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INTERNATIONAL A-LEVEL

FURTHER MATHEMATICS

FM05

(9665/FM05) Unit FM2 Mechanics

Mark scheme

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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)	$\mathbf{I} = 2\begin{bmatrix}2\\1\end{bmatrix} - 2\begin{bmatrix}4\\7\end{bmatrix} = \begin{bmatrix}-4\\-12\end{bmatrix}$ $\lvert\mathbf{I}\rvert = \sqrt{12^2 + 4^2} = \sqrt{160} = 4\sqrt{10}$ [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)	$\frac{80}{1.6}e = 5 \times 9.8$ $e = 0.98 \ [\text{m}]$	**M1** **A1**	Equation for equilibrium, using $\frac{\lambda e}{l}$ Correct extension AWRT 0.98
		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)	$144 = 5 \times 9.8 \times 1.42 + \frac{1}{2} \times \frac{80}{1.6} \times 0.98^2 + \frac{1}{2} \times 5v^2$ $144 = 69.58 + 24.01 + 2.5v^2$ $v = 4.5 \ [\text{m s}^{-1}]$	**M1** **M1** **A1** **A1**	Four term energy equation At least 3 correct energy terms Correct energy equation Correct speed (4.4904…) AWRT 4.5
		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
	$\cos\alpha = \sqrt{\frac{7}{27}}$		
	$\alpha = 59$	**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 or perpendicular to the wall with their α
	$\beta = 40$	**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 $\sin\alpha$ PI
	$\lvert\mathbf{I}\rvert = 0.1\times 6\sin\alpha + 0.1\times 3\sin\alpha$	**M1**	Impulse equation
	$= 0.9\times\frac{2\sqrt{15}}{9}$		
	$= \frac{\sqrt{15}}{5}$	**A1**	Correct impulse in required form Must be positive.
		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 three-term 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 $t = 12$ AWRT 37

	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** **A1**	Expression containing $0.6\cos(\omega t)$ 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** **A1**	Product of their ω and 0.6 Correct maximum speed
		2	

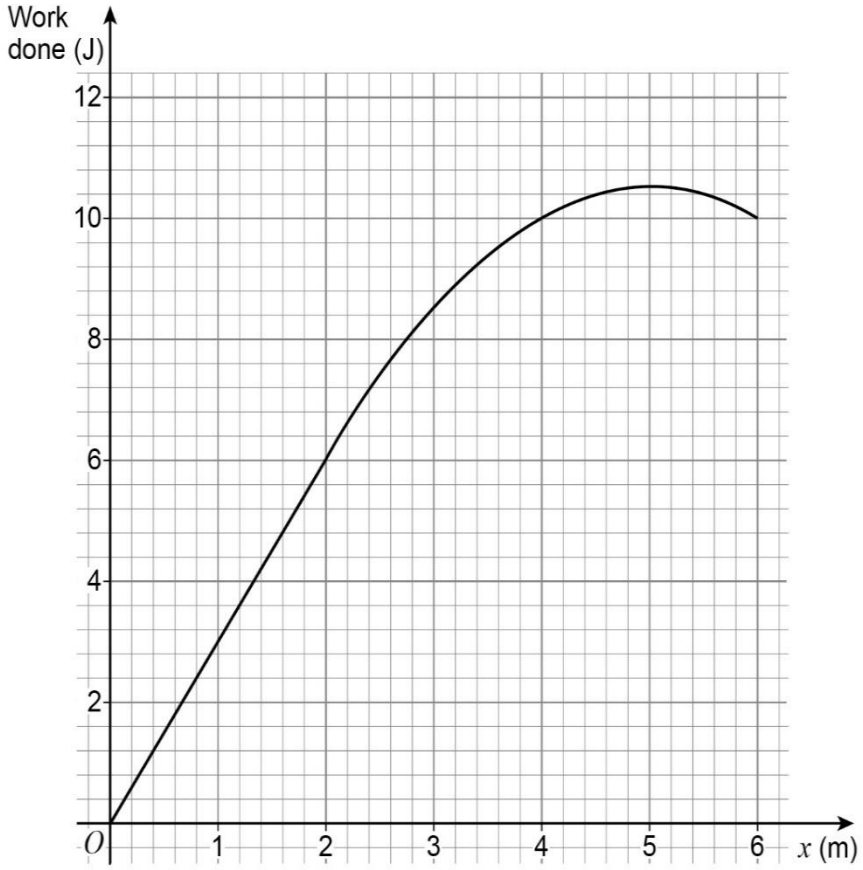
Q	Answer	Marks	Comments
5(c)	Max Acceleration $= 0.6 \times \left(\frac{1}{2}\right)^2 = 0.15 \left[\text{m s}^{-2}\right]$	**M1** **A1**	Product of their ω^2 and 0.6 Correct maximum acceleration
		2	

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)	$\pm 0.036 = 0.3\ddot{x}$ $\ddot{x} = \pm 0.12$	**B1**	Correct values of acceleration
	$\ddot{x} = 0.15\cos\left(\frac{1}{2}t\right)$	**M1**	Expression for acceleration in terms of t Allow sin or cos.
	$\pm 0.12 = 0.15\cos\left(\frac{1}{2}t\right)$	**A1**	Correct equation to find at least one value t
	$t = 1.287$ 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	

Q	Answer	Marks	Comments
5(e)ALT	$\pm 0.036 = 0.3\ddot{x}$ $\ddot{x} = \pm 0.12$	**B1**	Correct values of acceleration
	$\pm 0.12 = -\frac{1}{4}x$	**M1**	Forms equation to find a displacement
	$x = \pm 0.48$	**A1**	Obtains 0.48
	$x = 0.6 + 0.48 = 1.08$ [m] or $x = 0.6 - 0.48 = 0.12$ [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		
	$T = 210\left(x + 0.28\right)$	**M1**	Expression for tension (Must contain two terms.)
		A1	Correct tension (May be in terms of g and λ)
	$6\dfrac{\mathrm{d}^2x}{\mathrm{d}t^2} = 6\times 9.8 - 210\left(x + 0.28\right)$	**M1**	Four term equation of motion, including the acceleration in any form.
	$\dfrac{\mathrm{d}^2x}{\mathrm{d}t^2} = 9.8 - 35x - 9.8$		
	$\dfrac{\mathrm{d}^2x}{\mathrm{d}t^2} = -35x$	**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**	

	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 **AG** Must be convincingly shown.
		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 $\cos\theta$
	$\cos\theta = \frac{5}{6}$ or $\theta = 33.56°$	**A1**	Correct value for $\cos\theta$ or θ
	Percentage $= \left(1 - \frac{2\cos^{-1}\left(\frac{5}{6}\right)}{2\pi}\right) \times 100 = 81\%$	**A1**	Correct percentage **AWRT** 81
		8	

	Question 9 Total	**12**	