

**INTERNATIONAL A-LEVEL  
FURTHER MATHEMATICS**

**FM05**

(9665/FM05) Unit FM2 Mechanics

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Mark scheme

January 2026

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Version: 1.0 Final

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**Key to mark scheme abbreviations**

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





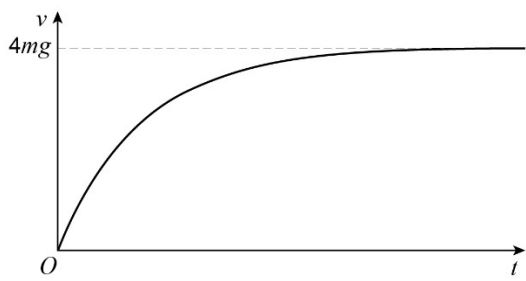
Q	Answer	Marks	Comments
<b>3(a)</b>	$T_1 = 5g$	<b>M1</b>	Equation for the extension of one string
	$5g = \frac{\lambda}{a}e_1$		
	$e_1 = \frac{5ag}{\lambda}$	<b>A1</b>	One correct extension
	$T_2 = 3g$	<b>A1</b>	Second correct extension
$3g = \frac{\lambda}{a}e_2$			
	$e_2 = \frac{3ag}{\lambda}$	<b>A1</b>	Correct length <i>OB</i> oe
	$OB = 2a + \frac{5ag}{\lambda} + \frac{3ag}{\lambda} = 2a \left( 1 + \frac{4g}{\lambda} \right)$		
		<b>4</b>	

Q	Answer	Marks	Comments
<b>3(b)(i)</b>	$2a = 2g + T_2$	<b>M1</b>	Applies Newton's Second Law to <i>A</i> Must use a mass of 2 kg. Allow $2a =$ any integer multiple of $g$
	$= 2g + 3g$		
	$a = \frac{5g}{2}$	<b>A1</b>	Correct acceleration
		<b>2</b>	

Q	Answer	Marks	Comments
<b>3(b)(ii)</b>	$3a = 3g - T_2$	<b>B1</b>	Correct acceleration
	$= 3g - 3g$		
	$a = 0$		
		<b>1</b>	

	<b>Question 3 Total</b>	<b>7</b>	
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Q	Answer	Marks	Comments
4(a)	$\frac{dv}{dt} = g - \frac{v}{4m}$ $\int \frac{1}{g - \frac{v}{4m}} dv = \int 1 dt$ $-4m \ln \left( g - \frac{v}{4m} \right) = t + c$ $t = 0, v = 0 \Rightarrow c = -4m \ln g$ $-4m \ln \left( g - \frac{v}{4m} \right) = t - 4m \ln g$ $\frac{g - \frac{v}{4m}}{g} = e^{-\frac{t}{4m}}$ $v = 4mg \left( 1 - e^{-\frac{t}{4m}} \right)$	<p><b>M1</b></p> <p><b>M1</b></p> <p><b>A1</b></p> <p><b>A1</b></p> <p><b>A1</b></p>	<p>Differential equation</p> <p>Separation of variables</p> <p>Correct integration</p> <p>Condone missing constant of integration</p> <p>Correct constant of integration</p> <p>Correct expression</p>
		<b>5</b>	

Q	Answer	Marks	Comments
4(b)		<p><b>B1</b></p> <p><b>B1</b></p>	<p>Correct shape</p> <p>Correct asymptote including correct label on the vertical axis</p>
		<b>2</b>	



Q	Answer	Marks	Comments
5(a)	$\text{EPE} = \frac{1}{2} \times \frac{125}{1.5} \times 0.6^2$	M1	Uses EPE formula
	$\text{EPE} = 15 \text{ [J]}$	A1	Correct EPE
		2	

Q	Answer	Marks	Comments
5(b)	Let $d$ be the distance that the particle moves $0.6 \leq d \leq 2.1$	B1	Correct range of values for $d$ PI by use of 0.6 and 2.1
	$15 = 4.2g\mu \times d$	M1 A1	M1: Two term energy equation A1: Correct equation PI by 0.174 or 0.607
	$\mu = \frac{15}{4.2gd}$	M1	Uses range of values for $d$ to find a range of values for $\mu$ Must not contain 0 or 1
	$\frac{15}{4.2g \times 2.1} \leq \mu \leq \frac{15}{4.2g \times 0.6}$	A1	Correct range of values Allow strict inequality signs.
		5	

Q	Answer	Marks	Comments
5(c)	$15 = 4.2g \times \frac{15}{4.2g \times 2.1} \times 0.6 + \frac{1}{2} \times 4.2v^2$	M1 A1ft	M1: Three term energy equation A1ft: Correct equation for their smallest coefficient of friction
	$v^2 = \frac{250}{49} = 5.0966\dots$ $v = \frac{5\sqrt{10}}{7} = 2.258\dots$ $v = 2.3 \text{ [m s}^{-1} \text{ to 2 sf]}$	A1	Correct speed $\frac{5\sqrt{10}}{7}$ or <b>AWRT</b> 2.3
		3	

	<b>Question 5 Total</b>	<b>10</b>	
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Q	Answer	Marks	Comments
6(a)	$\mathbf{v} = \begin{bmatrix} v\cos 45^\circ \\ v\sin 45^\circ \end{bmatrix}$ $\begin{bmatrix} -I\cos 60^\circ \\ I\sin 60^\circ \end{bmatrix} = \begin{bmatrix} mv\cos 45^\circ \\ mv\sin 45^\circ \end{bmatrix} - \begin{bmatrix} mu \\ 0 \end{bmatrix}$ $\begin{bmatrix} -\frac{1}{2}I \\ \frac{\sqrt{3}}{2}I \end{bmatrix} = m \begin{bmatrix} \frac{\sqrt{2}}{2}v - u \\ \frac{\sqrt{2}}{2}v \end{bmatrix}$ $\frac{\sqrt{3}}{2}I = m \frac{\sqrt{2}}{2}v$ $I = mv \frac{\sqrt{6}}{3}$ $-\frac{1}{2}I = m \left( \frac{\sqrt{2}}{2}v - u \right)$ $mu = mv \frac{\sqrt{2}}{2} + mv \frac{\sqrt{6}}{6}$ $u = v \left( \frac{\sqrt{2}}{2} + \frac{\sqrt{6}}{6} \right) = v \left( \frac{3\sqrt{2} + \sqrt{6}}{6} \right)$ $v = \left( \frac{3\sqrt{2} + \sqrt{6}}{6} \right)^{-1} u = \left( \frac{3\sqrt{2} - \sqrt{6}}{2} \right) u$	<p><b>M1</b></p> <p><b>A1</b></p> <p><b>A1</b></p> <p><b>M1</b></p> <p><b>A1</b></p>	<p>Uses impulse equation with vectors or components</p> <p>Correct equation(s)</p> <p>Correct impulse in terms of <math>v</math></p> <p>Uses their impulse to find <math>u</math> in terms of <math>v</math></p> <p>Correct <math>v</math> Allow any equivalent exact form eg <math>\left( \frac{2\sqrt{3}}{\sqrt{2} + \sqrt{6}} \right) u</math> or <math>u\sqrt{6 - 3\sqrt{3}}</math></p>
		<b>5</b>	

Q	Answer	Marks	Comments
<b>6(a)</b> <b>ALT</b>	$\mathbf{v} = \begin{bmatrix} v \cos 45^\circ \\ v \sin 45^\circ \end{bmatrix}$ $\begin{bmatrix} -I \cos 60^\circ \\ I \sin 60^\circ \end{bmatrix} = m\mathbf{v} - \begin{bmatrix} mu \\ 0 \end{bmatrix}$ $\mathbf{v} = \begin{bmatrix} u - \frac{1}{2m}I \\ \frac{\sqrt{3}}{2m}I \end{bmatrix}$ $\tan 45^\circ = 1$ $mu - \frac{1}{2}I = \frac{\sqrt{3}}{2}I$ $I = (\sqrt{3} - 1)mu$ $\mathbf{v} = \begin{bmatrix} u - \frac{1}{2}(\sqrt{3} - 1)u \\ \frac{\sqrt{3}}{2}(\sqrt{3} - 1)u \end{bmatrix} = \begin{bmatrix} \frac{3 - \sqrt{3}}{2} \\ \frac{3 - \sqrt{3}}{2} \end{bmatrix} u$ $v = \left( \sqrt{2 \left( \frac{3 - \sqrt{3}}{2} \right)^2} \right) u = \left( \frac{3\sqrt{2} - \sqrt{6}}{2} \right) u$	<p><b>M1</b></p> <p><b>A1</b></p> <p><b>A1</b></p> <p><b>M1</b></p> <p><b>A1</b></p>	<p>Uses impulse equation with vectors or components</p> <p>Correct expression for <math>\mathbf{v}</math></p> <p>Correct impulse</p> <p>Uses their impulse to find <math>\mathbf{v}</math></p> <p>Correct <math>v</math>                      Allow any equivalent exact form eg  <math>\left( \frac{2\sqrt{3}}{\sqrt{2} + \sqrt{6}} \right) u</math> or <math>u\sqrt{6 - 3\sqrt{3}}</math></p>
		<b>5</b>	

Q	Answer	Marks	Comments
<b>6(a)</b> <b>ALT</b>	$\mathbf{v} = \begin{bmatrix} v\cos 45^\circ \\ v\sin 45^\circ \end{bmatrix}$ $\mathbf{I} = \begin{bmatrix} mv\cos 45^\circ \\ mv\sin 45^\circ \end{bmatrix} - \begin{bmatrix} mu \\ 0 \end{bmatrix}$	<b>M1</b>	Uses impulse equation with vectors or components
	$\mathbf{I} = m \begin{bmatrix} \frac{\sqrt{2}}{2}v - u \\ \frac{\sqrt{2}}{2}v \end{bmatrix}$	<b>A1</b>	Correct impulse vector
	$\tan 120^\circ = -\sqrt{3}$ $\frac{\sqrt{2}}{2}v = -\sqrt{3} \left( \frac{\sqrt{2}}{2}v - u \right)$	<b>A1</b>	Correct equation in $u$ and $v$
	$\frac{v}{2}(\sqrt{2} + \sqrt{6}) = \sqrt{3}u$	<b>M1</b>	Solves equation to find $v$
	$v = \left( \frac{3\sqrt{2} - \sqrt{6}}{2} \right) u$	<b>A1</b>	Correct $v$ Allow any equivalent exact form eg $\left( \frac{2\sqrt{3}}{\sqrt{2} + \sqrt{6}} \right) u$ or $u\sqrt{6 - 3\sqrt{3}}$
		<b>5</b>	

Q	Answer	Marks	Comments
<b>6(b)</b>	$I = m \times \left( \frac{3\sqrt{2} - \sqrt{6}}{2} \right) u \times \frac{\sqrt{6}}{3}$	<b>M1</b>	Finds impulse
	$I = mu(\sqrt{3} - 1)$	<b>A1</b>	Correct impulse
		<b>2</b>	

	<b>Question 6 Total</b>	<b>7</b>	
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Q	Answer	Marks	Comments
7(a)	$\text{Period} = \frac{2\pi}{\sqrt{14}}$	<b>B1</b>	Correct period seen or stated <b>ACF</b> eg $2\pi\sqrt{\frac{0.7}{g}}$ or $\frac{\pi\sqrt{14}}{7}$
	$\frac{7\sqrt{14}}{75} = \frac{4 \times 0.7\alpha}{\left(\frac{2\pi}{\sqrt{14}}\right)}$	<b>M1</b>	Forms equation using any multiple of arc length over period
	$\alpha = \frac{\pi}{15}$	<b>A1</b>	Correct $\alpha$
		<b>3</b>	

Q	Answer	Marks	Comments
7(b)	$\frac{\pi}{45} = \frac{\pi}{15} \cos(\sqrt{14}t)$	<b>M1</b>	Forms equation to find time with the correct $\omega$ Allow $\frac{\pi}{45} = \frac{\pi}{15} \sin(\sqrt{14}t)$
	$\frac{1}{3} = \cos(\sqrt{14}t)$	<b>A1</b>	Correct equation
	$t = 0.329 \text{ [seconds to 3dp]}$	<b>A1</b>	Correct time
		<b>3</b>	

	<b>Question 7 Total</b>	<b>6</b>	
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Q	Answer	Marks	Comments
9(a)	$28e = 0.2 \times 9.8$	M1	Forms equation to find extension using Hooke's Law
	$e = \frac{0.2 \times 9.8}{28} = 0.070 \text{ [m]}$	A1	Correct extension Allow 0.07
		2	

Q	Answer	Marks	Comments
9(b)	Let $x$ be the displacement below the equilibrium position $T = 28(0.07 + x)$	B1	Correct expression for the tension
	$0.2 \frac{d^2x}{dt^2} = 0.2g - T$ $= 1.96 - 1.96 - 28x$	M1	Forms differential equation
	$\frac{d^2x}{dt^2} = -140x$	A1	Simplifies correct differential equation to SHM form Accept $\frac{d^2x}{dt^2} = -\frac{k}{m}x$
	$\therefore$ SHM as the acceleration is proportional to the displacement and in the opposite direction	E1	Concludes that motion is SHM from correct working
		4	

Q	Answer	Marks	Comments
9(c)	Period = $\frac{2\pi}{\sqrt{140}}$	B1	Correct period Accept $0.169\pi$ ACF eg $\frac{\sqrt{35}}{35}\pi$ or $\frac{\pi}{\sqrt{35}}$
		1	

Q	Answer	Marks	Comments
<b>9(d)</b>	$x = 0.03\cos(\sqrt{140}t)$ <p>For maximum value</p> $T = \frac{\cos^{-1}\left(\frac{0.01}{0.03}\right)}{\sqrt{140}} = 0.1040$ $b = 0.1040$ <p>For minimum value:</p> $T = 2 \times \left( \frac{2\pi}{4\sqrt{140}} - \frac{\cos^{-1}\left(\frac{0.01}{0.03}\right)}{\sqrt{140}} \right) = 0.0574$ $a = 0.0574$ $0.0574 \leq T \leq 0.1040$	<p><b>B1</b></p> <p><b>M1</b></p> <p><b>A1</b></p> <p><b>M1</b></p> <p><b>A1</b></p> <p><b>A1</b></p>	<p>Correct expression for the displacement Accept <math>x = 0.03\sin(\sqrt{140}t)</math></p> <p>Uses <math>\frac{\cos^{-1}\left(\frac{0.01}{0.03}\right)}{\sqrt{140}}</math></p> <p>Correct value for <math>b</math></p> <p>Forms an equation to find <math>a</math></p> <p>Correct equation to find <math>a</math></p> <p>Correct inequality</p>
		<p><b>6</b></p>	
	<p><b>Question 9 Total</b></p>	<p><b>13</b></p>	

Q	Answer	Marks	Comments
10	$2 \begin{bmatrix} 4 \\ -2 \end{bmatrix} + 3 \begin{bmatrix} 2 \\ 1 \end{bmatrix} = 2 \begin{bmatrix} 3 \\ 0 \end{bmatrix} + 3\mathbf{v}_B$ $3\mathbf{v}_B = \begin{bmatrix} 8 \\ -1 \end{bmatrix}$ $\mathbf{v}_B = \frac{1}{3} \begin{bmatrix} 8 \\ -1 \end{bmatrix}$ $\mathbf{I}_B = 3 \left( \frac{1}{3} \begin{bmatrix} 8 \\ -1 \end{bmatrix} - \begin{bmatrix} 2 \\ 1 \end{bmatrix} \right)$ $\mathbf{I}_B = \begin{bmatrix} 2 \\ -4 \end{bmatrix}$ $\frac{1}{3} \begin{bmatrix} 8 \\ -1 \end{bmatrix} \cdot \begin{bmatrix} 2 \\ -4 \end{bmatrix} = \frac{20}{3}$ $\frac{20}{3} = \sqrt{\frac{65}{9}} \times \sqrt{20} \cos \theta$ $\cos \theta = \frac{20}{\sqrt{20 \times 65}} = \frac{2\sqrt{13}}{13}$ $\theta = 56^\circ$	<p><b>M1</b></p> <p><b>A1</b></p> <p><b>M1</b></p> <p><b>A1</b></p> <p><b>M1</b></p> <p><b>A1</b></p> <p><b>A1</b></p>	<p>Uses conservation of momentum</p> <p>Correct velocity of B after the collision</p> <p>Finds impulse on one sphere</p> <p>Correct impulse</p> <p>Uses scalar product or finds two angles (<b>AWRT</b> 63 and <b>AWRT</b> 7).</p> <p>Correct equation to find angle</p> <p>Correct angle</p>
		<b>7</b>	
	<b>Question 10 Total</b>	<b>7</b>	

Q	Answer	Marks	Comments
11	$0 = 2V\sin\alpha - gt\cos\theta$ $t = \frac{2V\sin\alpha}{g\cos\theta}$ $0 = V\sin\beta - gt\cos\theta$ $t = \frac{V\sin\beta}{g\cos\theta}$ $x_A = 2V\cos\alpha t - \frac{1}{2}gt^2\sin\theta$ $x_B = V\cos\beta t + \frac{1}{2}gt^2\sin\theta$ $d = x_A + x_B$ $= 2V\cos\alpha \times \frac{2V\sin\alpha}{g\cos\theta} + V\cos\beta \times \frac{V\sin\beta}{g\cos\theta}$ $d = 2V^2 \frac{\sin(2\alpha)}{g\cos\theta} + \frac{1}{2}V^2 \frac{\sin(2\beta)}{g\cos\theta}$ $d = \frac{V^2}{2g\cos\theta} (4\sin(2\alpha) + \sin(2\beta))$	<p><b>M1</b></p> <p><b>A1</b></p> <p><b>A1</b></p> <p><b>M1</b></p> <p><b>M1</b></p> <p><b>M1</b></p> <p><b>A1</b></p>	<p>Equation for perpendicular velocity of one ball</p> <p>Time in terms of <math>\alpha</math></p> <p>Time in terms of <math>\beta</math></p> <p><b>PI</b> by <math>2\sin\alpha = \sin\beta</math> from work with perpendicular components.</p> <p>Expressions for distance parallel to the plane</p> <p>Expression for <math>d</math> not in terms of <math>t</math></p> <p>Uses double angle formula on a two term expression.</p> <p>Correct expression from correct working <b>AG</b> Must be convincingly shown</p>
		<b>7</b>	
	<b>Question 11 Total</b>	<b>7</b>	