

Version 1.0



General Certificate of Education (A-level)
June 2012

Mathematics

MM03

(Specification 6360)

Mechanics 3

Mark Scheme

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Key to mark scheme abbreviations

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
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
A2,1	2 or 1 (or 0) accuracy marks
-x EE	deduct x marks for each error
NMS	no method shown
PI	possibly implied
SCA	substantially correct approach
c	candidate
sf	significant figure(s)
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.

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.

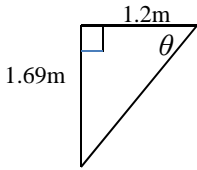
Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

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

MM03

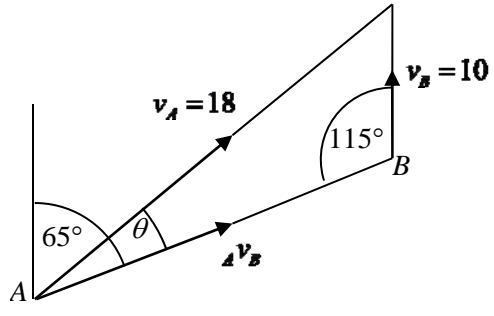
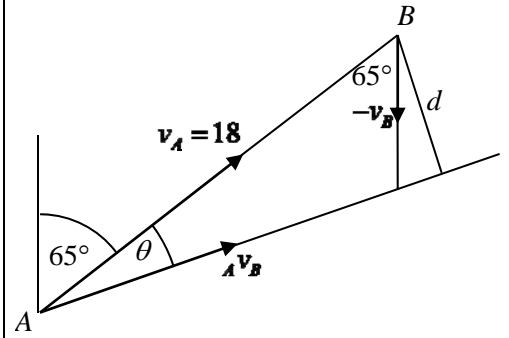
Q	Solution	Marks	Total	Comments
3(a)	$x = ut \cos \alpha$	M1		
	$t = \frac{x}{u \cos \alpha}$	A1		
	$y = -\frac{1}{2}gt^2 + ut \sin \alpha$	M1		Must have correct signs
	$y = -\frac{1}{2}g\left(\frac{x}{u \cos \alpha}\right)^2 + u\left(\frac{x}{u \cos \alpha}\right)\sin \alpha$	M1		
	$y = -\frac{gx^2}{2u^2 \cos^2 \alpha} + \frac{x \sin \alpha}{\cos \alpha}$			
	$y = -\frac{gx^2}{2u^2}(1 + \tan^2 \alpha) + x \tan \alpha$	A1		
	$k = -\frac{10(2k)^2}{2u^2}(1 + \tan^2 \alpha) + 2k \tan \alpha$	M1		
	$u^2 = -20k(1 + \tan^2 \alpha) + 2u^2 \tan \alpha$			
	$20k \tan^2 \alpha - 2u^2 \tan \alpha + u^2 + 20k = 0$	A1	7	AG
	(b) Pass through $P \Rightarrow$ Discriminant ≥ 0			
$(-2u^2)^2 - 4(20k)(u^2 + 20k) \geq 0$	M1A1			OE must be seen
$4u^4 - 80ku^2 - 1600k^2 \geq 0$				
$u^4 - 20ku^2 - 400k^2 \geq 0$	A1	3	AG	
	Total		10	

MM03

Q	Solution	Marks	Total	Comments
4(a)	 <p> $\theta = \tan^{-1} \frac{1.69}{1.2} = 54.623^\circ$ $u \cos 60^\circ = v \cos 54.623^\circ$ $eu \sin 60^\circ = v \sin 54.623^\circ$ $e = \frac{v \sin 54.623^\circ}{\frac{v \cos 54.623^\circ}{\cos 60^\circ} \times \sin 60^\circ}$ $e = 0.813 \text{ or } 0.812$ </p>	B1 M1 M1 m1 A1	5	AWRT 55° $v = 0.864u$ OE, dependent on both M1s ISW
(b)	<p> $I = 0.15u \sin 60^\circ + 0.15v \sin 54.623^\circ$ $= 0.15u \sin 60^\circ + 0.15 \times \frac{u \cos 60^\circ}{\cos 54.623^\circ} \times \sin 54.623^\circ$ $= 0.236u$ </p>	M1A1 m1 A1	4	Single angle values needed for A1 AG (condone 0.2355 or negative result)
(c)	<p>Attempt at considering motion parallel or perpendicular to AC</p> <p> $t = \frac{1.2}{u \cos 60^\circ}$ $t = \frac{12}{5u} \text{ or } \frac{2.4}{u}$ </p> <p>Alternative :</p> <p> $CP = \frac{1.2}{\cos 54.623^\circ} \quad (= 2.072703844 \text{ m})$ $t = \frac{\frac{1.2}{\cos 54.623^\circ}}{\frac{u \cos 60^\circ}{\cos 54.623^\circ}}$ $= \frac{12}{5u} \text{ or } \frac{2.4}{u}$ </p>	M1 M1 A1 (M1) (M1) (A1)	3	OE, No ISW (OE), No ISW
(d)	<p>Velocity (momentum) parallel to the cushion is unchanged, or, Restitution only affects motion perpendicular to the cushion</p>	E1	1	Accept 'horizontal component of velocity is unchanged'
Total			13	

Q	Solution	Marks	Total	Comments
5(a)	$0 = 15t \sin 30 - \frac{1}{2} g \cos 25 t^2$ $t = \frac{15 \sin 30}{\frac{1}{2} g \cos 25}$ $t = 1.69 \text{ sec.}$	M1A1 M1 A1F	4	Accept wrong angle(s) for M1 but not sin and cos in wrong places AWRT 1.69
(b)	$\perp \text{ to plane } \dot{y} = 15 \sin 30 - g \cos 25 \times \frac{15 \sin 30}{\frac{1}{2} g \cos 25}$ $\dot{y} = -7.5 \text{ ms}^{-1}$ $\parallel \text{ to plane } \dot{x} = 15 \cos 30 - g \sin 25 \times \frac{15 \sin 30}{\frac{1}{2} g \cos 25}$ $\dot{x} = 5.995766 \text{ or } 6.00 \text{ ms}^{-1}$ Restitution: Rebound $\dot{y} = \frac{2}{3} \times 7.5 = 5 \text{ ms}^{-1}$ $\dot{x} \text{ unchanged}$ Speed of rebound $= \sqrt{5.995766^2 + 5^2}$ $= 7.81 \text{ ms}^{-1}$	M1 A1F M1 A1F M1 B1 m1 A1F	8	Or -7.51 , ft from their answer in (a) Accept 5.99 Or 5.01 PI, dependent on the last M1 Dependent on the last three M1s
	Total		12	

MM03

Q	Solution	Marks	Total	Comments
6(a)	 <p> $\frac{\sin \theta}{10} = \frac{\sin 115^\circ}{18}$ $\theta = 30.2^\circ$ Bearing = 035° </p>	B1 M1 A1 A1	4	For any appropriate diagram PI by correct method Accept 034.8°
(b)(i)	 <p> $v_{AB}^2 = 18^2 + 10^2 - 2(18)(10)\cos 65^\circ$ $v_{AB} = 16.4881 \text{ ms}^{-1}$ $\frac{\sin 65^\circ}{16.4881} = \frac{\sin \theta}{10}$ $\theta = 33.3446^\circ$ $d = 12 \times \sin 33.3446^\circ$ $d = 6.60 \text{ km}$ </p>	B1 M1 A1 M1 A1F m1 A1F	7	For any appropriate diagram PI by correct method OE OE Dependent on the previous two M1s (AWRT 6.6 km)
(ii)	<p> $t = \frac{12 \times \cos 33.3446^\circ}{16.4881} = 0.607987 \text{ hours}$ (= 36.5 min) </p>	M1 A1F A1F	3	Or 0.608 hours LHS values Correct time
Total			14	

MM03

Q6 (b)(i) Alternative:

$r_A = [(18\cos 25)\mathbf{i} + (18\sin 25)\mathbf{j}]t$	
$r_B = [(12\cos 25)\mathbf{i} + (12\sin 25)\mathbf{j}] + 10\mathbf{j}t$	M1 for both
${}_A r_B = (-12\cos 25 + 18t\cos 25)\mathbf{i} + (-12\sin 25 + 18t\sin 25 - 10t)\mathbf{j}$	m1 A1
$ {}_A r_B ^2 = (-12\cos 25 + 18t\cos 25)^2 + (-12\sin 25 + 18t\sin 25 - 10t)^2$	A1
$\frac{d {}_A r_B ^2}{dt} = (36\cos 25)(-12\cos 25 + 18t\cos 25) + (36\sin 25 - 20)(-12\sin 25 + 18t\sin 25 - 10t) = 0$	m1
$t = 0.608$	A1
$d = 6.60 \text{ km} \quad \text{or} \quad 6.6 \text{ km}$	A1
The corresponding marks awarded for finding the closest approach time:	
$\frac{d {}_A r_B ^2}{dt} = (36\cos 25)(-12\cos 25 + 18t\cos 25) + (36\sin 25 - 20)(-12\sin 25 + 18t\sin 25 - 10t) = 0$	M1 A1
$t = 0.608 \quad (\text{or better})$	A1

(b)(i) Alternative (Not in the specification):

${}_A r_B = (-12\cos 25 + 18t\cos 25)\mathbf{i} + (-12\sin 25 + 18t\sin 25 - 10t)\mathbf{j}$	M1 A1
$[(-12\cos 25 + 18t\cos 25)\mathbf{i} + (-12\sin 25 + 18t\sin 25 - 10t)\mathbf{j}] \cdot [(18\sin 65)\mathbf{i} + (18\cos 65 - 10)\mathbf{j}] = 0$	m1
$(-12\cos 25 + 18t\cos 25)(18\sin 65) + (-12\sin 25 + 18t\sin 25 - 10t)(18\cos 65 - 10) = 0$	A1
$271.85t = 165.27$	m1
$t = 0.608 \quad (\text{or better})$	A1
$d = 6.60 \text{ km} \quad \text{or} \quad 6.6 \text{ km}$	A1
The corresponding marks awarded for finding the closest approach time:	
$(-12\cos 25 + 18t\cos 25)(18\sin 65) + (-12\sin 25 + 18t\sin 25 - 10t)(18\cos 65 - 10) = 0$	M1
$271.85t = 165.27$	A1
$t = 0.608 \quad (\text{or better})$	A1

(b)(ii) FT from their answers in part (b)(i)

MM03

Q	Solution	Marks	Total	Comments
7(a)	$2m(3i + j) + m(2i - 5j) = 2mv_A + m(2i + j)$ $8i - 3j = 2v_A + (2i + j)$ $v_A = 3i - 2j$	M1A1 A1	3	
(b)	$I = m(2i + j) - m(2i - 5j)$ $I = 6mj$	M1A1 A1	3	AG
(c)	$I = 6mj \Rightarrow$ Line of centres along j Restitution along j : $1 + 2 = e(5 + 1)$ $e = 0.5$ Accept energy methods	B1 M1A1 A1	4	PI
(d)	${}_A v_B = i - 3j$ ${}_A r_B = -0.1j + (i - 3j)t$ $1.1^2 = t^2 + (-0.1 - 3t)^2$ $10t^2 + 0.6t - 1.2 = 0$ $t = \frac{-0.6 \pm \sqrt{0.6^2 - 4(10)(-1.2)}}{2(10)} \quad (= 0.31770677)$ $t = 0.318$ or 0.317 sec.	M1A1 M1 m1 A1	5	OE Dependent on both M1s
	Total		15	
	TOTAL		75	