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FURTHER MATHEMATICS

FM05

(9665/FM05) Unit FM2 Mechanics

Mark scheme

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256XFM05/MS

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Examiner.

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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
√ **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)	$2\times 7+m\times(-4)=2\times 1$ $4m=12$ $m=3$	M1 A1	Equation for conservation of momentum in **j** direction Correct value for m
		2	

Q	Answer	Marks	Comments
1(b)	$2\times 4+3\times(-2)=2\times 2+3\times k$ $3k=-2$ $k=-\frac{2}{3}$	M1 A1ft	Equation for conservation of momentum in **i** direction with their value for m Correct value for k **ft** Their value for m
		2	

Q	Answer	Marks	Comments
1(c)	$\mathbf{I}=2\begin{bmatrix}2\\1\end{bmatrix}-2\begin{bmatrix}4\\7\end{bmatrix}=\begin{bmatrix}-4\\-12\end{bmatrix}$ $\lvert\mathbf{I}\rvert=\sqrt{12^2+4^2}=\sqrt{160}=4\sqrt{10}\ \ [\text{N s}]$	M1 A1 A1	Finds impulse Correct impulse Correct magnitude of impulse in exact form
		3	

	Question 1 Total	**7**	

Q	Answer	Marks	Comments
2(a)	$\frac{80}{1.6}e = 5 \times 9.8$	**M1**	Equation for equilibrium
	$e = 0.98 \ [\text{m}]$	**A1**	Correct extension
		2	

Q	Answer	Marks	Comments
2(b)(i)	$\text{EPE} = \frac{1}{2} \times \frac{80}{1.6} \times 2.4^2 = 144 \ [\text{J}]$	**M1** **A1**	EPE formula used Correct EPE
		2	

Q	Answer	Marks	Comments
2(b)(ii)	$144 = 5 \times 9.8 \times 1.42 + \frac{1}{2} \times \frac{80}{1.6} \times 0.98^2 + \frac{1}{2} \times 5v^2$	**M1** **M1**	Four term energy equation At least 3 correct energy terms
	$v = 4.5 \ [\text{m s}^{-1}]$	**A1** **A1**	Correct energy equation Correct speed
		4	

	Question 2 Total	**8**	

Q	Answer	Marks	Comments
3(a)	$4\sin\beta = 6\times 0.5\sin\alpha$	**M1**	Equations for motion parallel and perpendicular to the wall
	$4\cos\beta = 6\cos\alpha$	**A1**	Correct equations
	$16\cos^2\beta + 16\sin^2\beta = 36\cos^2\alpha + 9\sin^2\alpha$		
	$16 = 27\cos^2\alpha + 9$	**M1 A1**	**M1**: Equation in $\sin\alpha$ or $\cos\alpha$ only **A1**: Correct equation
	$\cos\alpha = \sqrt{\frac{7}{27}}$		
	$\alpha = 59^\circ$	**A1**	Correct value for α
		5	

Q	Answer	Marks	Comments
3(b)	$4\cos\beta = 6\times\sqrt{\frac{7}{27}}$	**M1**	Equation for motion parallel to the wall with their α
	$\beta = 40^\circ$	**A1**	Correct value for β
		2	

Q	Answer	Marks	Comments
3(c)	$\sin\alpha = \sqrt{1-\frac{7}{27}} = \sqrt{\frac{20}{27}} = \frac{2\sqrt{15}}{9}$	**M1**	Finds their exact value of $\sin\alpha$
	$\lvert\mathbf{I}\rvert = 0.1\times 6\sin\alpha + 0.1\times 3\sin\alpha$	**M1**	Impulse equation
	$= 0.9\times\frac{2\sqrt{15}}{9}$		
	$= \frac{\sqrt{15}}{5}$	**A1**	Correct impulse in required form
		3	

	Question 3 Total	**10**	

Q	Answer	Marks	Comments
4	$0.4\dfrac{\mathrm{d}v}{\mathrm{d}t} = 0.4\times 9.8 - \dfrac{v}{10}$	**M1**	Forms differential equation
	$\dfrac{\mathrm{d}v}{\mathrm{d}t} = 9.8 - \dfrac{v}{4}$		
	$\displaystyle\int \frac{1}{9.8-\frac{v}{4}}\,\mathrm{d}v = \int 1\,\mathrm{d}t$	**M1**	Separates variables to form integrals
	$-4\ln\left(9.8-\dfrac{v}{4}\right) = t + c$	**A1**	Correct integration
	$v = 0, t = 0 \Rightarrow c = -4\ln(9.8)$	**M1**	Finds constant of integration
	$-4\ln\left(9.8-\dfrac{v}{4}\right) = t - 4\ln(9.8)$		
	$\ln\left(\dfrac{9.8-\frac{v}{4}}{9.8}\right) = -\dfrac{t}{4}$		
	$9.8-\dfrac{v}{4} = 9.8\mathrm{e}^{-\frac{t}{4}}$		
	$v = 39.2\left(1-\mathrm{e}^{-\frac{t}{4}}\right)$	**A1**	Correct expression for the velocity
	$t = 12$		
	$v = 39.2\left(1-\mathrm{e}^{-3}\right) = 37\ \left[\mathrm{m\ s^{-1}}\right]$	**A1**	Correct velocity for $t = 12$

	Question 4 Total	**6**	

Q	Answer	Marks	Comments
5(a)	$\omega = \frac{1}{2}$	**B1**	Correct ω
	$x = 0.6 - 0.6\cos\left(\frac{1}{2}t\right)$	**M1**	Expression containing $0.6\cos\left(\frac{1}{2}t\right)$
		A1	Correct expression
		3	

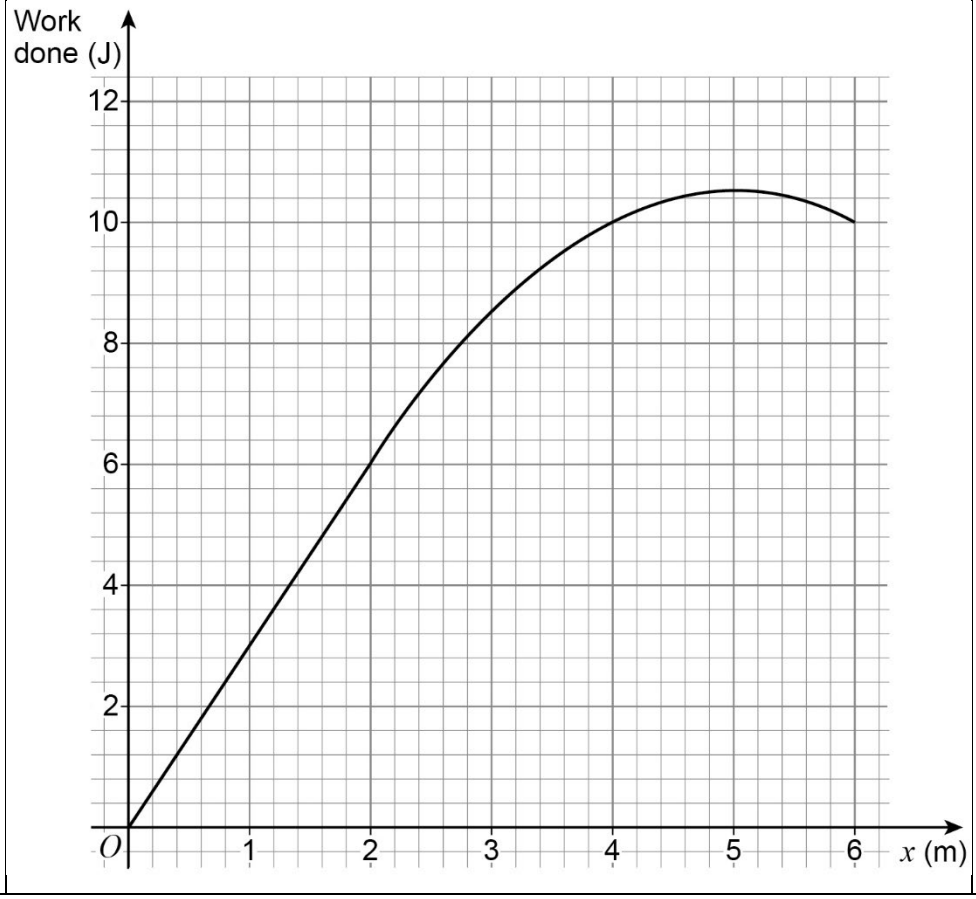
Q	Answer	Marks	Comments
5(b)	Max Speed $= 0.6 \times \frac{1}{2} = 0.3 \left[\text{m s}^{-1}\right]$	**M1**	Product of their ω and 0.6
		A1	Correct maximum speed
		2	

Q	Answer	Marks	Comments
5(c)	Max Acceleration $= 0.6 \times \left(\frac{1}{2}\right)^2 = 0.15 \left[\text{m s}^{-2}\right]$	**M1**	Product of their ω^2 and 0.6
		A1	Correct maximum acceleration
		2	

Q	Answer	Marks	Comments
5(d)	$v^2 = \left(\frac{1}{2}\right)^2 \left(0.6^2 - 0.5^2\right)$	**M1**	Uses SHM speed formula
	$= \frac{1}{4} \times \frac{11}{100}$	**A1ft**	Correct values **ft** Their ω
	$v = \frac{\sqrt{11}}{20} \left[\text{m s}^{-1}\right]$	**A1**	Correct speed
		3	

Q	Answer	Marks	Comments
5(e)	$\pm 0.036 = 0.3\ddot{x}$	**B1**	Correct magnitude of acceleration
	$\ddot{x} = \pm 0.12$ $\ddot{x} = 0.15\cos\left(\frac{1}{2}t\right)$	**M1**	Expression for acceleration in terms of t
	$\pm 0.12 = 0.15\cos\left(\frac{1}{2}t\right)$	**M1**	At least one correct time
	$t = 1.287$ or 4.996 $x = 0.12$ or 1.08 [m]	**M1 A1**	**M1**: At least one correct displacement **A1**: Both correct displacements Allow 1.1 for 1.08
		5	

	Question 5 Total	**15**	

Q	Answer	Marks	Comments
6		**B1** **B1** **B1**	Straight line from (0,0) to (2,6) Curved section with correct shape Maximum when $x = 5$ Finishes at (6,10)
	Question 6 Total	**4**	

Q	Answer	Marks	Comments
7(a)	Let e be the extension of the spring in equilibrium		
	$210e = 6 \times 9.8$	M1	Equation to find extension in equilibrium
	$e = 0.28$	A1	Correct extension
	Let x be the displacement of the sphere from its equilibrium position		
	$T = 210(x + 0.28)$	M1 A1	Expression for tension Correct tension
	$6\frac{\mathrm{d}^2x}{\mathrm{d}t^2} = 6 \times 9.8 - 210(x + 0.28)$	M1	Four term differential equation
	$\frac{\mathrm{d}^2x}{\mathrm{d}t^2} = 9.8 - 35x - 9.8$		
	$\frac{\mathrm{d}^2x}{\mathrm{d}t^2} = -35x$	A1	Correct simplified differential equation
	Acceleration is proportional to the displacement and in the opposite direction, so SHM	E1	Correct explanation
		7	

Q	Answer	Marks	Comments
7(b)	$x = 0.4\cos\left(\sqrt{35}t\right)$	M1	Expression for displacement with their ω
	$-0.1 = 0.4\cos\left(\sqrt{35}t\right)$	A1	Correct equation for time
	$t = 0.308$ [seconds]	A1	Correct time
		3	

	Question 7 Total	**10**	

Q	Answer	Marks	Comments
8	For both balls $0 = ut\sin\theta - \frac{1}{2}gt^2\cos\alpha$	**M1**	Expression to find time of flight
	$t = \frac{2u\sin\theta}{g\cos\alpha}$	**A1**	Correct time of flight
	$x_{AB} = u\cos\theta \times \frac{2u\sin\theta}{g\cos\alpha} - \frac{1}{2}g\sin\alpha\left(\frac{2u\sin\theta}{g\cos\alpha}\right)^2$	**M1**	Expression for *AB*
	$x_{AC} = u\cos\theta \times \frac{2u\sin\theta}{g\cos\alpha} + \frac{1}{2}g\sin\alpha\left(\frac{2u\sin\theta}{g\cos\alpha}\right)^2$	**M1**	Expression for *AC*
		A1	Both correct
	$BC = \frac{4u^2\sin\theta\cos\theta}{g\cos\alpha}$	**M1**	Expression for *BC*
	$= \frac{2u^2\sin 2\theta}{g\cos\alpha}$	**M1**	Uses trig identity
	Max $BC = \frac{2u^2}{g\cos\alpha}$	**A1**	Correct maximum distance

	Question 8 Total	**8**	

Q	Answer	Marks	Comments
9(a)	At the highest point of the circle: $mg + R = \frac{mU^2}{a}$	**M1**	Forms equation of motion at the highest point of the circle
	$R = \frac{mU^2}{a} - mg$ $R > 0$ $\frac{mU^2}{a} - mg > 0$	**A1**	Correct expression for R
	$\frac{U^2}{a} > g$	**M1**	Forms an inequality
	$U^2 > ag$	**A1**	Obtains the required result from correct working
		4	

Q	Answer	Marks	Comments
9(b)	$mg\cos\theta + R = \frac{mv^2}{a}$	**M1**	Resolves towards the centre of the circle
	$R = \frac{mv^2}{a} - mg\cos\theta$	**A1**	Correct expression
	$\frac{1}{2}mv^2 = \frac{1}{2}m \times \frac{ag}{2} + mga(1-\cos\theta)$	**M1**	Forms energy equation
	$v^2 = \frac{ag}{2} + 2ga(1-\cos\theta)$	**A1**	Correct equation
	$R = \frac{mg}{2} + 2mg(1-\cos\theta) - mg\cos\theta$ $R = 0$	**M1**	Eliminates v
	$3mg\cos\theta = \frac{5mg}{2}$	**M1**	Finds value for $\cos\theta$
	$\cos\theta = \frac{5}{6}$	**A1**	Correct value for $\cos\theta$
	$\text{Percentage} = \left(1 - \frac{2\cos^{-1}\left(\frac{5}{6}\right)}{2\pi}\right) \times 100 = 81\%$	**A1**	Correct percentage
		8	

	Question 9 Total	**12**	