OXFORD AQA
INTERNATIONAL QUALIFICATIONS

INTERNATIONAL AS/A-LEVEL
FURTHER MATHEMATICS
FM4M1

Further Mechanics 1

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(a)	$LT^{-1} = L^{\alpha} \times \left(ML^{-3}\right)^{\beta} \times \left(LT^{-2}\right)^{\gamma}$ $LT^{-1} = L^{\alpha-3\beta+\gamma} \times M^{\beta} \times T^{-2\gamma}$ $\alpha - 3\beta + \gamma = 1$ $\beta = 0$ $-2\gamma = -1$ $\alpha = \frac{1}{2}, \quad \beta = 0, \quad \gamma = \frac{1}{2}$	**M1** **M1** **A1**	Formulates the problem using dimensional analysis with at least two dimensions correct Compares dimensions to deduce three equations in terms of α, β and γ **PI** **CAO**
	Subtotal	**3**	

Q	Answer	Marks	Guidance
1(b)	$17\,\text{km}\,\text{h}^{-1} = 4.72...\,\text{m}\,\text{s}^{-1}$ $v = k\sqrt{dg} \Rightarrow k = \frac{v}{\sqrt{dg}}$ $k = \frac{4.72...}{\sqrt{2.3 \times 9.8}}$ $k = 0.99$	**B1** **M1** **A1**	Converts km h^{-1} into m s^{-1} Allow $\frac{85}{18}$ Substitutes values for v, d and g into the formula, **ft** their value for v and their answer to **part (a)** Condone $v = 17$ **AWRT** 0.99
	Subtotal	**3**	

Q	Answer	Marks	Guidance
1(c)	$v = k\sqrt{dg}$ $U = 0.99...\sqrt{4000 \times 9.8}$ $U = 197$	 **M1** **A1**	 Uses formula with their value of k from **part (b)** **AWFW** [196, 197]
	Subtotal	**2**	

	Question 1 Total	**8**	

Q	Answer	Marks	Guidance
2(a)	$I = \int_0^{0.15} kt\left(0.3-2t\right)^2 \,\mathrm{d}t$	**M1**	Integrates F with respect to t with correct limits
	$= k\int_0^{0.15} \left(0.09t - 1.2t^2 + 4t^3\right)\mathrm{d}t$		
	$= k\left[0.09\times\frac{t^2}{2} - 0.4t^3 + t^4\right]_0^{0.15}$	**m1**	Correct integration
	$= k\left(0.09\times\frac{0.15^2}{2} - 0.4\times0.15^3 + 0.15^4\right) - 0$		
	$= k\left(\frac{81}{80\,000} - \frac{27}{20\,000} + \frac{81}{160\,000}\right)$		
	$I = \frac{27k}{160\,000}$	**A1**	**AG** Must be convincingly shown with correct limits substituted and simplified before given result
	Subtotal	**3**	

Q	Answer	Marks	Guidance
2(b)	After the ball rebounds, the speed of the ball must be greater than 0	**B1**	Considers the lower bound of the speed **PI**
	and less than or equal to 6 m s^{-1}	**B1**	Considers the upper bound of the speed **PI**
	$I_{\min} = m\left(0-\left(-6\right)\right) = 6m$ $I_{\max} = m\left(6-\left(-6\right)\right) = 12m$		
	$6m < I \leq 12m$	**M1**	Sets up inequalities using both bounds of impulse
	$6m < \frac{27k}{160\,000} \leq 12m$	**m1**	Substitutes **part (a)** result into their inequality
	$\frac{320\,000m}{9} < k \leq \frac{640\,000m}{9}$	**A1**	**CAO**
	Subtotal	**5**	
	Question 2 Total	**8**	

Q	Answer	Marks	Guidance
3(a)	The logo is symmetric in the line through *C*, *B* and *M*	**E1**	Allow any mention of symmetry or that the centres of mass of the semicircle and the triangle both lie on *CBM*
	Subtotal	**1**	

Q	Answer	Marks	Guidance
3(b)	[C.O.M. of the semicircle from *C* is] $\frac{2d}{3\pi}$		
	[C.O.M. of the triangle from *C* is] $\left(\frac{2}{3}\times 2\sin(60°)+\frac{1}{2}\right)d=\left(\frac{2\sqrt{3}}{3}+\frac{1}{2}\right)d$	**B1**	**PI**
	$\sigma\left(\frac{1}{2}\times 4d^2\sin(60°)+\frac{1}{2}\times\pi\left(\frac{d}{2}\right)^2\right)\overline{Y}$		
	$=\sigma\left(\frac{1}{2}\times 4d^2\sin(60°)\times\left(\frac{2\sqrt{3}}{3}+\frac{1}{2}\right)d\right)$ $+\sigma\times\frac{1}{2}\times\pi\left(\frac{d}{2}\right)^2\times\left(\frac{2}{3\pi}\right)d$	**M1 m1 A1**	**M1**: At least one of the three main terms correct **m1**: At least two of the three main terms correct **A1**: Fully correct equation Condone lack of σ
	$\left(\sqrt{3}+\frac{\pi}{8}\right)\overline{Y}=\left(2+\frac{\sqrt{3}}{2}+\frac{1}{12}\right)d$		
	$\overline{Y}=\frac{2+\frac{\sqrt{3}}{2}+\frac{1}{12}}{\sqrt{3}+\frac{\pi}{8}}d$	**m1**	Arranges their equation into the form $\overline{Y}=kd$
	$[k=]1.388$	**A1**	**AWRT** 1.388
	Subtotal	**6**	

Q	Answer	Marks	Guidance
3(c)	$\tan\alpha = \dfrac{\left(\sqrt{3}+\dfrac{1}{2}-k\right)d}{d}$ $\alpha = \tan^{-1}\left(\sqrt{3}+\dfrac{1}{2}-1.388...\right)$	M1	Forms a correct equation involving the angle
	$[\alpha =]$ 40	A1	**AWRT** 40
	Subtotal	**2**	

	Question 3 Total	**9**	

Q	Answer	Marks	Guidance
4(a)	$12\cos 60° = v\cos 30°$ $v = \dfrac{12\cos 60°}{\cos 30°}$ $v = \dfrac{12 \times \frac{1}{2}}{\frac{\sqrt{3}}{2}} = \dfrac{12}{\sqrt{3}}$ $v = 4\sqrt{3}$	**M1 A1** **A1**	**M1**: Equation for motion parallel to wall with at least one side correct **A1**: Fully correct **ACF**
	Subtotal	**3**	

Q	Answer	Marks	Guidance
4(b)	$e \times 12\sin 60° = v\sin 30°$ $e \times 6\sqrt{3} = 2\sqrt{3}$ $e = \dfrac{1}{3}$	**M1 A1ft** **A1**	**M1**: Equation for motion perpendicular to wall with at least one side correct, **ft** their v **A1ft:** Fully correct, **ft** their v **CAO**
	Subtotal	**3**	

Q	Answer	Marks	Guidance
4(c)	$I = 0.5 \times \left(6\sqrt{3} - \left(-2\sqrt{3}\right)\right)$ $= 4\sqrt{3}$ [N s]	**M1 A1** **A1**	**M1**: Impulse equation with correct values. Condone sign errors **A1:** Fully correct **CAO**, **oe**
	Subtotal	**3**	

	Question 4 Total	**9**	

Q	Answer	Marks	Guidance
5(a)(i)	$\lvert v_{AB} \rvert^2 = 28^2 + 15^2 - 2(28)(15)\cos 65°$	**M1**	Uses the cosine rule
	$\left[\lvert v_{AB} \rvert =\right]$ 25.6 $\left[\text{km h}^{-1}\right]$	**A1**	**AWRT** 25.6
	Subtotal	**2**	

Q	Answer	Marks	Guidance
5(a)(ii)	$\frac{\sin 65°}{25.5734} = \frac{\sin\theta}{15}$	**M1**	Uses the sine rule
	$\sin\theta = 0.5315...$	**A1ft**	**AWRT** 0.53 **PI** by **AWRT** 32 **ft** their relative velocity
	$d = 12 \times \sin\theta$	**M1**	Equation to find minimum distance
	$d = 12 \times 0.5315...$		
	$\left[d =\right]$ 6.38 [km]	**A1**	**CAO** Condone omission of units
	Subtotal	**4**	

Q	Answer	Marks	Guidance
5(b)	$t = \frac{12 \times \cos(32.113°)}{25.5734} = 0.39744$ [hours]	**M1**	Correct equation to find time
	$= 23.8$ [minutes]		
	[Time at closest approach is] 13:24	**A1**	**CAO**
	Subtotal	**2**	

	Question 5 total	**8**	

Q	Answer	Marks	Guidance
6(a)(i)	$[7 \times 0.9 =]\ 6.3\ [\text{m s}^{-1}]$	B1	CAO
	Subtotal	1	

Q	Answer	Marks	Guidance
6(a)(ii)	$0.6 \times 2 + 1.2 \times (-6.3) = 0.6v_P + 1.2v_Q$	M1	Forms equation for conservation of linear momentum Condone sign errors
	$-10.6 = v_P + 2v_Q$		
	$v_P - v_Q = -0.5(2 - (-6.3))$	M1	Forms equation for restitution Condone sign errors
	$v_P - v_Q = -4.15$	A1	Pair of correct simultaneous equations for v_Q and v_P
	$v_Q = 2.15, \quad v_P = 6.3$	A1	CAO Condone $v_Q = -2.15, \quad v_P = -6.3$
	Subtotal	4	

Q	Answer	Marks	Guidance
6(a)(iii)	$I = 0.6 \times (-6.3 - 2)\ \ [= -4.98]$	M1	Applies impulse equation with their velocities Condone sign errors
	$\lvert I \rvert = 4.98$ [N s]	A1	CAO Condone omission of units
	Subtotal	2	

Q	Answer	Marks	Guidance
6(b)	$4.98 = 0.025F$ $F = \frac{4.98}{0.025} = 199[.2]$ [N]	**M1** **A1ft**	Uses $I = Ft$ with their impulse **AWRT** 199 Condone omission of units **ft** their impulse from **part (a)(iii)**
	Subtotal	**2**	

	Question 6 Total	**9**	

Q	Answer	Marks	Guidance
7(a)(i)	$[6g\cos 30° \times 0.5 =] \frac{3\sqrt{3}}{2}g$	**B1**	**CAO**
	Subtotal	**1**	

Q	Answer	Marks	Guidance
7(a)(ii)	$\frac{108 \times (11-6)^2}{2 \times 6} = 225$ [J]	**B1**	**AG** Must be convincingly shown
	Subtotal	**1**	

Q	Answer	Marks	Guidance
7(a)(iii)	$\frac{3\sqrt{3}}{2}gx + \frac{108\times(5-x)^2}{2\times 6} + \frac{176\times x^2}{2\times 4}$ $= 6gx\sin 30° + 225$	**M1 m1 A1**	**M1**: Forms an energy equation with at least 4 terms, with at least 3 terms from: • Work done [friction] • EPE in *PQ* • EPE in *PR* • Change in GPE • Initial EPE **m1**: All 5 terms correct with any signs **A1**: Fully correct energy equation
	$\frac{3\sqrt{3}}{2}gx + 9\left(25 - 10x + x^2\right) + 22x^2$ $= 3gx + 225$		
	$\frac{3\sqrt{3}}{2}gx - 90x + 9x^2 + 22x^2 = 3gx$		
	$31x^2 - \left(-\frac{3\sqrt{3}}{2}g + 90 + 3g\right)x = 0$	**A1**	Correct simplified three-term quadratic equation set equal to zero
	$\left(31x - \left(-\frac{3\sqrt{3}}{2}g + 90 + 3g\right)\right)x = 0$		
	$x = \frac{3g + 90 - \frac{3\sqrt{3}}{2}g}{31}$		
	$x = 3.03$	**A1**	**AWRT** 3.03
	Subtotal	**5**	

Q	Answer	Marks	Guidance
7(b)	Work is done against air resistance	**M1**	Correct reason
	so the value of x decreases	**A1**	Correct statement
	Subtotal	**2**	

	Question 7 Total	**9**	