

Centre Number						Candidate Number				
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For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
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5	
6	
7	
TOTAL	



General Certificate of Education
Advanced Level Examination
June 2015

Mathematics

MM03

Unit Mechanics 3

Wednesday 3 June 2015 9.00 am to 10.30 am

For this paper you must have:

- the blue AQA booklet of formulae and statistical tables.

You may use a graphics calculator.

Time allowed

- 1 hour 30 minutes

Instructions

- Use black ink or black ball-point pen. Pencil should only be used for drawing.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- Write the question part reference (eg (a), (b)(i) etc) in the left-hand margin.
- You must answer each question in the space provided for that question. If you require extra space, use an AQA supplementary answer book; do **not** use the space provided for a different question.
- Do not write outside the box around each page.
- Show all necessary working; otherwise marks for method may be lost.
- Do all rough work in this book. Cross through any work that you do not want to be marked.
- The **final** answer to questions requiring the use of calculators should be given to three significant figures, unless stated otherwise.
- Take $g = 9.8 \text{ m s}^{-2}$, unless stated otherwise.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 75.

Advice

- Unless stated otherwise, you may quote formulae, without proof, from the booklet.
- You do not necessarily need to use all the space provided.



J U N 1 5 M M 0 3 0 1

Answer **all** questions.

Answer each question in the space provided for that question.

- 1 A formula for calculating the lift force acting on the wings of an aircraft moving through the air is of the form

$$F = k v^\alpha A^\beta \rho^\gamma$$

where F is the lift force in newtons,
 k is a dimensionless constant,
 v is the air velocity in m s^{-1} ,
 A is the surface area of the aircraft's wings in m^2 , and
 ρ is the density of the air in kg m^{-3} .

By using dimensional analysis, find the values of the constants α , β and γ .

[6 marks]

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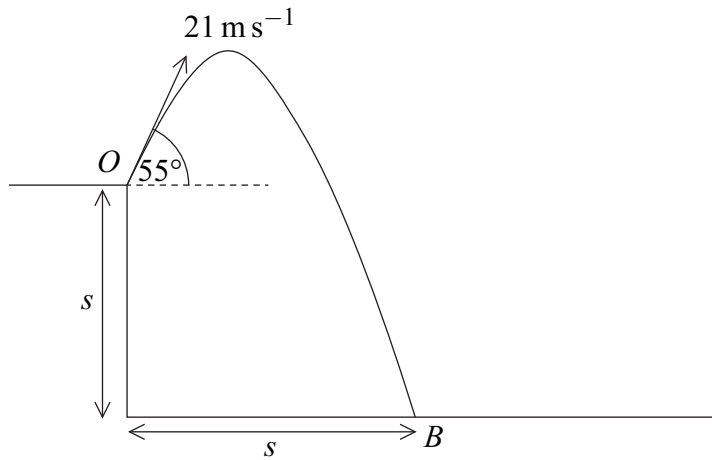
2 A projectile is launched from a point O on top of a cliff with initial velocity $u \text{ m s}^{-1}$ at an angle of elevation α and moves in a vertical plane. During the motion, the position vector of the projectile relative to the point O is $(x\mathbf{i} + y\mathbf{j})$ metres where \mathbf{i} and \mathbf{j} are horizontal and vertical unit vectors respectively.

(a) Show that, during the motion, the equation of the trajectory of the projectile is given by

$$y = x \tan \alpha - \frac{4.9x^2}{u^2 \cos^2 \alpha}$$

[5 marks]

(b) When $u = 21$ and $\alpha = 55^\circ$, the projectile hits a small buoy B . The buoy is at a distance s metres vertically below O and at a distance s metres horizontally from O , as shown in the diagram.



(i) Find the value of s .

[3 marks]

(ii) Find the acute angle between the velocity of the projectile and the horizontal just before the projectile hits B , giving your answer to the nearest degree.

[5 marks]

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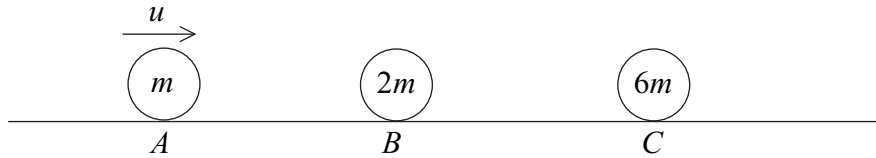
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- 4 Three uniform smooth spheres, A , B and C , have equal radii and masses m , $2m$ and $6m$ respectively. The spheres lie at rest in a straight line on a smooth horizontal surface with B between A and C . The sphere A is projected with speed u directly towards B and collides with it.



The coefficient of restitution between A and B is $\frac{2}{3}$.

- (a) (i) Show that the speed of B immediately after the collision is $\frac{5}{9}u$.
- (ii) Find, in terms of u , the speed of A immediately after the collision. **[6 marks]**
- (b) Subsequently, B collides with C . The coefficient of restitution between B and C is e . Show that B will collide with A again if $e > k$, where k is a constant to be determined. **[8 marks]**
- (c) Explain why it is not necessary to model the spheres as particles in this question. **[2 marks]**

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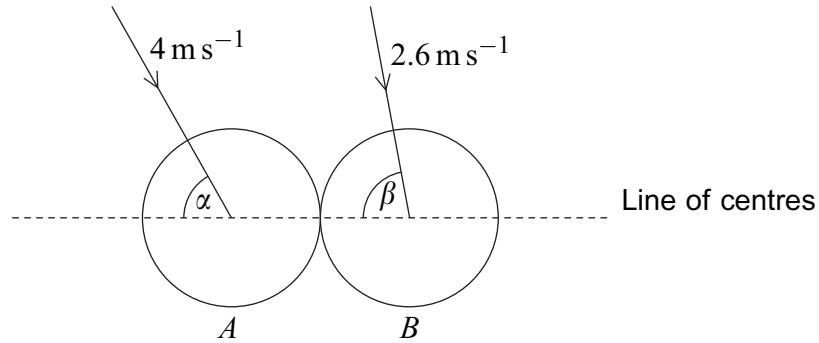
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Two smooth spheres, A and B , have equal radii and masses 2 kg and 1 kg respectively. The spheres move on a smooth horizontal surface and collide. As they collide, A has velocity 4 m s^{-1} in a direction inclined at an angle α to the line of centres, and B has velocity 2.6 m s^{-1} in a direction inclined at an angle β to the line of centres, as shown in the diagram.



The coefficient of restitution between A and B is $\frac{4}{7}$.

Given that $\sin \alpha = \frac{4}{5}$ and $\sin \beta = \frac{12}{13}$, find the speeds of A and B immediately after the collision.

[11 marks]

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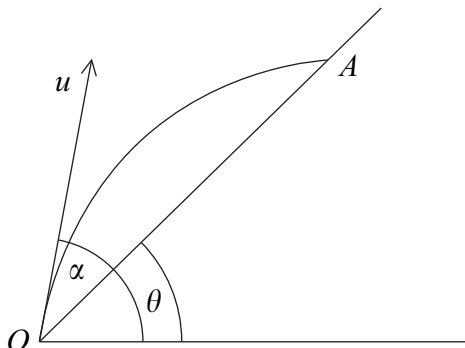
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- 7 A particle is projected from a point O on a plane which is inclined at an angle θ to the horizontal. The particle is projected up the plane with velocity u at an angle α **above the horizontal**. The particle strikes the plane for the first time at a point A . The motion of the particle is in a vertical plane which contains the line OA .



- (a) Find, in terms of u , θ , α and g , the time taken by the particle to travel from O to A . **[4 marks]**

- (b) The particle is moving horizontally when it strikes the plane at A .

By using the identity $\sin(P - Q) = \sin P \cos Q - \cos P \sin Q$, or otherwise, show that

$$\tan \alpha = k \tan \theta$$

where k is a constant to be determined.

[5 marks]

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END OF QUESTIONS



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