

Mark Scheme (Results)

October 2021

Pearson Edexcel International A Level In Mechanics M2 (WME02) Paper 01

Q	Solution	Mark	Guidance
1a	$F = \mu R = \frac{1}{5} mg \cos \alpha$	B1	Seen or implied
	Work done = force x distance	M1	Correct method for work done against friction
	$=\frac{1}{5}mg\times\frac{12}{13}\times d=\frac{12}{65}mgd *$	A1*	Obtain given answer from correct working.
		(3)	
1b	Work-energy equation	M1	All terms required and dimensionally correct. Condone sign errors and sin/cos confusion
	$\frac{1}{2}mv^2 = mg \times d \times \frac{5}{13} - \frac{12}{65}mgd\left(=\frac{13}{65}mgd\right)$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation
	$v = \sqrt{\frac{2gd}{5}}$	A1	Or exact equivalent e.g. $\sqrt{\frac{26}{65} gd}$, $\frac{1}{5} \sqrt{10gd}$
			Accept $0.63\sqrt{gd}$ or better
		(4)	
		[7]	
2	Equation of motion down the slope	M1	First equation (either direction). Condone sign errors and sin/cos confusion
	$F_1 + 450g \times \frac{1}{15} - R = 450 \times 0.5$ $\left(\frac{P}{12} + 30g - R = 225\right) \left(\frac{P}{12} - R = -69\right)$	A1 A1	Unsimplified equation with at most one error. Correct unsimplified equation in P or F_1
	Equation of motion up the slope	M1	Second equation. Condone sin/cos confusion. Signs consistent with first equation and change in direction of motion
	$F_2 - 450g \times \frac{1}{15} - R = 450 \times -0.5$ $\left(\frac{P}{6} - 30g - R = -225\right) \left(\frac{P}{6} - R = 69\right)$	A1	Correct unsimplified equation in P or F_2
	$F_1 = \frac{P}{12}$ or $F_2 = \frac{P}{6} \left(= \frac{2P}{12} \right)$	M1	Use of $P = Fv$ at least once
	Solve for P	DM1	Dependent on all previous M marks
	$\left(R = \frac{P}{8}\right)$ $P = 1660$ or $P = 1700$	A1	3 sf or 2 sf (follows use of 9.8) Allow 1.66 kW but not 1.66
		(8)	
		[8]	

3a	Use of $v = \frac{dx}{dt}$	M1	Recognisable attempt to differentiate the given
	$0 = 7t^{\frac{1}{2}} \left(t^2 - 5t + 4 \right)$	DM1	expression Set $v = 0$ and solve for t Dependent on first M1
	t = 1 and $t = 4$	A1	Correct solution only
		(3)	,
3b	$s = x_1 - x_0 + x_4 - x_1 $	M1	Correct strategy to find distance for their value(s) of t in [0,4] Allow M1 if there is no change of direction in the interval
	$= \left \frac{20}{3} - 0 \right + \left -\frac{128}{3} - \frac{20}{3} \right $	A1ft	Correct unsimplified expression for their distance (provided there was a change in direction in [0, 4]) Clearly using $x(4) + 2x(1)$ but $x(4)$ miscalculated so correct combined expression never seen. M1 only
	= 56	A1	Correct solution only
		(3)	
3c	Use of $a = \frac{dv}{dt}$	M1	Recognisable attempt to differentiate
	Use of $a = \frac{dv}{dt}$ $a = \frac{35}{2} \times 4^{\frac{3}{2}} - \frac{105}{2} \times 4^{\frac{1}{2}} + 14 \times 4^{-\frac{1}{2}}$	M1	Substitute $t = 4$ in their a and simplify
	= 42	A1	Correct solution only
		(3)	
		101	
		[9]	
-			

4	Use of $\mathbf{I} = m(\mathbf{v} - \mathbf{u})$	M1	As a single vector equation or two separate equations.
	$c \begin{pmatrix} -1 \\ 2 \end{pmatrix} = \frac{3}{4} \mathbf{v} - \begin{pmatrix} 3 \\ 0 \end{pmatrix}$	A1	Any equivalent substituted form
	$\left(\mathbf{v} = \frac{4}{3} \binom{3-c}{2c}\right)$		
	Use of Pythagoras	M1	
	$64 = \frac{16}{9} \left(\left(3 - c \right)^2 + 4c^2 \right)$	A1	Correct unsimplified equation in c or a component of \mathbf{v} .
			$(5a^2 - 32a = 0 \text{ or } 5b^2 - 16b - 192 = 0)$
	Simplify to 3 term quadratic and solve for <i>c</i>	M1	$5c^2 - 6c - 27 = 0$
	$c = 3$ or $c = -\frac{9}{5}(-1.8)$	A1	Correct only
	<u> </u>	(6)	
4 Alt	6	M1	Form vector triangle. Dimensionally correct
	$ \begin{array}{c c} 6 & & & \sqrt{5}c \\ & & & & & \\ \hline & & & & & \\ 3 & & & & & \\ \end{array} $	A1	Three correct lengths and $\left \cos\theta\right = \frac{1}{\sqrt{5}}$ seen or implied
	Use of cosine rule	M1	
	$36 = 9 + 5c^2 - 2 \times 3\sqrt{5}c\cos\theta$	A1	Correct unsimplified equation in c with $\cos \theta$ or their $\cos \theta$
	Rearrange as 3 term quadratic and solve for <i>c</i> .	M1	$5c^2 - 6c - 27 = 0$
	$c = 3$ or $c = -\frac{9}{5}(-1.8)$	A1	Correct only
		(6)	
		[6]	
<u> </u>			

5a			
Ja	c		
	α		
	2.5 m		
	4 m		
	B		
	2.5 m 2a		
			Dimensionally correct
			Condone sin/cos confusion and
	Moments about <i>B</i> :	M1	errors in angles OR: Correct moments equation
			and resolution
			Resolving where required
	$T \times 2.5 \sin \alpha = 70 \times 1.25 \sin 2\alpha$	A1	Unsimplified equation in α
	Or $T \times 2.5 \sin \alpha = 70 \times 2 \sin \alpha$	111	with at most one error
	Or use similar triangles $T \times \frac{3}{2} = 70 \times \frac{6}{5}$	A1	Correct unsimplified equation in α
			Obtain given answer from
	$T = 70 \times \frac{4}{5} = 56(N) *$	A1*	correct exact working and no
	3	(4)	errors seen
		(4)	
5b	Resolve horizontally:	M1	First equation
	$H = T \sin \alpha \left(= 33.6(N) \right)$	A1ft	Correct unsimplified equation
	Resolve vertically	M1	Second equation
	$V + T\cos\alpha = 70 (V = 25.2(N))$	A1ft	Correct unsimplified equation
	$V = \mu H$	M1	Use of $F = \mu R$ with their V, H
	$\mu = \frac{3}{2}$	A1	Correct only (no subst for g
	- 4		required)
5balt	Resolve parallel to the rod:	(6) M1	
Juan	H sin $2\alpha + 70\cos 2\alpha = 56\cos \alpha + V\cos 2\alpha$	A1ft	(24H - 7V = 630)
	Resolve perpendicular to the rod:	M1	(= ,, 330)
	$70 \sin 2\alpha = 56 \sin \alpha + V \sin 2\alpha + H \cos 2\alpha$	A1ft	(24V + 7H = 840)
	$V = \mu H$	M1	Use of $F = \mu R$ with their V, H
	,		Correct only (no subst for g
	$\mu = \frac{3}{4}$	A1	required)
		(6)	
		[10]	
	1	1	

$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	6a			
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		<i>→</i> x y <i>←</i>		
$5mv = 2m(v - (-x))$ $x = \frac{3v}{2}$ $5mv = 3m(v - (-y))$ or $2mx - 3my = 3mv - 2mv$ $y = \frac{2v}{3}$ A1 Seen or implied $2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$ M1 Use of $I = mv - mu$ or use of CLM $2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$ A1 Seen or implied $2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$ M1 Correct use of impact law (not necessarily with values in terms of v) Allow $v - v$ on LHS $e = \frac{12}{13}$ A1 0.92 or better $2 \times \frac{1}{2} \times 3m(y^2 - (vf)^2) = \frac{1}{2} \times 2m(x^2 - v^2)$ M1 Use of $I = mv - mu$ or use of CLM $1 \times v = \frac{1}{2} \times v = \frac{1}{2$		A B		
$x = \frac{3v}{2}$ $5mv = 3m(v - (-v))$ or $2mx - 3my = 3mv - 2mv$ $y = \frac{2v}{3}$ A1 Seen or implied $2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$ A1 Seen or implied $2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$ A1 Seen or implied $e = \frac{12}{13}$ Correct use of impact law (not necessarily with values in terms of v) Allow $v - v$ on LHS $e = \frac{12}{13}$ A1 0.92 or better $2 \times \frac{1}{2} \times 3m(y^2 - (vf)^2) = \frac{1}{2} \times 2m(x^2 - v^2)$ M1 Use KE to form an equation in f . Condone use of change in KE rather than loss Condone 2 on wrong side $3\left(\frac{4}{9} - f^2\right) = \left(\frac{9}{4} - 1\right)$ A1 Correct unsimplified equation for f . $\left(f^2 = \frac{1}{36}\right) f = \frac{1}{6}$ A1 NB: $\frac{\sqrt{31}}{6}$ comes from inconsistent subtraction.		$v \longleftarrow \longrightarrow v$		
$5mv = 3m(v - (-y))$ or $2mx - 3my = 3mv - 2mv$ M1 Use of $I = mv - mu$ or use of CLM $y = \frac{2v}{3}$ A1 Seen or implied $2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$ M1 $e = \frac{12}{13}$ A1 O.92 or better $2 \times \frac{1}{2} \times 3m\left(y^2 - (vf)^2\right) = \frac{1}{2} \times 2m\left(x^2 - v^2\right)$ M1 $3\left(\frac{4}{9} - f^2\right) = \left(\frac{9}{4} - 1\right)$ A1 Correct use of impact law (not necessarily with values in terms of v) Allow $v - v$ on LHS Use KE to form an equation in f . Condone use of change in KE rather than loss Condone 2 on wrong side 41 Correct unsimplified equation for f cao NB: $\frac{\sqrt{31}}{6}$ comes from inconsistent subtraction.		5mv = 2m(v - (-x))	M1	Use of $I = mv - mu$
or $2mx - 3my = 3mv - 2mv$ Al Seen or implied $2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$ $2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$ M1 Correct use of impact law (not necessarily with values in terms of v) Allow $v - v$ on LHS $e = \frac{12}{13}$ Al 0.92 or better (6) $2 \times \frac{1}{2} \times 3m \left(y^2 - (vf)^2\right) = \frac{1}{2} \times 2m \left(x^2 - v^2\right)$ M1 Use KE to form an equation in f . Condone use of change in KE rather than loss Condone 2 on wrong side $3\left(\frac{4}{9} - f^2\right) = \left(\frac{9}{4} - 1\right)$ Al Correct unsimplified equation for f cao NB: $\frac{\sqrt{31}}{6}$ comes from inconsistent subtraction.		$x = \frac{3v}{2}$	A1	Seen or implied
$2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$ m_1 $2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$ m_2 m_3 m_4 m_4 m_4 m_4 m_5 m_6 m_1 m_6 m_1 m_2 m_4 m_6 m_1 m_2 m_4 m_4 m_6 m_1 m_1 m_2 m_4 m		(' ' / /	M1	
$2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$ M1 necessarily with values in terms of v) Allow $v - v$ on LHS $e = \frac{12}{13}$ A1 0.92 or better (6) $2 \times \frac{1}{2} \times 3m \left(y^2 - (vf)^2\right) = \frac{1}{2} \times 2m \left(x^2 - v^2\right)$ M1 Use KE to form an equation in f . Condone use of change in KE rather than loss Condone 2 on wrong side $3\left(\frac{4}{9} - f^2\right) = \left(\frac{9}{4} - 1\right)$ A1 Correct unsimplified equation for f $\left(f^2 = \frac{1}{36}\right) f = \frac{1}{6}$ A1 NB: $\frac{\sqrt{31}}{6}$ comes from inconsistent subtraction.		$y = \frac{2v}{3}$	A1	Seen or implied
6b Speed of B after collision with wall = vf B1 Seen or implied $2 \times \frac{1}{2} \times 3m \left(y^2 - (vf)^2 \right) = \frac{1}{2} \times 2m \left(x^2 - v^2 \right)$ $3 \left(\frac{4}{9} - f^2 \right) = \left(\frac{9}{4} - 1 \right)$ A1 Correct unsimplified equation for f		$2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$	M1	necessarily with values in terms of <i>v</i>)
6b Speed of B after collision with wall = vf B1 Seen or implied $2 \times \frac{1}{2} \times 3m \left(y^2 - (vf)^2 \right) = \frac{1}{2} \times 2m \left(x^2 - v^2 \right)$ $3 \left(\frac{4}{9} - f^2 \right) = \left(\frac{9}{4} - 1 \right)$ A1 Correct unsimplified equation for f . $\left(f^2 = \frac{1}{36} \right) f = \frac{1}{6}$ A1 NB: $\frac{\sqrt{31}}{6}$ comes from inconsistent subtraction. (4)		$e = \frac{12}{13}$	A1	0.92 or better
$2 \times \frac{1}{2} \times 3m \left(y^2 - (vf)^2\right) = \frac{1}{2} \times 2m \left(x^2 - v^2\right)$ $3 \left(\frac{4}{9} - f^2\right) = \left(\frac{9}{4} - 1\right)$ 41 41 $Condone use of change in KE rather than loss Condone 2 on wrong side Correct unsimplified equation for f Cao NB: \frac{\sqrt{31}}{6} \text{ comes from inconsistent subtraction.} (4)$			(6)	
$2 \times \frac{1}{2} \times 3m \left(y^2 - (vf)^2\right) = \frac{1}{2} \times 2m \left(x^2 - v^2\right)$ $3 \left(\frac{4}{9} - f^2\right) = \left(\frac{9}{4} - 1\right)$ 41 41 $Condone use of change in KE rather than loss Condone 2 on wrong side Correct unsimplified equation for f Cao NB: \frac{\sqrt{31}}{6} \text{ comes from inconsistent subtraction.} (4)$				
$2 \times \frac{1}{2} \times 3m \left(y^2 - (vf)^2\right) = \frac{1}{2} \times 2m \left(x^2 - v^2\right)$ M1 $f. \text{ Condone use of change in KE rather than loss}$ $Condone 2 \text{ on wrong side}$ $3 \left(\frac{4}{9} - f^2\right) = \left(\frac{9}{4} - 1\right)$ A1 $Correct unsimplified equation for f$ cao $NB: \frac{\sqrt{31}}{6} \text{ comes from inconsistent subtraction.}$ (4)	6b	Speed of B after collision with wall = vf	B1	Seen or implied
$\left(f^{2} = \frac{1}{36}\right) f = \frac{1}{6}$ A1 NB: $\frac{\sqrt{31}}{6}$ comes from inconsistent subtraction.		$2 \times \frac{1}{2} \times 3m \left(y^2 - (vf)^2 \right) = \frac{1}{2} \times 2m \left(x^2 - v^2 \right)$	M1	f. Condone use of change in KE rather than loss
$\left(f^2 = \frac{1}{36}\right) f = \frac{1}{6}$ A1 NB: $\frac{\sqrt{31}}{6}$ comes from inconsistent subtraction.		$3\left(\frac{4}{9}-f^2\right) = \left(\frac{9}{4}-1\right)$	A1	
(4)		$\left(f^2 = \frac{1}{36}\right) f = \frac{1}{6}$	A1	NB: $\frac{\sqrt{31}}{6}$ comes from
			(4)	meonsistent suottaction.

7a	Use of $\frac{2a \times \frac{1}{2}}{3 \times \frac{\pi}{6}} \left(= \frac{2a}{\pi} \right)$	B1	Seen or implied
	Moments about EC:	M1	Dimensionally correct Condone use of a parallel axis
	$ad \times \frac{d}{2} = \frac{1}{6}\pi a^2 \times \frac{2a}{\pi} \times \sin\frac{\pi}{6}$	A1	Correct unsimplified equation
	$ad \times \frac{d}{2} = \frac{1}{6}\pi a^2 \times \frac{2a}{\pi} \times \sin\frac{\pi}{6}$ $\Rightarrow \left(d^2 = \frac{a^2}{3}\right) a = \sqrt{3}d^{-8}$	A1*	Obtain given answer from correct working
		(4)	
7b	Mass ratios $\frac{a^2}{\sqrt{3}} : \frac{\pi a^2}{6} : \frac{a^2}{\sqrt{3}} + \frac{\pi a^2}{6}$	B1	Or equivalent. Seen or implied
	Moments about BC	M1	Dimensionally correct Condone use of a parallel axis
	$\frac{1}{\sqrt{3}} \times \frac{a}{2} + \frac{\pi}{6} \times \frac{2a}{\pi} \times \frac{\sqrt{3}}{2} = \left(\frac{1}{\sqrt{3}} + \frac{\pi}{6}\right) y$	A1ft	Correct unsimplified. Follow their $\frac{2a}{\pi}$
	Distance from $BC = y = \frac{6a}{6 + \sqrt{3}\pi}$	A1	Or equivalent $\left(y = \frac{6d}{2\sqrt{3} + \pi}\right)$
	Use of trig to find a relevant angle	M1	
	$\tan \beta^{\rm C} = \frac{6}{6 + \sqrt{3}\pi} \times \sqrt{3} \qquad \left(\frac{\overline{y}}{d}\right)$	A1ft	Or equivalent correct unsimplified equation for the required angle
	$\beta = 0.737 (0.74)$	A1	0.74 or better 42.2° implies correct method
		(7)	
		[11]	
		1	

8a	Conservation of energy	M1	Need all three terms and dimensionally correct. Condone sign errors.
	$\frac{1}{2}m \times 10^2 + mgh = \frac{1}{2}m \times 18^2$ $h = 11.4 (11)$	A1	Correct unsimplified equation
	h = 11.4 (11)	A1	3 sf or 2 sf only $\left(\text{not } \frac{80}{7}\right)$
		(3)	
8b	Vertical distance	M1	Complete method using <i>suvat</i> to find angle of projection
	$10\sin\alpha \times 2.5 - \frac{1}{2}g \times 2.5^2 = -11.4$	A1ft	Follow their <i>h</i>
	$\alpha = 50.2^{\circ}$ or $10 \sin \alpha = v_V = 7.7678$	A1	50° or better (50.1618) Accept 50.3° from11.4 Seen or implied Might see $\sin \alpha = \frac{43}{56}$ or $v_V = \frac{215}{28}$
	Horizontal distance = $10\cos\alpha \times 2.5$ or $\sqrt{100 - {v_v}^2} \times 2.5$	M1	
	=16.0 (16)(m)	A1	3 sf or 2 sf only
		(5)	
8c	Using energy: $\frac{1}{2}m \times 64 + mgs = \frac{1}{2}m \times 100$	M1	Complete method to find height above A
	<i>s</i> = 1.8367	A1	1.8 or better
	Use of suvat to form equation in <i>t</i>	M1	
	$1.84 = 10\sin 50.2 \times t - 4.9t^2$	A1	Correct unsimplified equation
	Solve for <i>t</i> and find difference between roots	DM1	Complete method to find the required time Dependent on 2 previous M marks
	T = 0.98 or 0.978	A1	2 sf or 3 sf
		(6)	
8c alt	Use of Pythagoras	M1	Complete method to find vertical component of speed
	Vertical speed $\sqrt{64 - (10\cos\alpha)^2} = 4.8$	A1	Awrt 4.8 or better
	Use of $10\sin\alpha - gt = \pm v$ to find t	M1	
	$\begin{cases} 10\sin 50.2^{\circ} - gt_1 = 4.8\\ 10\sin 50.2 - gt_2 = -4.8 \end{cases}$	A1	Correct unsimplified equations Could also find time to top
	$T = t_2 - t_1 = 1.27 0.29$	DM1	Complete method to find the required time Dependent on 2 previous M marks
	= 0.98 or 0.978	A1	Final answer. 2 sf or 3 sf
		(6)	
8calt	Use of Pythagoras to form quadratic in t	M1	
	$(10\sin\theta - gt)^2 + (10\cos\theta)^2 = 64$	A1	

Simplify and substitute for trig	M1	
$36 + 9.8^2 t^2 - 150.5t = 0$	A1	
$T = t_2 - t_1 = 1.27 0.29$	DM1	Complete method to find the required time Dependent on 2 previous M marks
= 0.98 or 0.978	A1	Final answer. 2 sf or 3 sf
	[14]	