OXFORD AQA
INTERNATIONAL QUALIFICATIONS

# INTERNATIONAL A-LEVEL
# FURTHER MATHEMATICS
# FM05

(9665/FM05) Unit FM2 Mechanics

Mark scheme

January 2026

Version: 1.0 Final

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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 | $4\cos 60° = v\cos\theta$<br>$v\cos\theta = 2$<br>$\frac{1}{3}\times 4\sin 60° = v\sin\theta$<br>$v\sin\theta = \frac{2\sqrt{3}}{3}$ | M1 A1 | **M1** Equations for motion parallel and perpendicular to the wall<br>**A1** Both correct<br>**PI** by correct expression for $\tan\theta$ |
| | $\tan\theta = \frac{1}{\sqrt{3}} = \frac{\sqrt{3}}{3}$ | M1 | Uses tan to find an angle |
| | $\theta = 30$ | A1 | **CAO** |
| | | 4 | |

| | | | |
|---|---|---|---|
| | **Question 1 Total** | **4** | |

| Q | Answer | Marks | Comments |
|---|---|---|---|
| **2(a)** | Work Done $= \int_0^5 \frac{x(5-x)}{4}\,\mathrm{d}x$<br><br>Work Done $= \left[\frac{5x^2}{8} - \frac{x^3}{12}\right]_0^5$<br>$= \frac{125}{24}$ [J] | **M1 A1**<br><br>**A1** | **M1** Sets up an integral to find the work done<br><br>**A1** Correct integral with correct limits<br><br>Correct value **oe** eg $5\frac{5}{24}$ |
| | | **3** | |

| Q | Answer | Marks | Comments |
|---|---|---|---|
| **2(b)** | $\frac{125}{24} = \frac{3}{2}v^2 - \frac{3}{2}\times 4^2$<br><br>$v^2 = \frac{701}{36}$<br>$v = \frac{\sqrt{701}}{6}$ $\left[\text{m s}^{-1}\right]$ | **M1**<br><br>**A1** | Uses change in KE equals work done<br>**ft** their work done from part (a).<br>Condone sign errors<br>**PI** by expression for $v$ with no more than one error eg<br>$6v^2 = \frac{5}{3}x^2 - \frac{1}{3}x^3 + 96$<br><br>Correct speed |
| | | **2** | |

| | | | |
|---|---|---|---|
| | **Question 2 Total** | **5** | |

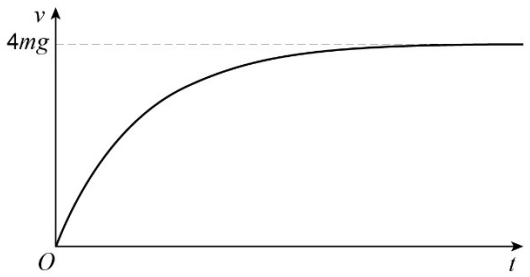
| Q | Answer | Marks | Comments |
|---|---|---|---|
| **3(a)** | $T_1 = 5g$<br>$5g = \frac{\lambda}{a}e_1$ | **M1** | Equation for the extension of one string |
| | $e_1 = \frac{5ag}{\lambda}$ | **A1** | One correct extension |
| | $T_2 = 3g$<br>$3g = \frac{\lambda}{a}e_2$<br>$e_2 = \frac{3ag}{\lambda}$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

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

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

| | | | |
|---|---|---|---|
| | **Question 3 Total** | **7** | |

| Q | Answer | Marks | Comments |
|---|---|---|---|
| 4(a) | $\frac{\mathrm{d}v}{\mathrm{d}t} = g - \frac{v}{4m}$ | M1 | Differential equation |
| | $\int \frac{1}{g - \frac{v}{4m}} \mathrm{d}v = \int 1 \, \mathrm{d}t$ | M1 | Separation of variables |
| | $-4m \ln\left(g - \frac{v}{4m}\right) = t + c$ | A1 | Correct integration<br>Condone missing constant of integration |
| | $t = 0, v = 0 \Rightarrow c = -4m \ln g$ | A1 | Correct constant of integration |
| | $-4m \ln\left(g - \frac{v}{4m}\right) = t - 4m \ln g$ | | |
| | $\frac{g - \frac{v}{4m}}{g} = \mathrm{e}^{-\frac{t}{4m}}$ | A1 | Correct expression |
| | $v = 4mg\left(1 - \mathrm{e}^{-\frac{t}{4m}}\right)$ | | |
| | | 5 | |

| Q | Answer | Marks | Comments |
|---|---|---|---|
| 4(b) |  | B1 | Correct shape |
| | | B1 | Correct asymptote including correct label on the vertical axis |
| | | 2 | |

| Q | Answer | Marks | Comments |
|---|---|---|---|
| **4(c)** | $2mg = 4mg\left(1-\mathrm{e}^{-\frac{t}{4m}}\right)$<br>$\frac{1}{2} = 1-\mathrm{e}^{-\frac{t}{4m}}$<br>$-\frac{t}{4m} = \ln\frac{1}{2}$<br>$t = m\ \ln 16$ | **M1**<br><br>**A1** | Forms equation and solves for $t$<br>**ft** their expression for $v$<br><br>Correct result using the correct expression for $v$ |
| | | **2** | |

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|---|---|---|---|
| | **Question 4 Total** | **9** | |

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

| Q | Answer | Marks | Comments |
|---|---|---|---|
| **5(b)** | Let $d$ be the distance that the particle moves<br>$0.6 \leq d \leq 2.1$ | **B1** | Correct range of values for $d$<br>**PI** by use of 0.6 and 2.1 |
| | $15 = 4.2g\mu \times d$ | **M1 A1** | **M1**: Two term energy equation<br>**A1**: Correct equation<br>**PI** by 0.174 or 0.607 |
| | $\mu = \frac{15}{4.2gd}$<br>$\frac{15}{4.2g \times 2.1} \leq \mu \leq \frac{15}{4.2g \times 0.6}$ | **M1** | Uses range of values for $d$ to find a range of values for $\mu$<br>Must not contain 0 or 1 |
| | $0.174 \leq \mu \leq 0.607$ | **A1** | Correct range of values<br>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<br>**A1ft**: Correct equation for their smallest coefficient of friction |
| | $v^2 = \frac{250}{49} = 5.0966...$<br>$v = \frac{5\sqrt{10}}{7} = 2.258...$<br>$v = 2.3$ [m s$^{-1}$ to 2 sf] | **A1** | Correct speed $\frac{5\sqrt{10}}{7}$ or **AWRT** 2.3 |
| | | **3** | |

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|---|---|---|---|
| | **Question 5 Total** | **10** | |

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

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

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

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

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|---|---|---|---|
| | **Question 6 Total** | **7** | |

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

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

| | | | |
|---|---|---|---|
| | **Question 7 Total** | **6** | |

| Q | Answer | Marks | Comments |
|---|---|---|---|
| 8 | $mg\cos 30° = \frac{mv^2}{r}$<br>$v^2 = gr\cos 30°$ | M1 A1 | **M1**: Resolves radially<br>**A1**: Correct equation |
| | $\frac{1}{2}mU^2 + mgr(1-\cos 30°) = \frac{1}{2}mv^2$<br>$\frac{1}{2}mU^2 + mgr(1-\cos 30°) = \frac{1}{2}mgr\cos 30°$ | M1 A1 | **M1**: Three term energy equation<br>**A1**: Correct energy equation |
| | $U^2 = gr\cos 30° - 2gr + 2gr\cos 30°$<br>$= gr\left(\frac{3\sqrt{3}}{2} - 2\right)$<br>$U = \sqrt{gr\left(\frac{3\sqrt{3}}{2} - 2\right)}$ | A1 | Correct $U$<br>**oe**<br>Accept $\sqrt{0.598...gr}$ or $0.773...\sqrt{rg}$ |
| | | **5** | |

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| | **Question 8 Total** | **5** | |

| Q | Answer | Marks | Comments |
|---|---|---|---|
| **9(a)** | $28e = 0.2 \times 9.8$ | **M1** | Forms equation to find extension using Hooke's Law |
| | $e = \dfrac{0.2 \times 9.8}{28} = 0.070$ [m] | **A1** | Correct extension<br>Allow 0.07 |
| | | **2** | |

| Q | Answer | Marks | Comments |
|---|---|---|---|
| **9(b)** | Let $x$ be the displacement below the equilibrium position<br>$T = 28(0.07 + x)$ | **B1** | Correct expression for the tension |
| | $0.2\dfrac{\mathrm{d}^2x}{\mathrm{d}t^2} = 0.2g - T$<br>$= 1.96 - 1.96 - 28x$ | **M1** | Forms differential equation |
| | $\dfrac{\mathrm{d}^2x}{\mathrm{d}t^2} = -140x$ | **A1** | Simplifies correct differential equation to SHM form<br>Accept $\dfrac{\mathrm{d}^2x}{\mathrm{d}t^2} = -\dfrac{k}{m}x$ |
| | $\therefore$ 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 $= \dfrac{2\pi}{\sqrt{140}}$ | **B1** | Correct period<br>Accept $0.169\,\pi$<br>ACF eg $\dfrac{\sqrt{35}}{35}\pi$ or $\dfrac{\pi}{\sqrt{35}}$ |
| | | **1** | |

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

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|---|---|---|---|
| | **Question 9 Total** | **13** | |

| Q | Answer | Marks | Comments |
|---|---|---|---|
| 10 | $2\begin{bmatrix}4\\-2\end{bmatrix}+3\begin{bmatrix}2\\1\end{bmatrix}=2\begin{bmatrix}3\\0\end{bmatrix}+3\mathbf{v}_B$ | **M1** | Uses conservation of momentum |
| | $3\mathbf{v}_B=\begin{bmatrix}8\\-1\end{bmatrix}$<br>$\mathbf{v}_B=\frac{1}{3}\begin{bmatrix}8\\-1\end{bmatrix}$ | **A1** | Correct velocity of B after the collision |
| | $\mathbf{I}_B=3\left(\frac{1}{3}\begin{bmatrix}8\\-1\end{bmatrix}-\begin{bmatrix}2\\1\end{bmatrix}\right)$ | **M1** | Finds impulse on one sphere |
| | $\mathbf{I}_B=\begin{bmatrix}2\\-4\end{bmatrix}$ | **A1** | Correct impulse |
| | $\frac{1}{3}\begin{bmatrix}8\\-1\end{bmatrix}\bullet\begin{bmatrix}2\\-4\end{bmatrix}=\frac{20}{3}$ | **M1** | Uses scalar product or finds two angles (**AWRT** 63 and **AWRT** 7). |
| | $\frac{20}{3}=\sqrt{\frac{65}{9}}\times\sqrt{20}\cos\theta$ | **A1** | Correct equation to find angle |
| | $\cos\theta=\frac{20}{\sqrt{20\times65}}=\frac{2\sqrt{13}}{13}$<br>$\theta=56°$ | **A1** | Correct angle |
| | | **7** | |

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|---|---|---|---|
| | **Question 10 Total** | **7** | |

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

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|---|---|---|---|
| | **Question 11 Total** | **7** | |