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General Certificate of Education

Mathematics 6360

MM05 Mechanics 5

Mark Scheme

2008 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.

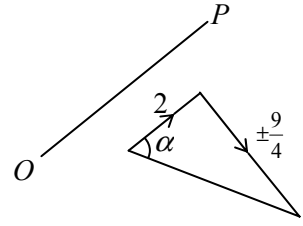
Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

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

MM05

Q	Solution	Marks	Total	Comments
1(a)(i)	$T = 2\pi\sqrt{\frac{2}{9.8}}$	M1		
	$T = 2.83845 \quad T \approx 2.84 \text{ sec}$	A1	2	AG
(ii)	$f = \frac{1}{T} = 0.352 \text{ cps}$	B1	1	AG
(b)	$2.5 = 2\pi\sqrt{\frac{l}{9.8}}$	M1		
	$l = 1.55 \text{ metres}$	A1	2	
Total			5	
2(a)	$x = A \cos 4t + B \sin 4t$			Alt: $m^2 + 16 = 0$ B1
	$\dot{x} = -4A \sin 4t + 4B \cos 4t$	B1		$m = \pm 4i$ B1
	$\ddot{x} = -16A \cos 4t - 16B \sin 4t$	B1		$x = A \cos 4t + B \sin 4t$ M1
	Substitute into $\ddot{x} + 16x = 0$	M1		A1
	Satisfactory conclusion	A1	4	
(b)	$t = 0, \dot{x} = 0: 0 = 0 + 4B \rightarrow B = 0$	B1	1	AG
(c)	$x = A \cos 4t$			
	$t = \frac{\pi}{12}, x = h: h = A \cos \frac{\pi}{3}$ $A = 2h$	M1 A1	2	
(d)	$\dot{x} = -8h \sin 4t$ Max speed = $8h \text{ ms}^{-1}$	B1	1	
(e)	$F = m(-32h \cos 4t)$	M1		
	$ F_{\max} = 32hm \text{ N}$	A1	2	
Total			10	

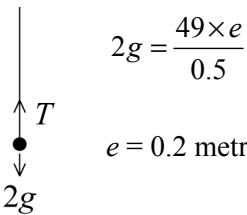
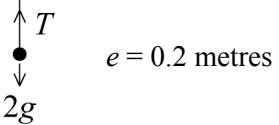
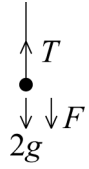

MM05 (cont)

Q	Solution	Marks	Total	Comments
3(a)	$r = t^2$ $\theta = \frac{9}{\pi^2} \sin\left(\frac{\pi t}{6}\right)$ $\dot{r} = 2t$ $\dot{\theta} = \frac{3}{2\pi} \cos\left(\frac{\pi t}{6}\right)$ $t = 3, \dot{r} = 6, r = 9, \dot{\theta} = 0$ Components: \dot{r} $r\dot{\theta}$ $\dot{r} = 6$ $r\dot{\theta} = 0$	M1 A1	4	differentiation $\dot{\theta}$
	$\ddot{r} = 2$ $\ddot{\theta} = -\frac{1}{4} \sin\left(\frac{\pi t}{6}\right)$ $t = 3, \ddot{r} = 2$ $\ddot{\theta} = -\frac{1}{4}$ Components: $\ddot{r} - r\dot{\theta}^2$ $r\ddot{\theta} + 2\dot{r}\dot{\theta}$ $= 2$ $= -\frac{9}{4}$	M1 A1F A1F M1 A1F		5
(c)	 $\tan \alpha = \pm \frac{9}{8}$ $\alpha = \pm 0.844 \text{ rads}$ or $\pm 2.30 \text{ rads}$	M1 A1	2	any one of these; allow degrees (48.4°)
Total			11	

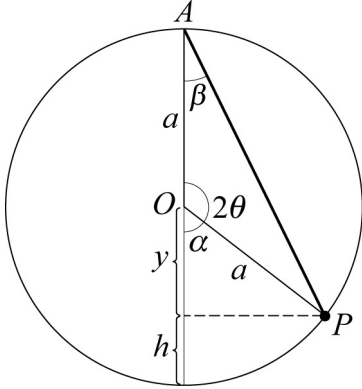
MM05 (cont)

Q	Solution	Marks	Total	Comments
4(a)	$(m + \delta m)(v + \delta v) - mv - \delta m(v - V) = -mg\delta t$	M1A2	8	
	$m\delta v + \delta mV = -mg\delta t$			
	$\Rightarrow \frac{m\delta v}{\delta t} + \frac{V\delta m}{\delta t} = -mg$	M1		
	$m = (1000 - 10t) \quad \frac{dm}{dt} = -10$	B1 B1		
	$(1000 - 10t)\frac{dv}{dt} + 1400(-10) = -(1000 - 10t)9.8$	m1		
	$\frac{dv}{dt} = \frac{420 + 9.8t}{100 - t}$	A1		
	$\left(= \frac{1400 - 980 + 9.8t}{100 - t} = -9.8 + \frac{1400}{100 - t} \right)$			
(b)	$\int_0^v dv = \int_0^t \left\{ -9.8 + \frac{1400}{100 - t} \right\} dt$	M1	3	AG
	$v = \left[-9.8t - 1400 \ln(100 - t) \right]_0^t$	A1		
	$v = -9.8t + 1400 \ln \left(\frac{100}{100 - t} \right)$	A1		
(c)	$t = 80, \quad v = 1469$	B1	4	
	$0 = 1469 - 9.8t$	M1		
	$t = 150$	A1		
	Total time = 230 sec	A1		
	Total		15	

MM05 (cont)

Q	Solution	Marks	Total	Comments
5(a)	 $2g = \frac{49 \times e}{0.5}$	M1		
	 $e = 0.2 \text{ metres}$	A1	2	
(b)	 $2\ddot{x} = 2g + F - T$	M1A1		
	 $2\ddot{x} = 2g + 12 \cos nt - \frac{49(x + 0.2)}{0.5}$	B1F		Tension ft (a)
	$2\ddot{x} = 2g + 12 \cos nt - 98x - 19.6$	A1F		ft (a)
	$\ddot{x} + 49x = 6 \cos nt$	A1	5	AG
(c)	$n = 5 \quad \text{PI, } x = A \cos 5t + B \sin 5t$ $\dot{x} = -5A \sin 5t + 5B \cos 5t$ $\ddot{x} = -25A \cos 5t - 25B \sin 5t$	M1 A1 A1		Accept cos term only
	Subs: $-25A \cos 5t - 25B \sin 5t +$ $49A \cos 5t + 49B \sin 5t = 6 \cos 5t$			
	$B = 0, \quad A = \frac{1}{4}$	A1		
	A. eqn: $m^2 + 49 = 0 \quad m = \pm 7i$	M1		
	C.F.: $x = C \cos 7t + D \sin 7t$	A1		
	Gen sol: $x = C \cos 7t + D \sin 7t + \frac{1}{4} \cos 5t$	M1		
	$t = 0, x = 0: \quad 0 = C + \frac{1}{4} \quad C = -\frac{1}{4}$	A1		
	$\dot{x} = -7C \sin 7t + 7D \cos 7t - \frac{5}{4} \sin 5t$	m1		
	$t = 0, \dot{x} = 0: \quad D = 0$			
	$x = \frac{1}{4} (\cos 5t - \cos 7t)$	A1	10	
(d)	Resonance occurs when $n = 7$	B1	1	
	Total		18	

MM05 (cont)

Q	Solution	Marks	Total	Comments
6				
(a)(i)	Extension $2a \sin \theta - a$ $\text{EPE} = \frac{4mg}{2a} (2a \sin \theta - a)^2$ $= 2mga(2 \sin \theta - 1)^2$	B1 M1 A1	3	AG
(ii)	$y = a \cos \alpha = a \cos(\pi - 2\theta) = -a \cos 2\theta$ $h = a - y = a + a \cos 2\theta$ $V = mga(1 + \cos 2\theta) + 2mga(2 \sin \theta - 1)^2$ $= mga(1 + 1 - 2 \sin^2 \theta + 8 \sin^2 \theta - 8 \sin \theta + 2)$ $V = 2mga(3 \sin^2 \theta - 4 \sin \theta + 2)$	B1 B1 M1 A1 A1	5	Alt: $AP \cos \beta = 2a \sin \theta \cos \beta = 2a \sin^2 \theta$ B1 $h = 2a - 2a \sin^2 \theta$ B1 $V = mga(2a - 2a \sin^2 \theta) + \text{EPE}$ M1 Simplify A1 AG A1
(b)	$\frac{dv}{d\theta} = 2mga(6 \sin \theta \cos \theta - 4 \cos \theta)$ $\frac{dv}{d\theta} = 0$ if $\cos \theta = 0$ or $6 \sin \theta - 4 = 0$ ie $\theta = 1.57$ or $\theta = 0.73$	M1A1 m1 A1	4	
(c)	$\frac{dv}{d\theta} = 2mga(3 \sin 2\theta - 4 \cos \theta)$ $\frac{d^2v}{d\theta^2} = 2mga(6 \cos 2\theta + 4 \sin \theta)$ $\theta = 1.57, \frac{d^2v}{d\theta^2} = -4mga$ equil unstable $\theta = 0.73, \frac{d^2v}{d\theta^2} = 6.7mga$ equil stable	M1A1F A1 A1	4	OE PE slip
	Total		16	
	TOTAL		75	