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MA05

(9660/MA05) Unit M2 Mechanics

Mark scheme

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256XMA05/MS

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Key to mark scheme abbreviations

M	Mark is for method
m	Mark is dependent on one or more M marks and is for method
A	Mark is dependent on M or m marks and is for accuracy
B	Mark is independent of M or m marks and is for method and accuracy
E	Mark is for explanation
$\surd$ **or ft**	Follow through from previous incorrect result
CAO	Correct answer only
CSO	Correct solution only
AWFW	Anything which falls within
AWRT	Anything which rounds to
ACF	Any correct form
AG	Answer given
SC	Special case
oe	Or equivalent
A2, 1	2 or 1 (or 0) accuracy marks
–*x* EE	Deduct x marks for each error
NMS	No method shown
PI	Possibly implied
SCA	Substantially correct approach
sf	Significant figure(s)
dp	Decimal place(s)
ISW	Ignore subsequent working

Q	Answer	Marks	Comments
1(a)	$a = \dfrac{2\times3+8\times9+6\times9+10\times3+7\times6}{2+8+6+10+7}$	M1	At least 4 correct terms in the numerator
	$a = \dfrac{68}{11}$	A1	**ACF**
		2	

Q	Answer	Marks	Comments
1(b)	$\overline{Y} = \dfrac{2\times4+8\times4+6k+10k+7\times10}{2+8+6+10+7}$	M1	At least 4 correct terms in the numerator
	$\dfrac{110+16k}{33} = 14$		
	$110+16k = 462$		
	$k = 22$	A1	**CAO**
		2	

	Question 1 Total	**4**	

Q	Answer	Marks	Comments
2(a)(i)	$\lvert\mathbf{r}\rvert = \sqrt{\left(30\cos\left(4t\right)\right)^2 + \left(30\sin\left(4t\right)\right)^2}$ $\lvert\mathbf{r}\rvert = \sqrt{30^2\cos^2\left(4t\right) + 30^2\sin^2\left(4t\right)}$ $\lvert\mathbf{r}\rvert = \sqrt{30^2}$ $\lvert\mathbf{r}\rvert = 30$	**M1** **A1**	 Must be convincingly shown
		2	

Q	Answer	Marks	Comments
2(a)(ii)	Circular path [with centre *O* and radius 30 metres]	**E1**	Any correct description
		1	

Q	Answer	Marks	Comments
2(b)	$\lvert\mathbf{F}\rvert = m\omega^2 r$ $\lvert\mathbf{F}\rvert = 7.5 \times (4)^2 \times 30$ $\lvert\mathbf{F}\rvert = 3600$ [N] Direction: Towards *O*	 **M1** **A1** **B1**	 **oe**
		3	

	Question 2 Total	**6**	

Q	Answer	Marks	Comments
3(a)(i)	At maximum speed $\frac{P}{v} - R = 0$ $P = \left[c\,v^{1.06} \times v = \right] \; c\,v^{2.06}$ $c = \left[\frac{P}{v^{2.06}} = \right] \frac{250}{6.7^{2.06}}$ $c = 4.968...$ $c = 5.0$	**M1 A1** **A1**	**M1**: Use of $P = Fv$ **A1**: Correct relationship for maximum speed **AG** Must be convincingly shown
		3	

Q	Answer	Marks	Comments
3(a)(ii)	$\frac{P}{v} - cv^{1.06} = ma$ $a = \frac{\frac{250}{2.1} - 5.0 \times 2.1^{1.06}}{95}$ $a = 1.1$	**M1** **A1**	Note: if $c = 5.0$ is used, unrounded value is 1.137… if $c = 4.968...$ is used, unrounded value is 1.138…
		2	

Q	Answer	Marks	Comments
3(b)	Increase power output of motor	**B1**	Any valid modification, such as reduce the air resistance acting on the tricycle [make more 'streamlined']
		1	

Q	Answer	Marks	Comments
3(c)	[Maximum speed] increases	B1	
	A component of the weight will also act down the hill/slope in the direction of motion	E1	Any valid reason
		2	

	Question 3 Total	8	

Q	Answer	Marks	Comments
4(a)	$\mathbf{r} = \begin{bmatrix} \ln(2+t) + c_1 \\ 4e^{\frac{t}{2}} + c_2 \end{bmatrix}$	M1 A1	**M1**: At least one component correct **A1**: Both components correct Condone omission of constants of integration for **M1 A1**
	When $t = 0$		
	$\begin{bmatrix} \ln(2) + c_1 \\ 4 + c_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 7 \end{bmatrix}$		
	$\mathbf{r} = \begin{bmatrix} \ln(2+t) - \ln(2) \\ 4e^{\frac{t}{2}} + 3 \end{bmatrix}$	M1 A1	**M1**: At least one component correct **A1**: Both components correct **ACF** For **i** component
		4	

Q	Answer	Marks	Comments
4(b)	$\mathbf{a} = \begin{bmatrix} -(2+t)^{-2} \\ e^{\frac{t}{2}} \end{bmatrix}$	M1 A1	**M1**: At least one component correct **A1**: Both components correct
	When $t = 2$		
	$\mathbf{a} = \begin{bmatrix} -(2+0.05)^{-2} \\ e^{\frac{0.05}{2}} \end{bmatrix}$	M1	PI
	$\lvert\mathbf{a}\rvert = \sqrt{\left(\frac{1}{2.05^2}\right)^2 + \left(e^{\frac{0.05}{2}}\right)^2}$	m1	
	$\lvert\mathbf{a}\rvert = 1.053 \ \left[\text{m s}^{-2}\right]$	A1	
		5	

	Question 4 Total	**9**	

Q	Answer	Marks	Comments
5(a)	Forces up the slope $50 + F$ Forces down the slope $20 \times 9.8 \times \sin(25°) = 82.833...$ [N]	M1	At least one of the expressions for the 'forces up the slope' or 'forces down the slope' correct **PI** By correct equation for F or μ
	Equilibrium (in the direction parallel to the slope) requires $50 + F = 82.833...$	A1	Correct equation involving F or μ
	$F = 32.833...$ [N] Equilibrium (in the direction perpendicular to the slope) requires $R = [20 \times 9.8 \times \cos(25°) =]\ 177.636...$ [N]	M1	R = reaction force acting on block due to contact with slope
	$F = \mu R$ $\mu = \left[\dfrac{32.833...}{177.636...} =\right]\ 0.185$	A1	
		4	

Q	Answer	Marks	Comments
5(b)(i)	Constant acceleration of the block down the slope		
	$a = \left[\frac{50}{20} =\right]\ 2.5\ \left[\text{m s}^{-1}\right]$	B1	
	Distance moved down the slope in the first 6 seconds		
	$s = ut + \frac{1}{2}at^2$		
	$s = \frac{1}{2} \times 2.5 \times (6)^2$	M1	
	$s = 45\ [\text{m}]$	A1	
	Work done against friction		
	$W = Fs$		
	$W = 32.833... \times 45$		
	$W = 1500$	B1ft	**ft** Their F and their s Note: unrounded answer is 1477.49…
	J	B1	Correct units, allow J or joules
		5	

Q	Answer	Marks	Comments
5(b)(ii)	Change in height during the first 6 seconds		
	$\Delta h = [45\sin(25°) =]\ 19.0178...\ [\text{m}]$	B1	
	Loss in GPE		
	$mg\Delta h = 20 \times 9.8 \times 19.017...$	M1	
	$mg\Delta h = 3730\ [\text{J}]$	A1	Note: unrounded answer is 3727.49… [J]
		3	

Q	Answer	Marks	Comments
5(b)(iii)	Conservation of Energy 3727.49… $-$ 1477.49… $=$ 2250 [J]	 **B1ft**	 **ft** Their GPE $-$ their work done
		1	

	Question 5 Total	**13**	

Q	Answer	Marks	Comments
6	$\bar{X} = \dfrac{m \times \left(-\dfrac{4 \times 3}{3\pi}\right) + 2m \times \left(\dfrac{4 \times 3}{3\pi}\right)}{m + 2m}$	**M1 A1**	**M1**: At least one numerator term correct **PI** **A1**: Fully correct **PI**
	$\bar{X} = \dfrac{4}{3\pi}$	**A1**	Correct x-coordinate for COM of C
	$\tan\theta = \dfrac{\left(\dfrac{4}{3\pi}\right)}{3}$	**M1**	**ft** Their x-coordinate for the COM
	$\theta = 8^\circ$	**A1**	Note: unrounded answer is $8.052...^\circ$

	Question 6 Total	**5**	

Q	Answer	Marks	Comments
7(a)	The mass of the rod is negligible	E1	Any correct explanation Allow 'rod has zero mass'
		1	

Q	Answer	Marks	Comments
7(b)(i)	$\sin\alpha = \frac{1.2}{2.0}\ \left[=\frac{3}{5}\right]$ or $\sin\beta = \frac{1.6}{2.0}\ \left[=\frac{4}{5}\right]$	M1	Finds a trigonometric relationship for α or β
	$OP = 1.6\sin\alpha$ or $OP = 1.2\sin\beta$		
	$OP = 0.96\ [\text{m}]$	A1	**CAO**
		2	

Q	Answer	Marks	Comments
7(b)(ii)	$v = r\omega$	M1	
	$\omega = \frac{7}{0.96}$		
	$\omega = 7.3\ \left[\text{rad s}^{-1}\right]$	A1ft	**oe, AWRT** 7.3 Note: unrounded answer is 7.2916… rad s^{-1} **ft** Their OP from **part (b)(i)**
		2	

Q	Answer	Marks	Comments
7(b)(iii)	$\omega = \frac{2\pi}{T} \Rightarrow T = \frac{2\pi}{\omega}$		
	$T = \frac{2\pi}{7.29166} = 0.86\ [\text{s}]$	B1	**oe, AWRT** 0.86 Note: unrounded answer is 0.86169… s
		1	

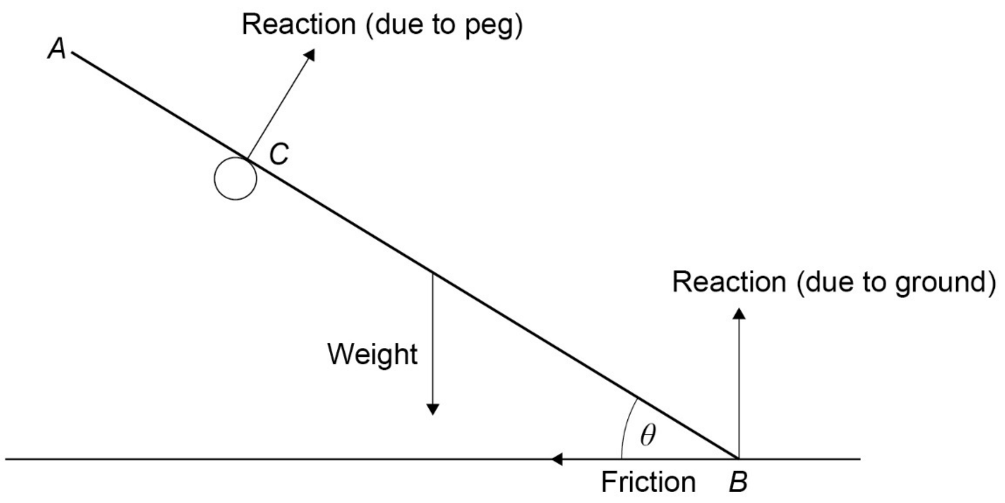
Q	Answer	Marks	Comments
7(c)	$\tan\alpha = \frac{3}{4}$ $\left[= \frac{1.2}{1.6}\right]$ $\sin\beta = \frac{4}{5}$ $\left[= \frac{1.6}{2.0}\right]$ $\cos\beta = \frac{3}{5}$ $\left[= \frac{1.2}{2.0}\right]$	B1	Three trigonometric relationships or correct values for α and β seen or used anywhere in the solution
	Equilibrium of forces in the vertical direction $T_R\cos\alpha = mg + T_S\cos\beta$	B1	
	Resultant force towards O $T_R\sin\alpha + T_S\sin\beta = \frac{mv^2}{r}$	B1	
	$T_R = \frac{mg + T_S\cos\beta}{\cos\alpha}$ $\tan\alpha\left(mg + T_S\cos\beta\right) + T_S\sin\beta = \frac{mv^2}{r}$ $T_S = \frac{\frac{mv^2}{r} - mg\tan\alpha}{\tan\alpha\cos\beta + \sin\beta}$ $T_S = \frac{\frac{15\times 7^2}{0.96} - 15\times 9.8\times\frac{3}{4}}{\frac{3}{4}\times\frac{3}{5}+\frac{4}{5}}$	M1	Attempts to solve equations simultaneously by eliminating T_R or T_S **PI** By at least one correct value for T_R or T_S
	$T_S = 524$	A1	At least one value for T_R or T_S correct, to 3 sf or more Note: unrounded value for T_S is 524.3…
	$T_R = 577$	A1	Both values of T_R and T_S correct to 3 sf Note: unrounded value for T_R is 576.975
		6	

	Question 7 Total	**12**	

Q	Answer	Marks	Comments
8(a)	[Time taken for the ball to cover the 5 m or 5.25 m horizontal displacement]		
	$T = \dfrac{5}{8\cos\theta}$, $T = \dfrac{5.25}{8\cos\theta}$ or $T = \dfrac{d}{8\cos\theta}$	**B1**	Any subject
	$\left[s=\right]$ $8\sin\theta\, T - 0.5\times 9.8\times T^2$	**M1 A1**	**M1**: Use of $s = ut + \frac{1}{2}at^2$ with $u = 8\sin\theta$ and $a = \pm 9.8$ **PI** **A1**: Fully correct
	$\left[s=\right]$ $8\sin\theta\times\dfrac{d}{8\cos\theta}$ $- 0.5\times 9.8\times\left(\dfrac{d}{8\cos\theta}\right)^2$	**m1**	Eliminating T **PI**
	$\left[s=\right]$ $d\tan\theta - \dfrac{49d}{640\cos^2\theta}$		Correct simplification with second term in $\cos^2\theta$
	$\left[s=\right]$ $d\tan\theta - \dfrac{49d}{640}\times\left(1+\tan^2\theta\right)$	**m1**	Use of $\sec^2\theta = 1+\tan^2\theta$
	$0.75 = d\tan\theta - \dfrac{49d^2}{640} - \dfrac{49d^2}{640}\tan^2\theta$	**B1**	Use of $s = 0.75$
	$0.75 = d\tan\theta - \dfrac{49d^2}{640} - \dfrac{49d^2}{640}\tan^2\theta$		
	When $d = 5$ $\tan\theta = 1.8665...$[, $0.7456...$]	**M1**	**PI** At least one correct value for $\tan\theta$ for either $d = 5$ or $d = 5.25$
	$\theta = 61.82...$	**A1**	At least one correct value of θ
	When $d = 5.25$ $\tan\theta = 1.6820...$[, $0.8058...$]		
	$\theta = 59.26...$	**A1**	Both values of θ correct
	$59.3 < \theta < 61.8$	**A1ft**	Range of values to 3 sf, **ft** their two values of θ
		10	

Q	Answer	Marks	Comments
8(b)	61.8 [°]	B1ft	Upper limit of range
	This angle means the coin bounces on the front of the top of the platform, and therefore gives the best chance of the coin coming to rest on the platform	E1	Any plausible reason
		2	

	Question 8 Total	**12**	

Q	Answer	Marks	Comments
9(a)	**See artwork below**	**B1**	Both forces correctly drawn and named. Do not condone 'gravity' in place of 'weight'
			
		1	

Q	Answer	Marks	Comments
9(b)(i)	Taking moments about *B* $14g\cos\theta \times 3 = R_{\text{peg}} \times 6$	**M1**	At least one side correct R_{peg} = reaction force on rod due to peg
	$R_{\text{peg}} = 7g\cos\theta$	**A1**	**oe**, such as $R_{\text{peg}} = 68.6\cos\theta$
		2	

Q	Answer	Marks	Comments
9(b)(ii)	Forces in equilibrium (vertical)		
	$R_{\text{peg}}\cos\theta + R_{\text{ground}} = 14g$	B1	Both sides correct R_{ground} = reaction force on rod due to ground
	Forces in equilibrium (horizontal)		
	$R_{\text{peg}}\sin\theta = F$	B1	F = friction on rod due to rough ground
	Friction acting on rod		
	$F = \mu R_{\text{ground}}$	B1	
	$R_{\text{peg}}\cos\theta + \dfrac{R_{\text{peg}}\sin\theta}{\mu} = 14g$	M1	Eliminates R_{ground} or R_{peg}
	$7g\cos^2\theta + \dfrac{7g\cos\theta\sin\theta}{\mu} = 14g$	m1	Eliminates R_{peg} or R_{ground}
	$\cos^2\theta + \dfrac{1}{\mu}\cos\theta\sin\theta = 2$		
	$\cos\theta\sin\theta = \mu\left(2 - \cos^2\theta\right)$		
	$\mu = \dfrac{\cos\theta\sin\theta}{2 - \cos^2\theta}$	A1	**AG** Must be convincingly shown
		6	

Q	Answer	Marks	Comments
9(b)(iii)	When $\theta = 16^\circ$ $\mu = \dfrac{\cos(16^\circ)\sin(16^\circ)}{2-\cos^2(16^\circ)}$ $\mu = 0.246...$	**B1**	One correct value for $\theta = 16^\circ$ or $\theta = 17^\circ$
	When $\theta = 17^\circ$ $\mu = \dfrac{\cos(17^\circ)\sin(17^\circ)}{2-\cos^2(17^\circ)}$ $\mu = 0.257...$		
	When $\theta = 16^\circ$, $\mu < 0.25$ and when $\theta = 17^\circ$, $\mu > 0.25$, hence $16^\circ < \theta < 17^\circ$	**E1**	Correct conclusion based upon both correct values for $\theta = 16^\circ$ and $\theta = 17^\circ$
		2	

	Question 9 Total	**11**	