OXFORD AQA
INTERNATIONAL QUALIFICATIONS

INTERNATIONAL A-LEVEL
FURTHER MATHEMATICS
FM8M2

Further Mechanics 2

Mark scheme

Specimen

Version: 1.0

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
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
NMS	No method shown
PI	Possibly implied
sf	Significant figure(s)
dp	Decimal place(s)
ISW	Ignore subsequent working

Mark Scheme Alignment

Marks in the Marks column will typically align with the relevant line of mathematics in the Answer column where the mark is awarded. If two or more marks are awarded for the same line of mathematics, then the Guidance column will give further details as to how each mark is awarded.

Square Brackets

Where square brackets appear in a line of the mark scheme where one or more marks are awarded, the mathematics inside the square bracket is not required for marks to be awarded. Instead, they are intended to be helpful to users of the mark scheme.

Exceptions to this include integration, vectors and matrices where square brackets carry a different mathematical meaning.

Q	Answer	Marks	Guidance
1	$W = \int_0^8 6\mathrm{e}^{-0.1x}\,\mathrm{d}x$	M1	Uses formula for work done by a variable force Condone missing or incorrect limits
	$= \left[-60\mathrm{e}^{-0.1x}\right]_0^8$	A1	Correct integration
	$= 60 - 60\mathrm{e}^{-0.8}$		
	$= 33.040...$		
	$W = 33.0$	A1	**AG** Must be convincingly shown with a correct exact form for the work done before final answer following fully correct working
	Question 1 Total	**3**	

Q	Answer	Marks	Guidance
2(a)	$3\begin{bmatrix}2\\9\end{bmatrix}+8\begin{bmatrix}5\\-4\end{bmatrix}=3\begin{bmatrix}6\\1\end{bmatrix}+8\mathbf{v}_B$ $8\mathbf{v}_B=\begin{bmatrix}28\\-8\end{bmatrix}$ $\left[\mathbf{v}_B=\right]\begin{bmatrix}3.5\\-1\end{bmatrix}\quad\left[\text{m s}^{-1}\right]$	**M1 A1** **A1**	**M1**: Applies conservation of momentum in a vector form **A1**: Correct vector equation **CAO**
	Subtotal	**3**	

Q	Answer	Marks	Guidance
2(b)	$\mathbf{I}=3\begin{bmatrix}6\\1\end{bmatrix}-3\begin{bmatrix}2\\9\end{bmatrix}$ $=\begin{bmatrix}12\\-24\end{bmatrix}$ $\lvert\mathbf{I}\rvert=\sqrt{12^2+24^2}$ $\left[\lvert\mathbf{I}\rvert=\right]\ 12\sqrt{5}\ \ \left[\text{N s}\right]$	**M1** **A1** **A1**	Uses impulse equation with vectors Correct impulse **CAO**
	Subtotal	**3**	

	Question 2 Total	**6**	

Q	Answer	Marks	Guidance
3	$0.2\frac{\mathrm{d}v}{\mathrm{d}t} = 0.2\times 9.8 - \frac{v}{8}$	**M1**	Uses $a = \frac{\mathrm{d}v}{\mathrm{d}t}$ to form a differential equation
	$\frac{\mathrm{d}v}{\mathrm{d}t} = 9.8 - \frac{5v}{8}$		
	$\int \frac{1}{9.8 - \frac{5v}{8}}\ \mathrm{d}v = \int \mathrm{d}t$	**M1**	Separates variables to form integrals
	$-\frac{8}{5}\ln\left(9.8 - \frac{5v}{8}\right) = t + c$	**A1**	Correct integration
	$v = 0, t = 0 \Rightarrow c = -\frac{8}{5}\ln(9.8)$	**M1**	Finds constant of integration
	$-\frac{8}{5}\ln\left(9.8 - \frac{5v}{8}\right) = t - \frac{8}{5}\ln(9.8)$		
	$\ln\left(\frac{9.8 - \frac{5v}{8}}{9.8}\right) = -\frac{5}{8}t$		
	$9.8 - \frac{5v}{8} = 9.8\mathrm{e}^{-\frac{5}{8}t}$		
	$v = \frac{8}{5}\times 9.8\left(1 - \mathrm{e}^{-\frac{5}{8}t}\right)$	**A1**	Correct expression for the velocity
	$v = \frac{8}{5}\times 9.8\left(1 - \mathrm{e}^{-\frac{5}{8}\times 11}\right)$		
	$[v =]15.7 \quad [\mathrm{m\ s^{-1}}]$	**A1**	**AWRT** 15.7
	Question 3 Total	**6**	

Q	Answer	Marks	Guidance
4	Mass $= \rho\pi\int_0^3 \left(9-x^2\right)^2 \mathrm{d}x$	B1	Deduces correct limits for the integration Can be seen at any point in their working
	$= \rho\pi\int_0^3 \left(81-18x^2+x^4\right)\mathrm{d}x$		
	$= \rho\pi\left[81x-6x^3+\frac{1}{5}x^5\right]_0^3$		
	$= \rho\pi\left(81\times 3-6\times 3^3+\frac{1}{5}\times 3^5\right)-0$		
	$= \frac{648\rho\pi}{5}$	B1	Correct mass of solid Condone $\frac{648}{5}$
	$\frac{648\rho\pi}{5}\bar{X} = \rho\pi\int_0^3 x\left(9-x^2\right)^2 \mathrm{d}x$	M1	Sets up an equation including an integral to find centre of mass
	$= \rho\pi\int_0^3 \left(81x-18x^3+x^5\right)\mathrm{d}x$		
	$= \rho\pi\left[\frac{81}{2}x^2-\frac{9}{2}x^4+\frac{1}{6}x^6\right]_0^3$		
	$= \rho\pi\left(\frac{81}{2}\times 3^2-\frac{9}{2}\times 3^4+\frac{1}{6}\times 3^6\right)-0$		
	$\frac{648\rho\pi}{5}\bar{X} = \frac{243\rho\pi}{2}$	A1	Integrates right-hand side correctly Condone $\frac{243}{2}$
	$\frac{648}{5}d = \frac{243}{2}$		
	$d = \frac{\left(\frac{243}{2}\right)}{\left(\frac{648}{5}\right)}$		
	$d = \frac{15}{16}$	A1	**CAO** Condone omission of ρ throughout Do not condone omission of π
	Question 4 Total	**5**	

Q	Answer	Marks	Guidance
5	Change in GPE $= 1.3mg$	B1	Correct Change in GPE from lowest point to the highest point **PI**
	$\frac{1}{2}mU^2 = 1.3mg + \frac{1}{2}mv^2$	M1	Sets up an energy equation using their change in GPE
	$U^2 = 2.6g + v^2$		
	$mg\cos\theta + R = \frac{mv^2}{0.65}$	M1	Sets up a two-term force equation set equal to $\frac{mv^2}{r}$
	When $\theta = 0°$ and $R = 0$		
	$mg = \frac{mv^2}{0.65}$		
	$v^2 = 0.65g$	A1	Finds minimum speed at top of track from correct working
	$U^2 = 2.6g + 0.65g = 3.25g$		
	$U = \frac{\sqrt{13g}}{2}$	A1	**CAO**
	Question 5 Total	**5**	

Q	Answer	Marks	Guidance
6(a)	$4^2 = \omega^2\left(A^2 - 3^2\right)$ and $6^2 = \omega^2\left(A^2 - 2^2\right)$	**M1 A1**	**M1**: Forms two equations for the amplitude **A1**: Two correct equations for the amplitude
	$\frac{9}{4} = \frac{A^2 - 4}{A^2 - 9}$ $4\left(A^2 - 4\right) = 9\left(A^2 - 9\right)$	**M1**	Eliminates ω
	$5A^2 = 65$	**m1**	Attempts to solve for the amplitude
	$\left[A =\right] \sqrt{13}$ [m]	**A1**	**CAO** Condone omission of units
	Subtotal	**5**	

Q	Answer	Marks	Guidance
6(b)	$16 = \omega^2\left(13 - 9\right)$	**M1**	Forms equation for ω^2 using their amplitude
	$4\omega^2 = 16$ $\omega = 2$ [rad s^{-1}]	**A1**	Correct value for ω
	$T = \frac{2\pi}{2}$ $\left[T =\right]\ \pi$ [s]	**A1**	**CAO** Condone omission of units
	Subtotal	**3**	

Q	Answer	Marks	Guidance
6(c)	$-3 = \sqrt{13}\cos(2t_1)$ or $-3 = \sqrt{13}\sin(2t_1)$	M1	Forms equation for one displacement
	$t_1 = 1.276795...$ or $t_1 = -0.491396...$	A1	A correct time
	$2 = \sqrt{13}\cos(2t_2)$ or $2 = \sqrt{13}\sin(2t_2)$		
	$t_2 = 0.491396...$ or $t_2 = 0.2940013...$	A1	A second correct time
	$t = 1.276795... - 0.491396...$ or $t = 0.2940013... - (-0.491396...)$		
	$[t =]\ 0.785\ [\text{s}]$	A1	**AWRT** 0.785 Condone omission of units
	Subtotal	**4**	

	Question 6 Total	**12**	

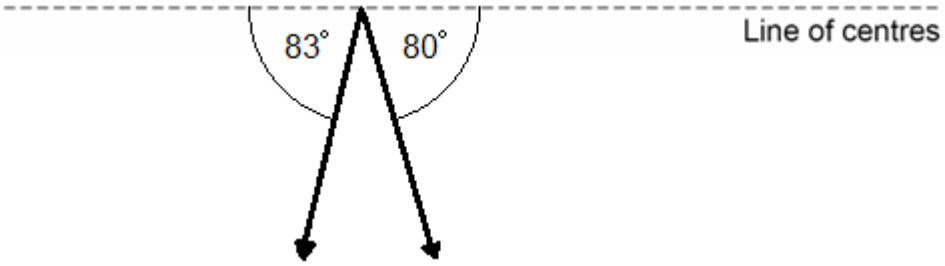
Q	Answer	Marks	Guidance
7(a)	$0^2 = (28\sin 40°)^2 + 2 \times s \times (-9.8\cos 20°)$	**M1 A1**	**M1**: Forms equation based on motion perpendicular to the slope to find the maximum distance from the plane **A1**: Correct equation
	$s = \dfrac{(28\sin(40°))^2}{2 \times 9.8\cos(20°)}$	**M1**	Attempts to solve for the maximum distance
	$[s =]$ 17.6 [m]	**A1**	**CAO** Condone omission of units
	Subtotal	**4**	

Q	Answer	Marks	Guidance
7(b)	$0 = (28\sin(40°))t - 4.9(\cos(20°))t^2$	**M1 A1**	**M1**: Forms equation to find time of flight **A1**: Correct equation
	$t = \dfrac{28\sin(40°)}{4.9\cos(20°)}$	**A1**	Correct time **PI** by 3.91
	$v_x = 28\cos(40°) - 9.8\sin(20°) \times \left(\dfrac{28\sin(40°)}{4.9\cos(20°)}\right)$		
	$[v_x =]$ 8.347... [m s^{-1}]	**M1**	Finds at least one correct component of velocity on impact
	$v_y = 28\sin(40°) - 9.8\cos(20°) \times \left(\dfrac{28\sin(40°)}{4.9\cos(20°)}\right)$		
	$[v_y =]$ −17.99... [m s^{-1}]	**A1**	Both components of velocity on impact correct
	$\tan\theta = \dfrac{17.99...}{8.347...}$	**M1**	Forms equation for angle
	$\theta = 65°$	**A1**	**AWRT** 65°
	Subtotal	**7**	

	Question 7 Total	**11**	

Q	Answer	Marks	Guidance
8(a)	Along the line of centres		
	$4\times 8\cos(30°)+2\times(-6\cos(45°)) = 4v_A+2v_B$	M1 A1	**M1**: Forms equation using conservation of momentum **A1**: Correct equation
	$8\sqrt{3}-3\sqrt{2}=2v_A+v_B$		
	$v_B=8\sqrt{3}-3\sqrt{2}-2v_A$		
	$v_B-v_A=e\left(8\cos(30°)+6\cos(45°)\right)$	M1 A1	**M1**: Forms equation using coefficient of restitution **A1**: Correct equation
	$v_B-v_A=e\left(4\sqrt{3}+3\sqrt{2}\right)$		
	$v_A=v_B-e\left(4\sqrt{3}+3\sqrt{2}\right)$		
	$=8\sqrt{3}-3\sqrt{2}-2v_A-e\left(4\sqrt{3}+3\sqrt{2}\right)$		
	$3v_A=8\sqrt{3}-3\sqrt{2}-e\left(4\sqrt{3}+3\sqrt{2}\right)$		
	$v_A=\frac{1}{3}\left(8\sqrt{3}-3\sqrt{2}-e\left(4\sqrt{3}+3\sqrt{2}\right)\right)$	M1	Equation for v_A in terms of e
	$\frac{2}{3}\le e\le 1$		
	$\frac{1}{3}\left(8\sqrt{3}-3\sqrt{2}-\left(4\sqrt{3}+3\sqrt{2}\right)\right)$ $\le v_A \le$ $\frac{1}{3}\left(8\sqrt{3}-3\sqrt{2}-\frac{2}{3}\left(4\sqrt{3}+3\sqrt{2}\right)\right)$		
	$\frac{1}{3}\left(4\sqrt{3}-6\sqrt{2}\right)\le v_A\le\frac{1}{3}\left(\frac{16}{3}\sqrt{3}-5\sqrt{2}\right)$		
	$\frac{4\sqrt{3}-6\sqrt{2}}{3}\le v_A\le\frac{16\sqrt{3}-15\sqrt{2}}{9}$		

	$-0.519026... \le v_A \le 0.7221788...$	**A1**	Correct inequality **PI** by ± 0.5190 and ± 0.7222
	Perpendicular to the line of centres $v_A = 8\sin 30° = 4$	**B1**	Correct perpendicular component
	$4\left[.00 \text{ m s}^{-1}\right] \le$ speed of $A \le 4.06\left[\text{m s}^{-1}\right]$	**A1**	Correct inequality for the speed Condone omission of units
	Subtotal	**8**	

Q	Answer	Marks	Guidance
8(b)	$\tan\theta_1 = \dfrac{4}{0.5190}$	**M1**	Uses tan to find at least one angle
	$\theta_1 = 83°$	**A1**	At least one correct angle Allow 7°
	$\tan\theta_2 = \dfrac{4}{0.7222}$		
	$\theta_2 = 80°$	**A1**	Both angles correct Allow 10°
		A1	Correct diagram
			
	Subtotal	**4**	

	Question 8 Total	**12**	