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General Certificate of Education

Mathematics 6360

MM03 Mechanics 3

Mark Scheme

2009 examination - June series

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Key to mark scheme and abbreviations used in marking

M	mark is for method
m or dM	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 or F	follow through from previous incorrect result	MC	mis-copy
CAO	correct answer only	MR	mis-read
CSO	correct solution only	RA	required accuracy
AWFW	anything which falls within	FW	further work
AWRT	anything which rounds to	ISW	ignore subsequent work
ACF	any correct form	FIW	from incorrect work
AG	answer given	BOD	given benefit of doubt
SC	special case	WR	work replaced by candidate
OE	or equivalent	FB	formulae book
A2,1	2 or 1 (or 0) accuracy marks	NOS	not on scheme
–*x* EE	deduct *x* marks for each error	G	graph
NMS	no method shown	c	candidate
PI	possibly implied	sf	significant figure(s)
SCA	substantially correct approach	dp	decimal place(s)

No Method Shown

Where the question specifically requires a particular method to be used, we must usually see evidence of use of this method for any marks to be awarded. However, there are situations in some units where part marks would be appropriate, particularly when similar techniques are involved. Your Principal Examiner will alert you to these and details will be provided on the mark scheme.

Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn **no marks**.

Where a question asks the candidate to state or write down a result, no method need be shown for full marks.

Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

Otherwise we require evidence of a correct method for any marks to be awarded.

MM03

Q	Solution	Marks	Total	Comments
1	$L = M^{\alpha}(LT^{-1})^{\beta}(LT^{-2})^{\gamma}$	M1A1		
	$\beta + \gamma = 1$ $-\beta - 2\gamma = 0$			
	$\alpha = 0$	m1		Getting three equations
	$\gamma = -1$	m1		Solution
	$\beta = 2$	A1F	5	
	Total		**5**	
2(a)	$x = 2t$	M1		
	$y = -\frac{1}{2}gt^2 + 10t$	M1		
	$t = \frac{x}{2}$			
	$y = -\frac{1}{2}g\left(\frac{x}{2}\right)^2 + 10\left(\frac{x}{2}\right)$	m1		
	$y = -\frac{g}{8}x^2 + 5x$	A1	4	AG
(b)	$1 = -\frac{g}{8}x^2 + 5x$	M1		
	$gx^2 - 40x + 8 = 0$			
	$x = \frac{40 \pm \sqrt{(-40)^2 - 4\times 8g}}{2g}$	M1		
	$x = 3.871,\ 0.211$	A1		A1 for both answers
	Distance $= 3.66\,\text{m}$	A1	4	
(c)	$t = \frac{3.66}{2}$	M1		
	$t = 1.83$ sec	A1	2	
	Total		**10**	

MM03 (cont)

Q	Solution	Marks	Total	Comments
3(a)	${}_{\mathrm{P}}v_{\mathrm{F}} = \sqrt{4^2 + 2^2}$	M1		
	$= 4.47 \text{ m s}^{-1}$ or $2\sqrt{5}\ ms^{-1}$ or $\sqrt{20}\ ms^{-1}$	A1		
	$\theta = \tan^{-1}\frac{2}{4}$	M1		
	$\theta = 26.6°$	A1F		
	Bearing $= 40° + 180° - 26.6°$			
	$= 193°$	A1F	5	
	Alternative:			
	Comp. due west $= 4\sin 40° - 2\sin 50° = 1.04 \text{ m s}^{-1}$ Comp. due south $= 2\cos 50° + 4\cos 40° = 4.35 \text{ m s}^{-1}$	(M1)		OE; resolving in two directions
	${}_{\mathrm{P}}v_{\mathrm{F}} = \sqrt{1.04^2 + 4.35^2} = 4.47 \text{ m s}^{-1}$	(A1)		
	$\theta = \tan^{-1}\frac{1.04}{4.35}$ or $\tan^{-1}\frac{4.35}{1.04}$	(M1)		
	$\theta = 13.4°$ or $76.6°$	(A1F)		
	Bearing $= 13.4° + 180°$ or $270° - 76.6°$			
	$= 193°$	(A1F)		
	Alternative:			
	Correct triangle	(M1)		Any orientation
	${}_{P}v_{F} = \sqrt{1.04^2 + 4.35^2} = 4.47 \text{ms}^{-1}$	(A1)		
	Rel. Vel. Triangle angle $26.6°$ or $63.4°$	(A1)		
	Bearing $= 40° + 180° - 26.6°$ or $63.4° + 40° + 90°$	(M1)		
	$= 193°$	(A1F)		
(b)(i)	$v_{\mathrm{F}} = v_{\mathrm{P}} + {}_{\mathrm{P}}v_{\mathrm{F}}$			
	$\frac{\sin\alpha}{2} = \frac{\sin 140°}{4}$	M1A1		
	$\alpha = 18.7°$	A1F		
	Bearing $= 90° + 18.7°$			
	$= 109°$	A1F	4	
	Alternative:			
	$2\sin 40° = 4\sin\alpha$	(M1)		
	$\alpha = \sin^{-1}\left(\frac{1}{2}\sin 40°\right)$	(A1)		
	$\alpha = 18.7°$	(A1F)		
	Bearing $= 109°$	(A1F)		

MM03 (cont)

Q	Solution	Marks	Total	Comments
3(b)(ii)	$\beta = 180° - (140° + 18.7°)$ $= 21.3°$	B1F		
	$\frac{{}_{\mathrm{P}}v_{\mathrm{F}}}{\sin 21.3°} = \frac{4}{\sin 140°}$	M1		
	${}_{\mathrm{P}}v_{\mathrm{F}} = 2.2568\,\mathrm{m\,s^{-1}}$	A1F		
	$t = \frac{1500}{2.2568}$ $= 665$ sec	A1F	4	
	Alternative:			o.e. resolving in two directions
	${}_{\mathrm{F}}v_{\mathrm{P}} = 4\cos 18.7 - 2\cos 40 = 2.2568$	(M1) (A2,1,0)		
	$t = \frac{1500}{2.2568} = 665$ sec	(A1F)		
(iii)	No cross wind, calm lake, instantaneous change of direction by the patrol boat	B1	1	Any sensible assumption
	Total		**14**	
4(a)	$\mathrm{I} = \int_0^4 (t^3 + t)\,\mathrm{d}t$	M1		
	$= \left[\frac{1}{4}t^4 + \frac{1}{2}t^2\right]_0^4$	m1		
	$= 72\,\mathrm{N\,s}$	A1	3	
(b)	$72 = 0.5v - 0.5(0)$	M1		Condone $-5(0)$
	$v = 144$	A1F	2	
(c)	$\int_0^T (t^3 + t)\,\mathrm{d}t = 0.5(12) - 0.5(0)$	M1		Condone $-5(0)$
	$\left[\frac{1}{4}t^4 + \frac{1}{2}t^2\right]_0^T = 6$			
	$T^4 + 2T^2 - 24 = 0$	A1		
	$T^2 = \frac{-2 \pm \sqrt{2^2 - 4(1)(-24)}}{2(1)}$	m1 A1F		
	or $(T^2 - 4)(T^2 + 6) = 0$			
	$T^2 = 4$ $T = 2$	A1F	5	
	Total		**10**	

MM03 (cont)

Q	Solution	Marks	Total	Comments
5(a)	Momentum of B perpendicular to the line of centres is unchanged			
	$m_B v \sin 40° = 3m_B$	M1A1		
	$v = 4.667 \text{ ms}^{-1} = 4.67 \text{ ms}^{-1}$ (3sf)	A1	3	AG
(b)	$e = \dfrac{4.67\cos 40°}{5\cos 30°}$	M1A1		
	$e = 0.826$	A1F	3	
(c)	Impulse on A = change in momentum of A along the line of centres			
	$= 0.5 \times 5\cos 30° = 2.165$	M1A1		
	$= 2.17$ Ns	A1	3	AG
(d)	$2.165 = m_B(4.667)\cos 40°$	M1A1		
	$m_B = 0.6056 = 0.606$ kg (3sf)	A1F	3	Condone use of premature rounding giving 0.605kg or 0.607 kg
	Total		**12**	
6(a)	$5mu + 7mu = mv_A + 7mv_B$	M1A1		Allow consistent use of positive or negative sign for v_A.
	$12u = v_A + 7v_B$			
	$e = \dfrac{-v_A + v_B}{4u}$	M1		
	$-v_A + v_B = 4eu$			
	$8v_B = 12u + 4eu$	m1		
	$v_B = \dfrac{u}{2}(e+3)$	A1	5	AG
(b)	$v_A = \dfrac{u}{2}(e+3) - 4eu$	M1		
	$v_A = \dfrac{u}{2}(3-7e)$	A1F		
	$\dfrac{u}{2}(3-7e) < 0$	M1		
	$3 - 7e < 0$			
	$e > \dfrac{3}{7}$	A1	4	AG
(c)	$w_B = \dfrac{u}{4}(e+3)$	M1		
	$\dfrac{u}{2}(7e-3) < \dfrac{u}{4}(e+3)$	M1		
	$2(7e-3) < e+3$			
	$13e < 9$	m1		
	$e < \dfrac{9}{13}$	A1	4	AG
	Total		**13**	

MM03 (cont)

Q	Solution	Marks	Total	Comments
7(a)	$y = 10t\sin 40° - \frac{1}{2}gt^2\cos 30°$	M1A1		
	$y = 0 \Rightarrow t = \frac{20\sin 40°}{g\cos 30°}$	A1	3	AG
(b)	$\dot{x} = 10\cos 40° + g\sin 30°\left(\frac{20\sin 40°}{g\cos 30°}\right)$	M1		
	$\dot{x} = 15.08\ \text{m s}^{-1}$	A1		
	$\dot{y} = 10\sin 40° - g\cos 30°\left(\frac{20\sin 40°}{g\cos 30°}\right)$	M1		
	$\dot{y} = -6.427\ \text{m s}^{-1}$	A1	4	Allow 3 sf
(c)	$\dot{x}$ will be unchanged	B1		
	Rebound $\dot{y} = 6.427 \times 0.5 = 3.214$	M1		Allow using 3 sf
	Rebound speed $= \sqrt{15.08^2 + 3.214^2}$	m1		
	$= 15.4\ \text{m s}^{-1}$	A1F	4	
	Total		**11**	
	TOTAL		**75**	