere G	M1	Complete method to form an equation in <i>k</i> and <i>W</i> only Dimensionally correct but condone use of incorrect distsance(s)
	$T_A + k$	W = W						
	$T_A \left(\frac{4(}{3}\right)$	$\frac{(67-3\pi)}{(28-\pi)}$	$\left(\frac{1}{2}a\right) = kV$	$V \left(6a -$	$\frac{4(67-3)}{3(28-3)}$	$\left(\frac{\pi}{\pi}\right)a$		
							A1	Correct unsimplified equation
								$\left(\text{NB} \frac{4(67 - 3\pi)}{3(28 - \pi)} a = 3.088a \right)$
		k = 0.5	51				A1	Q asks for 2dp
	-						(3)	
							[8]	

		1	T
4	$\frac{\theta}{\theta} P$ $\frac{1}{60^{\circ}} J \text{Ns}$ 5 ms^{-1}		Resolving parallel and perpendicular to the original direction of motion
	Use of $J = m(v - u)$	M1	Use of $J = m(v - u)$ parallel or
			perpendicular to original direction
	$J\cos 30^\circ = 2.4\cos\theta$	A1	One correct unsimplified
	or $J \cos 60^{\circ} = 2.4 \sin \theta - 1.5$	2.54	equation
	Use of $J = m(v - u)$	M1	Use of $J = m(v - u)$ to form
		A1	second equation 2 nd correct unsimplified
		711	equation
	The first 4 marks are available for a correct equation in vector form.		
	$2.4^2 = \frac{3J^2}{4} + \frac{J^2}{4} + 1.5J + 1.5^2$	DM	Form an equation in J only
	$ \left(J^2 + 1.5J - 3.51 = 0 \right) $	1	Dependent on previous two M1 marks
	J=1.3	A1	1.3 or better (1.268)
		(6)	
	NB Use of initial velocity parallel to final vel is a method error, not a misread	ocity or	final velocity parallel to impulse
			See over for alternatives

4 Al t 1	8 ms ⁻¹ 5 ms ⁻¹		Resolving parallel and perpendicular to the direction of the impulse.
	Use of $J = m(v - u)$	M1	Use of $J = m(v - u)$ in any
			direction
	$J = 0.3(8\cos\alpha - 5\cos60^{\circ})$	A1	Correct unsimplified equation
	Or $5\sin 60^\circ = 8\sin \alpha$		$2.4\cos\alpha = J + 1.5\cos 60^{\circ}$
			$2.4\sin\alpha = 1.5\sin 60^{\circ}$
	Use of $J = m(v - u)$	M1	Use of $J = m(v - u)$ in
			perpendicular direction
		A1	Correct unsimplified equation
	$2.4^2 = \left(J + \frac{3}{4}\right)^2 + \left(\frac{3}{2}\right)^2 \times \frac{3}{4}$	DM	Form an equation in <i>J</i> only Dependent on previous two M1
		DM 1	marks
	$(J^2 + 1.5J - 3.51 = 0)$	1	
	J = 1.3	A1	1.3 or better (1.268)
	Could have a mixture of the first 2 alternative	s. M1A	A1M1A1 for 2 independent
	equations. DM1A1 for solving		
4		(6)	
4 A1 t 2	120° 2.4 1.5		Using vector triangle.
	Impulse momentum triangle	M1	Form dimensionally correct vector triangle (for impulse or momentum)
	Use of cosine rule	M1	Use of cosine rule in momentum or velocity triangle
	$2.4^2 = J^2 + 1.5^2 - 3J\cos 120^\circ$	A1	unsimplified equation in v or mv with at most one error
		A 1	
	$J^2 + 1.5J - 3.51 = 0$	A1 DM 1	Correct unsimplified equation Form a simplified equation in J Dependent on previous two M1
	$J^2 + 1.5J - 3.51 = 0$ $J = 1.3$	DM	Correct unsimplified equation Form a simplified equation in J Dependent on previous two M1 marks
		DM 1	Correct unsimplified equation Form a simplified equation in J Dependent on previous two M1

5a			
	C		
	T		
	3a 55°		
	B 55°		
	70° $5a$ 70° \uparrow^{V}		
	$Mg \downarrow H \setminus A$		
	Moments about <i>A</i> :	M1	Need all terms and
			dimensionally correct.
			Condone sign errors, incorrect
			angles and sin/cos confusion
			Or complete method to form
	5 T -: 550 A 200 M	A 1	equation in T (and M).
	$5a \times T \sin 55^\circ = 4a \cos 20^\circ \times Mg$	A1	Correct unsimplified equation
	4 200		in T (and M).
	$T = \frac{4\cos 20^{\circ}}{5\sin 55^{\circ}} Mg \left(= 0.918 Mg\right)$	A1	Or equivalent
	5sin 55°	(2)	(Exact or 0.92Mg or better)
		(3)	
5b	Resolve vertically	M1	Need all terms. Condone sign
30	Resolve vertically	1011	errors, incorrect angle and
			sin/cos confusion
	$\updownarrow: Mg = V + T\cos 55^{\circ}$	A1	Correct unsimplified equation
			in T or their T
	(V = 0.47Mg)		
	Resolve horizontally	M1	Condone consistent sin/cos
	** #	1	confusion
	$H = T\sin 55^{\circ}$	A1	Correct unsimplified equation
	(H = 0.75Mg)		in T or their T
	Resultant $\lambda = \sqrt{(0.4736)^2 + (0.7517)^2}$	M1	Substitute for <i>T</i> and use
	Resultant $\lambda = \sqrt{(0.4/30) + (0./31/)}$		Pythagoras
	= 0.89	A1	The Q asks for 2 sf
		(6)	
			See over for further alternative
			See over for further afternative
		1	

5b	Moments about B		Dimensionally correct. Need
alt		M1	all terms. Condone sign
			errors and sin/cos confusion
	$Mga\cos 20^{\circ} + 5aH\cos 70^{\circ} = 5aV\cos 20^{\circ}$	A1	Correct unsimplified equation
	Moments about C		Dimensionally correct.
		M1	Condone sign errors and
			sin/cos confusion
	$5aH = 4aMg\cos 20^{\circ}$	A1	Correct unsimplified equation
	Resultant $\lambda = \sqrt{(0.4736)^2 + (0.7517)^2}$	M1	Use Pythagoras
	= 0.89	A 1	The Q asks for 2 sf
	M1A1M1A1 for 2 independent equations M1	lA1 to s	solve for λ

6a	GPE lost	M1	Need all terms. Condone sign
	$=3g\times2-2g\times2\sin\theta$		errors and sin/cos confusion Correct unsimplified. Accept
	$ (=6g-4g\times\frac{5}{13}) $	A1	±
	$(=6g-4g\times\frac{5}{13})$ $=\frac{58}{13}g=43.7(44)(J)$	A1	Must be positive. Exact multiple of g or 3 sf or 2 sf
		(3)	
6b	Normal reaction = $2g \cos \theta \left(= \frac{24}{13}g \right)$	B1	Condone $\frac{1176}{65}$
	$F_{\text{max}} = \frac{3}{8} \times R \left(= \frac{9g}{13} \right)$	M1	Use $F = \mu R$ with their R $\left(\frac{441}{65}\right)$
	Work done = $2 \times F_{\text{max}}$	M1	Their F_{max}
	$\left(=\frac{18g}{13}\right) = 13.6(J) \ 14(J)$	A1	Exact multiple of g or 3 sf or 2 sf . Not $\frac{882}{65}$
		(4)	
6c	Total KE gained = GPE lost - total WD against friction	M1	Must be using work-energy. Dimensionally correct. Required terms and no extras. Condone sign errors.
	$\frac{1}{2}(2+3)v^{2} = (their(a)) - (their(b))$ $\left(\frac{5}{2}v^{2} = \frac{58}{13}g - \frac{18}{13}g = \frac{40}{13}g\right)$	A2ft	Follow their (a) and (b) -1 each error
	$v = \sqrt{\frac{16}{13}g} = 3.47 (\text{m s}^{-1}) \text{ or } 3.5 (\text{m s}^{-1})$	A1	3 sf or 2 sf (need to substitute for <i>g</i>)
		(4)	
6d	KE lost = GPE gained + WD against friction	M1	Must be using work-energy. Dimensionally correct. Required terms and no extras. Condone sign errors.
	$\frac{1}{2} \times 2 \times \frac{16}{13} g = 2g \times d \sin \theta + \frac{3}{8} \times 2g \times \frac{12}{13} d$ $\frac{1}{2} \times 2 \times v^2 = 2g \times d \sin \theta + d \times F_{\text{max}}$ $\frac{16}{13} g = \left(\frac{10}{13}g + \frac{9}{13}g\right) d$ $d = \frac{16}{19}$	A2ft	Follow their (c) and their F_{max} -1 each error
	$d = \frac{16}{19}$	Al	g cancels. 0.84 or better (0.8421)
	-	[15]	

7a	-12 = 12 - gt	M1	Use <i>suvat</i> to find time taken
	$t = \frac{24}{g}(=2.45)$	A1	
	AB = 6t	M1	Horizontal distance
	=14.7 (15) (m)	A1	3 sf or 2 sf Not $\frac{720}{49}$ (follows use of 9.8) Not $\frac{144}{g}$ (do not accept g in the denominator)
		(4)	
7b	Vertical component of velocity = $(\pm)8$	B1	
	$v^2 = u^2 + 2as$	M1	Complete method using <i>suvat</i> to find <i>h</i>
	$\Rightarrow 8^2 = 12^2 - 2gh$	A1	Correct unsimplified equation
	h = 4.08 (4.1)	A1	3 sf or 2 sf Not $\frac{200}{49}$ (follows use of 9.8) Not $\frac{40}{g}$ (do not accept g in the denominator)
		(4)	
7b alt	$\mathbf{v} = \begin{pmatrix} 6 \\ 12 \end{pmatrix} - \begin{pmatrix} 0 \\ g \end{pmatrix} t \implies 12 - gt = (\pm)8$ $h = 12t - \frac{1}{2}gt^2$	B1	Correct expression for critical value(s) of <i>t</i>
	$h = 12t - \frac{1}{2}gt^2$	M1	Complete method using <i>suvat</i> to find <i>h</i>
	$=\frac{48}{g} - \frac{8}{g}$ or $=\frac{240}{g} - \frac{200}{g}$	A1	Correct unsimplified equation
	h = 4.08 (4.1)	A1	3 sf or 2 sf
		(4)	
7b alt	Conservation of energy	M1	Need all terms and dimensionally correct
	$mgh + \frac{1}{2}m \times 10^2 = \frac{1}{2}m(12^2 + 6^2)$	A(B)1	Unsimplified equation with at most one error
	L 400 (41)	A1	Correct unsimplified equation
	h = 4.08 (4.1)	A1	3 sf or 2 sf
		(4)	
			See over for (c)
<u> </u>		1	(-)

7c		M1	Complete method to find vertical component at <i>C</i> .		
	$\Rightarrow v = 3$	A1			
	$\mathbf{v} = 6\mathbf{i} + 3\mathbf{j} \ \left(\mathbf{m} \mathbf{s}^{-1} \right)$	A1	Must be a vector in terms of i and j		
	If see $\binom{6}{12} \cdot \binom{6}{v} = 0$ leading to $\mathbf{v} = 6\mathbf{i} - 3\mathbf{j}$ mark as a misread: M1A0A0				
		(3)			
		[11]			
	Accept working in column vectors throughout apart from the final A1				

8a	—————————————————————————————————————		
	$\begin{pmatrix} A \\ 2m \end{pmatrix} \qquad \begin{pmatrix} B \\ m \end{pmatrix} \qquad \begin{pmatrix} C \\ 3m \end{pmatrix}$		
	$\longrightarrow v \longrightarrow w$		
	$\longrightarrow x \longrightarrow y$		
	Use CLM: $4mu = 2mv + mw$	M1	Need all terms. Condone sign
			errors. Dimensionally correct
			but allow with <i>m</i> cancelled
	(4u = 2v + w)	A1	Correct unsimplified. Signs
	**	3.51	correct for their v, w
	Use Impact law	M1	Used the right way round.
	w-v=2ue	A1	Condone sign errors.
	w-v=2ue	AI	Correct unsimplified. Signs consistent with CLM equation.
	. 4 2(2)	DM1	Solve for <i>v</i> or <i>w</i> .
	$\Rightarrow 4u = 2(w - 2ue) + w$	DIVII	Dependent on previous 2 M
			marks
	4 (1) **	A1*	Obtain given result from
	$3w = 4u + 4ue$, $w = \frac{4}{3}u(1+e)$ *		correct working
		A1	Or equivalent.
	$v = \frac{2}{3}u(2-e)$		Must be positive
		(7)	-
8b	2 > e so A moving towards centre	B1	Correct statement about
	S		direction of travel for A
	mw - 3mu = mx + 3my	M1	Use CLM and impact law
	(4 <i>u</i> 4 <i>eu</i>)		correctly to form simultaneous
	$y - x = e\left(u + \frac{4u}{3} + \frac{4eu}{3}\right)$		equations in <i>x</i> and <i>y</i> .
	4 5 .	A1	Both equations correct
	$\frac{4}{3}eu - \frac{5}{3}u = x + 3y$		unsimplified in u, e, x and y
	3y - 3x = e(7u + 4ue)		-
	$\frac{3y}{3x} = \frac{5y}{x} = \frac{5y}{x}$	DM1	C 1 C
	$4x = \frac{4}{3}ue - \frac{5}{3}u - 7ue - 4ue^2$	DM1	Solve for <i>x</i>
	$4x = \frac{4}{3}ue - \frac{5}{3}u - 7ue - 4ue^{2}$ $x = -\frac{5}{12}u - \frac{17}{12}ue - ue^{2}$	A 1	A 11 C
	$x = -\frac{5}{12}u - \frac{1}{12}ue - ue^2$	A1	Allow for a correct constant
		A d ste	multiple of x
	e > 0, $u > 0$ so B moving towards centre	A1*	Obtain given answer from
	from opposite direction, hence they		correct working
	collide.*	(6)	
	Alternative for last 2 marks	(6)	
	Alternative for last 3 marks; C moving towards centre implies B moving		
	towards centre, so collision.		
	C moving away from centre, so $y > 0$,	DM1	Consider direction of <i>C</i>
		וואוע	Consider direction of C
	$x = w - 3u - 3y = -\frac{8u}{3} + \frac{4eu}{3} - 3y$		
	3 3		

$=-\frac{u}{3}(8-4e)-3y$	A1	
< 0 because $e \le 1$ and $y > 0$ hence B moving towards centre from opposite direction, and they will collide.*	A1*	Obtain given answer from correct working
	[13]	