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EDEXCEL A LEVEL FURTHER MATHEMATICS: QUESTIONS BY TOPIC

Motion in a Circle (1)

Further Mechanics 2 · Topic 1

7 questions · 62 marks · Mark schemes included

Pearson Edexcel A Level Further Mathematics (9FM0), June 2019 - June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

QUESTION	SOURCE	MARKS	PAGE
1.1 HORIZONTAL CIRCULAR MOTION		5 Qs · 39 marks	3
1. Q1	Option 4C: Further Mechanics 2 June2019	6	4
2. Q4	Option 4C: Further Mechanics 2 June2022	8	6
3. Q3	Option 4C: Further Mechanics 2 June2024	9	10
4. Q6	Option 4C: Further Mechanics 2 June2023	9	14
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1.2 VERTICAL CIRCULAR MOTION		2 Qs · 23 marks	20
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QUESTIONS

7 questions · 62 marks · 2 sub-topics



SUB-TOPIC 1.1

HORIZONTAL CIRCULAR MOTION

Sub-topic 1.1 · 5 questions · 39 marks · lowest tariff first



1.

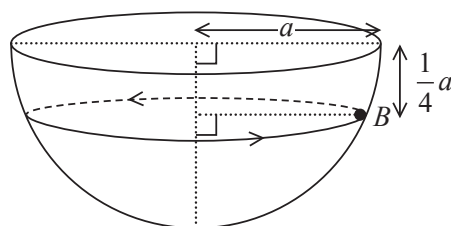


Figure 1

A hemispherical shell of radius a is fixed with its rim uppermost and horizontal. A small bead, B , is moving with constant angular speed, ω , in a horizontal circle on the smooth inner surface of the shell. The centre of the path of B is at a distance $\frac{1}{4}a$ vertically below the level of the rim of the hemisphere, as shown in Figure 1.

Find the magnitude of ω , giving your answer in terms of a and g .

(6)



Question 4 continued

Lined area for writing the answer to Question 4 continued.



Question 4 continued

(Total for Question 4 is 8 marks)



3.

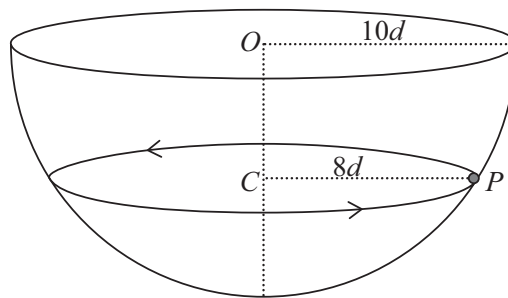


Figure 2

Figure 2 shows a hemispherical bowl of internal radius $10d$ that is fixed with its circular rim horizontal.

The centre of the circular rim is at the point O .

A particle P moves with **constant** angular speed on the smooth inner surface of the bowl.

The particle P moves in a horizontal circle with radius $8d$ and centre C .

- (a) Find, in terms of g , the exact magnitude of the acceleration of P .

(6)

The time for P to complete one revolution is T .

- (b) Find T in terms of d and g .

(3)





(Total for Question 9 is 7 marks)



6.

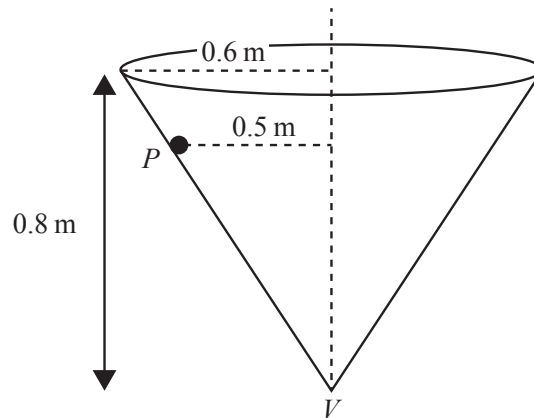


Figure 4

A hollow right circular cone, of internal base radius 0.6 m and height 0.8 m , is fixed with its axis vertical and its vertex V pointing downwards, as shown in Figure 4.

A particle P of mass $m\text{ kg}$ moves in a horizontal circle of radius 0.5 m on the rough inner surface of the cone.

The particle P moves with constant angular speed $\omega\text{ rad s}^{-1}$

The coefficient of friction between the particle P and the inner surface of the cone is 0.25

Find the greatest possible value of ω

(9)



[illegible]

(Total for Question 6 is 9 marks)



SUB-TOPIC 1.2

VERTICAL CIRCULAR MOTION

Sub-topic 1.2 · 2 questions · 23 marks · lowest tariff first







(Total for Question 3 is 11 marks)



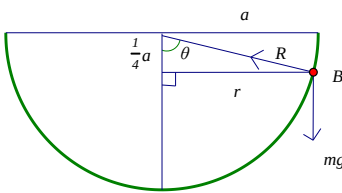
Question 8 continued



MARK SCHEMES

official mark schemes

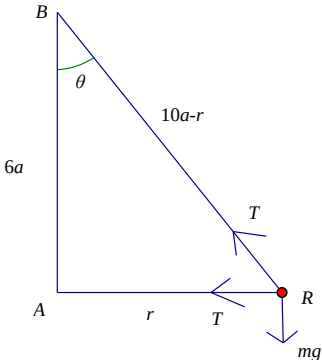


Question	Scheme	Marks	AOs
1			
	$\uparrow R \cos \theta = mg$	M1	3.1b
	$\leftrightarrow R \sin \theta = mr\omega^2$	M1	3.3
		A1	1.1b
	$\tan \theta = \frac{r}{a/4} \quad (\tan \theta = \sqrt{15})$	B1	1.1b
	Complete strategy to find ω	M1	3.1b
	$\tan \theta = \frac{mr\omega^2}{mg} = \frac{4r}{a}, \Rightarrow \omega^2 = \frac{4g}{a}, \omega = 2\sqrt{\frac{g}{a}}$	A1	1.1b
		(6)	
	Alternative:		
	$\uparrow R \cos \theta = mg$	M1	3.1b
	$\leftrightarrow R \sin \theta = ma \sin \theta \omega^2$	M1	3.3
		A1	1.1b
	$\cos \theta = \frac{1}{4}$	B1	1.1b
	Complete strategy to find ω	M1	3.1b
	$\Rightarrow R = 4mg, 4mg = ma\omega^2 \Rightarrow \omega = 2\sqrt{\frac{g}{a}}$	A1	1.1b
(6 marks)			

Question	Marks	Marking Guidance
1		Check their diagram to see where they have put θ Check the working carefully, particularly the value of r : some errors in the working can lead to a fortuitously correct answer
	M1	Resolve vertically. Must be dimensionally correct.

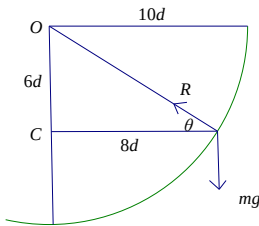
	M1	Resolve horizontally and form equation for circular motion. Must be dimensionally correct.
	A1	Correct pair of equations for their unknowns (any r)
	B1	Correct trig ratio(s) seen or implied. Allow for $r = \frac{\sqrt{15}}{4}a$
	M1	Complete strategy to form and solve a set of equations with $r \neq a$ to find ω . For solving their 2 equations – not dependent
	A1	Eliminate additional variables to obtain ω . Accept equivalent exact forms.
	(6)	
		If R does not act through the centre of the hemisphere then the maximum available is M1M1A0B0M0A0: 2/6



Question	Scheme	Marks	AOs
4(a)			
	Resolve vertically	M1	3.4
	$T \cos \theta = mg$	A1	1.1b
	$T = \left(\frac{mg}{\cos \theta} = \frac{6.8mg}{6} \right) = \frac{17mg}{15}$	A1	1.1b
		(3)	
4(b)	Equation of motion	M1	3.1b
	$mr\omega^2 = T + T \sin \theta \quad \left(m \times 3.2a\omega^2 = \text{their } T \left(1 + \frac{8}{17} \right) \right)$	A1 A1	1.1b 1.1b
	Solves for ω or ω^2	M1	1.1b
	$\left(\frac{r\omega^2}{g} = \frac{1 + \sin \theta}{\cos \theta} = \frac{6.8 + 3.2}{6}, \quad \omega^2 = \frac{10g}{6 \times 3.2a} \right) \quad \omega = \sqrt{\frac{25g}{48a}} = \frac{5}{4} \sqrt{\frac{g}{3a}}$	A1	1.1b
		(5)	
(8 marks)			
Notes:			
(a)M1	Need all terms. Condone sin/cos confusion		
A1	Correct unsimplified equation.		
A1	Correct answer only 1.1mg or better (1.13...mg) Do not ignore subsequent working if they try to combine this with a tension in AR		
(b)M1	Equation for circular motion. Need all terms and dimensionally correct. Condone sin/cos confusion and sign errors. Any correct form for acceleration		
A1 A1	Unsimplified equation with at most one error Correct unsimplified equation		

	Allow M1A1A0 for $mr\omega^2 = T' + (their\ (a))\sin\theta$
M1	Clear attempt to substitute for trig and tension or divide their two equations to solve for ω or ω^2 in terms of a and g Independent M mark but requires an equation using tension and trig.
A1	Any equivalent form $0.72\sqrt{\frac{g}{a}}$ or better (0.7216...)

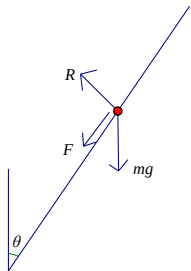


Ques tion	Scheme		Marks	AOs
3a				
	Resolve vertically		M1	3.3
	$R \sin \theta = mg$		A1	1.1b
	Horizontal equation of motion		M1	3.3
	$R \cos \theta = ma (= mr\omega^2)$		A1	1.1b
	Solve for a		DM1	2.1
	$\frac{g}{a} = \tan \theta \Rightarrow a = \frac{4}{3}g$		A1	1.1b
			(6)	
3b	$8d\omega^2 = \frac{4}{3}g \Rightarrow \omega = \sqrt{\frac{g}{6d}}$		M1	3.4
	Use of $T = \frac{2\pi}{\omega}$		M1	1.1b
	$T = 2\pi\sqrt{\frac{6d}{g}}$ oe OR $15\sqrt{\frac{d}{g}}$ or better		A1	1.1b
			(3)	
Total 9 marks				
Notes:				
3a	M1	Dimensionally correct equation. Condone sine / cosine confusion for their angle		
	A1	Correct unsimplified equation		
	M1	Dimensionally correct equation. Condone sine / cosine confusion for their angle. Accept any correct form for the acceleration.		
	A1	Correct unsimplified equation. Accept any correct form for the acceleration.		
	DM1	Eliminate R and θ to solve for a . Dependent on both previous M marks.		
	A1	Correct only (or exact equivalent)		
3b	M1	Use $a = r\omega^2$ or $a = \frac{v^2}{r}$ to obtain ω or v $\left(v = \sqrt{\frac{32dg}{3}}\right)$		

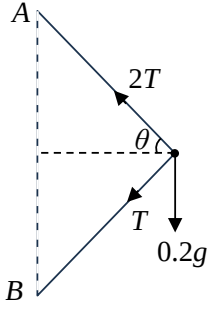


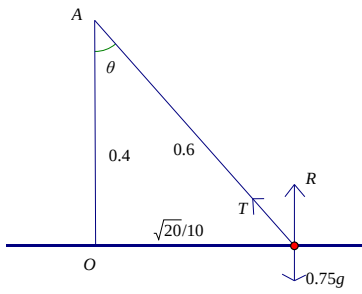
	M1	Complete method to find T
	A1	$15\sqrt{\frac{d}{g}}$ or better - must be in terms of d and g . Accept $T = \frac{2\pi}{\sqrt{\frac{g}{6d}}}$



Question	Scheme	Marks	AOs
6			
	Resolve vertically	M1	3.4
	$F \cos \theta + mg = R \sin \theta$ $(4F + 5mg = 3R)$	A1 A1	1.1b 1.1b
	Equation for motion towards centre	M1	3.4
	$F \sin \theta + R \cos \theta = m \times 0.5\omega^2$ $(3F + 4R = m \times 2.5\omega^2)$	A1 A1	1.1b 1.1b
	At max ω $R + 5mg = 3R \quad \left(R = \frac{5mg}{2}\right)$ $\frac{3}{4}R + 4R = m \times 2.5\omega^2 \quad (19R = 10m\omega^2)$	M1	1.2
	Solve for ω : $19 \times \frac{5mg}{2} = 10m\omega^2$	DM1	3.1a
	$\omega^2 = \frac{19g}{4} \Rightarrow \max \omega = 6.8 \text{ (6.82)}$	A1	2.2a
		(9)	
	(9 marks)		
Notes:			
M1	Need all terms. Condone sign errors and sin/cos confusion.		
A1 A1	Unsimplified equation with at most one error. Correct unsimplified equation.		
M1	Need all terms. Condone sign errors and sin/cos confusion in R or their R .		
A1 A1	Unsimplified equation with at most one error. Correct unsimplified equation in R or their R .		
	NB: if F in wrong direction count this as one error (not one in each equation) and deduct one accuracy mark in the first equation affected. Either / both equation(s) could be replaced with equations for resolving parallel and perpendicular to the surface. Perpendicular: $R = mg \sin \theta + m\omega^2 \cos \theta \quad \left(R = \frac{3}{5}mg + \frac{2}{5}m\omega^2\right)$		

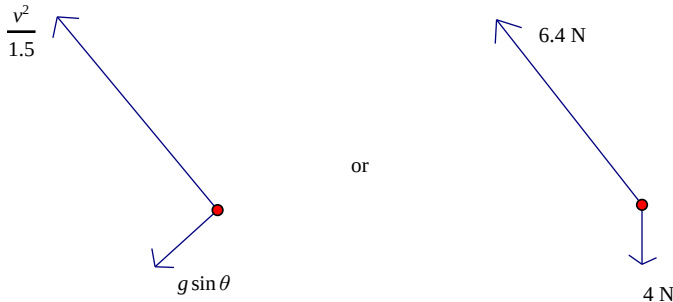
	Parallel: $F + mg \cos \theta = mr\omega^2 \sin \theta$ $\left(F + \frac{4}{5}mg = \frac{3}{10}m\omega^2 \right)$ If they have more than 2 equations, mark the correct equations. If they go on to use an incorrect equation then DM0.
M1	Use of $F = \mu R$ to eliminate F or R Condone inequality
DM1	Complete method including substitution of trig values to obtain a value for ω
A1	2 s.f or 3 s.f only $\sqrt{\frac{19g}{4}}$ is A0 Must be an equation

Question	Scheme	Marks	AOs
3	 $\begin{pmatrix} \sin \theta = \frac{2}{3} \\ \cos \theta = \frac{\sqrt{5}}{3} \\ r = \frac{\sqrt{5}}{5} \end{pmatrix}$		
	Resolve vertically	M1	3.4
	$\uparrow 2T \sin \theta = 0.2g + T \sin \theta \quad (T \sin \theta = 0.2g)$	A1	1.1b
	Equation of motion	M1	3.4
	$0.2r\omega^2 = 2T \cos \theta + T \cos \theta \quad (0.12\omega^2 = 3T)$	A1 A1	1.1b 1.1b
	Complete strategy to find ω	DM1	3.1a
	$\omega^2 = 25T = \frac{5g}{\sin \theta} = \frac{15g}{2} \quad \omega = 8.6 \quad (8.57)$	A1	1.1b
(7 marks)			
Notes:			
M1	Correct number of terms. Condone sin/cos confusion and sign errors		
A1	Correct unsimplified equation. Accept $T_A \sin \theta = 0.2g + T_B \sin \theta$ Allow m in place of 0.2 and their numerical $\sin \theta / \cos \theta$		
M1	Circular motion. Correct number of terms. Condone sin/cos confusion. Acceleration must be $r\omega^2$ or v^2/r		
A1	Unsimplified equation with at most one error. Allow m in place of 0.2 and their numerical $\sin \theta / \cos \theta$		
A1	Correct unsimplified equation. Accept $0.2r\omega^2 = T_A \cos \theta + T_B \cos \theta$ Allow m in place of 0.2 and their numerical $\sin \theta / \cos \theta$		
DM1	Complete strategy to form sufficient equations to solve for ω including upper tension being twice lower tension and a method to find r . Dependent on both previous M marks.		
A1	2 or 3 sf only		

Question	Scheme	Marks	AOs
5(a)			
	Resolve vertically	M1	3.4
	$\uparrow 0.75g = T \cos \theta + R$ $\left(\frac{3g}{4} = \frac{2}{3}T + R \right)$	A1	1.1b
	Equation of motion	M1	3.4
	$\leftrightarrow 0.75 \times \sin \theta \times 9 = T \sin \theta$ $\left(0.75 \times \frac{\sqrt{20}}{10} \times 9 = T \times \frac{\sqrt{20}}{6} \right)$	A1	1.1b
	Complete strategy to find T and R	M1	3.1a
	$T = \frac{6 \times 0.75 \times 9}{10} = 4.05 \text{ (N)}$	A1	1.1b
	$R = 0.75g - \frac{2}{3}T = 4.65 \text{ (N) or } 4.7 \text{ (N)}$	A1	1.1b
		(7)	
(b)	Use $R = 0$ to form revised equations	M1	3.4
	$T \cos \theta = 0.75g$, $T \sin \theta = 0.75 \times \frac{10\sqrt{20}}{100} \omega^2$ $\left(\text{or } T \sin \theta = 0.75 \times 0.6 \sin \theta \times \omega^2 \right)$	A1	1.1b
	Complete strategy to find ω e.g. $\Rightarrow \tan \theta = \frac{\sqrt{20}\omega^2}{10g} = \frac{\sqrt{20}}{4}$	M1	1.1b
	$\omega = \sqrt{\frac{5g}{2}} = 4.95 \text{ (rad/s)}$	A1	1.1b
		(4)	
(11 marks)			

Notes:		
(a)	M1	Correct number of terms
	A1	Correct unsimplified equation
	M1	Circular motion. Condone confusion over units. $\frac{\sqrt{20}}{10}$ might not be seen as r cancels.
	A1	Correct unsimplified equation
	M1	Complete strategy to form sufficient equations to solve for T and R .
	A1	One force correct
	A1	Both correct (Finding value for R involves g)
(b)	M1	Correct interpretation of loss of contact
	A1	Revised equations
	M1	Solve for ω
	A1	Exact, 4.9 or 4.95 (non-exact answer requires substitution for g).



Question	Scheme	Marks	AOs
8(a)	Conservation of energy:	M1	3.1a
	$\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + mg \times r(1 - \cos \theta)$	A1 A1	1.1b 1.1b
	Equation of motion	M1	3.1a
	$T - mg \cos \theta = \frac{mv^2}{r}$	A1	1.1b
	Complete strategy to find T	M1	2.1
	$T = \frac{4 \times 18}{15} + 1.6 = 6.4 \text{ (N) } ^*$	A1*	2.2a
		(7)	
8(b)	$\cos \theta = 0.4$	B1	1.1b
		B1 B1	1.1b 1.1b
	Use of Pythagoras or cosine rule and $F = ma$	M1	3.1a
	$ a = \sqrt{12^2 + 100 \times \frac{21}{25}} = 2\sqrt{57} = 15 \text{ (ms}^{-2}\text{)}$	A1	1.1b
		(5)	
(12 marks)			
Notes:			
SC	Candidates who use $g = 9.8$ are eligible for all marks except the final A1 in each of parts (a) and (b). If they only use $g = 9.8$ in one part, then this penalty only applies to that part. In part (b) candidates are also eligible for all marks except the final A1 if they use the given answer of 6.4 from (a) along with $g = 9.8$ in their other work.		
(a)M1	Need all terms. Dimensionally correct. Condone sign errors and sin/cos confusion		
A1	Unsimplified equation with at most one error		
A1	Correct unsimplified equation. Accept with g or 10		
M1	Need all terms. Dimensionally correct. Condone sign errors and sin/cos confusion		



A1	Correct unsimplified equation. Accept with g or 10
M1	Complete strategy to find T e.g. use conservation of energy, circular motion and substitute value for v to form sufficient equations to find T
A1*	Obtain given answer from correct working. N.B. $g = 9.8$ gives $T = 6.32$ (but scores A0)
(b)B1	Correct only. Must be seen or used in part (b). Award for $\sin \theta = \frac{\sqrt{21}}{5}$ N.B. $g = 9.8$ gives $\cos \theta = \frac{19}{49}$ ($= 0.38775\dots$), $\sin \theta = \frac{2\sqrt{510}}{49}$ ($= 0.92176\dots$)
B1 B1	One component of acceleration or force correct (unsimplified) Both components of acceleration or force correct (unsimplified) N.B. $g = 9.8$ gives components as 12 & 9.03 (velocity) or 6.32 and 3.92 (force)
M1	Complete strategy to find magnitude of acceleration. $ F = \sqrt{6.4^2 + 4^2 - 2 \times 6.4 \times 4 \times \cos \theta} = 0.4a$
A1	Accept 15 or better (15.09966887...) including exact equivalent N.B. $g = 9.8$ gives 15.01998... but scores A0 $g = 9.8$ and $T = 6.4$ gives 15.18025... but scores A0

