

General Certificate of Education

Mathematics 6360

MM05 Mechanics 5

Mark Scheme

2008 examination - June series

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Dr Michael Cresswell Director General

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				
В	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		
	$T = 2.83845$ $T \approx 2.84 \text{ sec}$	A1	2	AG
(ii)	$f = \frac{1}{T} = 0.352 \text{ cps}$	В1	1	AG
(b)	$2.5 = 2\pi \sqrt{\frac{l}{9.8}}$	M1		
	l = 1.55 metres	A1	2	
	Total		5	2
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		$x = A\cos 4t + B\sin 4t \qquad \qquad \mathbf{M}1$
				A1
	Substitute into $\ddot{x} + 16x = 0$	M1		
	Satisfactory conclusion	A 1	4	
(b)	$t = 0, \ \dot{x} = 0: \ 0 = 0 + 4B \ \to B = 0$	B1	1	AG
(c)	$x = A\cos 4t$			
	$t = \frac{\pi}{12} , x = h : h = A \cos \frac{\pi}{3}$	M1		
	A = 2h	A1	2	
(d)	$\dot{x} = -8h\sin 4t$			
	$Max speed = 8h ms^{-1}$	B1	1	
(e)	$F = m(-32h\cos 4t)$	M1		
	$ F_{\text{max}} = 32hm \text{ N}$	A1	2	
	Total		10	

Q Q	<i>)</i>	Solution	Marks	Total	Comments
3(a)	$r = t^2$	$\theta = \frac{9}{\pi^2} \sin\left(\frac{\pi t}{6}\right)$ $\dot{\theta} = \frac{3}{2\pi} \cos\left(\frac{\pi t}{6}\right)$			
	$\dot{r} = 2t$	$\dot{\theta} = \frac{3}{2\pi} \cos\left(\frac{\pi t}{6}\right)$	M1 A1		differentiation $\dot{\theta}$
	$t=3, \dot{r}=6, n$	$r = 9, \dot{\theta} = 0$			
	Components:	$\dot{r} \qquad r\dot{\theta}$ $\dot{r} = 6 \qquad r\dot{\theta} = 0$	M1 A1	4	subs attempted
(b)	$\ddot{r}=2$	$\ddot{\theta} = -\frac{1}{4}\sin\left(\frac{\pi t}{6}\right)$ $\ddot{\theta} = -\frac{1}{4}$ $\ddot{r} - r\dot{\theta}^2 \qquad r\ddot{\theta} + 2\dot{r}\dot{\theta}$	M1 A1F		differentiation ft slip in $\dot{\theta}$
	$t=3$, $\ddot{r}=2$	$\ddot{\theta} = -\frac{1}{4}$	A1F		ft slip in $\dot{\theta}$
	Components:	$\ddot{r} - r\dot{\theta}^2 \qquad r\ddot{\theta} + 2\dot{r}\dot{\theta}$	M1		subs attempted
		$=2$ $=-\frac{9}{4}$	A1F	5	ft slip in $\dot{\theta}$
(c)	/	P			
	o $\frac{2}{\alpha}$	$\pm \frac{9}{4}$			
	$\tan \alpha = \pm \frac{9}{8}$		M1		
	$\alpha = \pm 0.844$ rad	ds or ± 2.30 rads	A1	2	any one of these; allow degrees (48.4°)
		Total		11	

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

MM05 (cont	Solution	Marks	Total	Comments
5(a)	$2g = \frac{49 \times e}{0.5}$	M1		
	$ \uparrow T \\ $	A1	2	
(b)	$ \oint_{\bullet} T 2\ddot{x} = 2g + F - T $ $ \downarrow \bigvee_{\bullet} F 2\ddot{x} = 2g + 12\cos nt - \frac{49(x + 0.2)}{0.5} $	M1A1		
	$2\ddot{g} = 2\ddot{g} + 12\cos nt - \frac{49(x+0.2)}{0.5}$	B1F		Tension ft (a)
	$2\ddot{x} = 2g + 12\cos nt - 98x - 19.6$ $\ddot{x} + 49x = 6\cos nt$	A1F A1	5	ft (a) AG
(c)	$n = 5 PI, x = A\cos 5t + B\sin 5t$ $\dot{x} = -5A\sin 5t + 5B\cos 5t$ $\ddot{x} = -25A\cos 5t - 25B\sin 5t$	M1 A1 A1		Accept cos term only
	Subs: $-25A\cos 5t - 25B\sin 5t +$	111		
	$49A\cos 5t + 49B\sin 5t = 6\cos 5t$ $B = 0, A = \frac{1}{4}$	A1		
	A. eqn: $m^2 + 49 = 0$ $m = \pm 7i$	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		
	$t = 0, x = 0: 0 = C + \frac{1}{4} C = -\frac{1}{4}$	A1		
	$\dot{x} = -7C\sin 7t + 7D\cos 7t - \frac{5}{4}\sin 5t$	m1		
	$t = 0, \ \dot{x} = 0: D = 0$			
	$x = \frac{1}{4}(\cos 5t - \cos 7t)$	A1	10	
(d)	Resonance occurs when $n = 7$	B1	1	
	Total		18	

MM05 (cont	Solution	Marks	Total	Comments
6	$ \begin{array}{c} A \\ A \\ B \\ O \\ 2\theta \\ y \\ A \end{array} $ $ \begin{array}{c} A \\ O \\ 2\theta \\ y \\ A \end{array} $			
(a)(i)	Extension $2a\sin\theta - a$	B1		
	$EPE = \frac{4mg}{2a} (2a\sin\theta - a)^2$	M1		
	$=2mga(2\sin\theta-1)^2$	A 1	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	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)	$\frac{dv}{d\theta} = 2mga(6\sin\theta\cos\theta - 4\cos\theta)$ $\frac{dv}{d\theta} = 0 \text{ if } \cos\theta = 0 \text{ or } 6\sin\theta - 4 = 0$ ie $\theta = 1.57 \text{ or } \theta = 0.73$	M1A1 m1 A1	4	
(c)	$\frac{dv}{d\theta} = 2mga(3\sin 2\theta - 4\cos \theta)$ $\frac{d^2v}{d\theta^2} = 2mga(6\cos 2\theta + 4\sin \theta)$ $\theta = 1.57, \frac{d^2v}{d\theta^2} = -4mga \text{equil unstable}$	M1A1F		OE PE slip
	$\theta = 1.57$, $\frac{d\theta^2}{d\theta^2} = -4mga$ equil unstable $\theta = 0.73$, $\frac{d^2 v}{d\theta^2} = 6.7mga$ equil stable	A1 A1	4	
	Total		16	
	TOTAL		75	