

Please write clearly in block capitals.

Centre number

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I declare this is my own work.

# INTERNATIONAL A-LEVEL FURTHER MATHEMATICS

(9665/FM05) Unit FM2 Mechanics

Thursday 13 June 2024      07:00 GMT      Time allowed: 1 hour 30 minutes

## Materials

- For this paper you must have the OxfordAQA Booklet of Formulae and Statistical Tables (enclosed).
- You may use a graphical calculator.

## 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.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.
- The **final** answer to questions requiring the use of calculators should be given to two significant figures, unless stated otherwise.
- Unless stated otherwise, the acceleration due to gravity,  $g$ , should be taken as  $9.8 \text{ m s}^{-2}$

## Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

## Advice

- Unless stated otherwise, you may quote formulae, without proof, from the booklet.
- Show all necessary working; otherwise marks may be lost.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
<b>TOTAL</b>	



J U N 2 4 F M 0 5 0 1

Answer **all** questions in the spaces provided.

- 1** A ball of mass  $0.3 \text{ kg}$  falls vertically from rest.  
It hits a horizontal surface and rebounds to a height of  $0.4 \text{ metres}$  above the surface.

- 1 (a)** Calculate the speed at which the ball leaves the horizontal surface.

**[2 marks]**

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Answer \_\_\_\_\_

- 1 (b)** The impulse exerted on the ball by the surface has magnitude  $3.24 \text{ N s}$   
Find the coefficient of restitution between the ball and the surface.

**[4 marks]**

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Answer \_\_\_\_\_



**[3 marks]**

Magnitude \_\_\_\_\_

Direction \_\_\_\_\_

**[5 marks]**

[illegible]

Answer

**3** A particle of mass 2 kg is initially at rest at the point  $O$  on a rough horizontal surface.

A horizontal force of magnitude  $F$  newtons and constant direction starts to act on the particle.

When the displacement of the particle from  $O$  is  $x$  metres,  $F$  is given by

$$F = 10e^{-0.1x}$$

The particle passes through the point  $A$  which is 5 metres from  $O$

**3 (a)** Find the work done by the force  $F$  as the particle moves from  $O$  to the point  $A$  **[3 marks]**

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Answer \_\_\_\_\_

**3 (b)** The coefficient of friction between the particle and the surface is 0.2

**3 (b) (i)** Find the speed of the particle at  $A$  **[3 marks]**

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Answer \_\_\_\_\_



Use a change of sign numerical method to verify that  $d = 23$  correct to the nearest integer.

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**Turn over for the next question**



- 4 (b)** On the axes below sketch a graph to show how the velocity of the particle varies with its displacement from  $O$

[2 marks]



- 4 (c)** On the axes below sketch a graph to show how the acceleration of the particle varies with its displacement from  $O$

[3 marks]

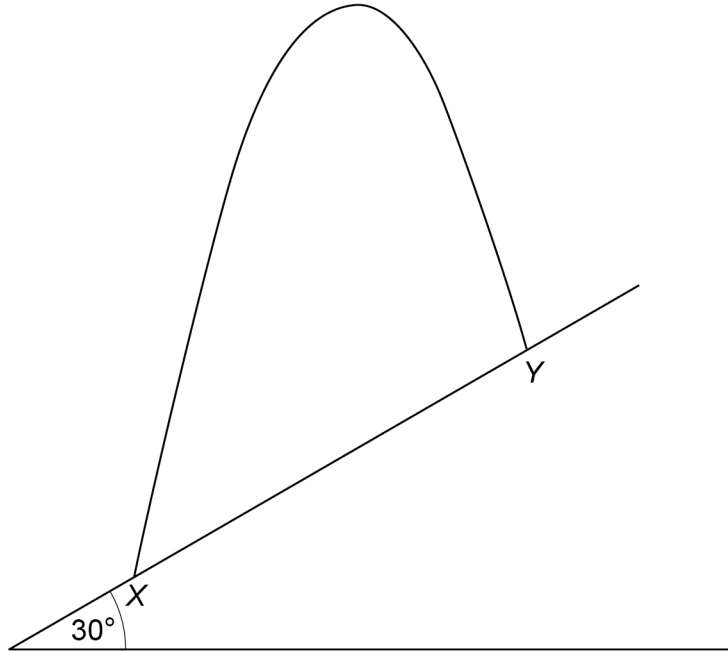


5

A plane is inclined at an angle of  $30^\circ$  to the horizontal.

A ball is projected up the plane from a point  $X$  on the plane.

The ball hits the plane for the first time at a point  $Y$  as shown in the diagram.



The line  $XY$  is a line of greatest slope of the plane.

The distance between the points  $X$  and  $Y$  is 4 metres.

The initial velocity of the ball is  $10 \text{ m s}^{-1}$  at an angle  $\alpha^\circ$  above the plane, where  $\alpha < 60$

By using the components of the ball's motion parallel and perpendicular to the plane, find the possible values of  $\alpha$

Give your values to the nearest integer.

**[8 marks]**

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Answer \_\_\_\_\_

**6** Two spheres  $A$  and  $B$  are moving on a smooth horizontal surface.

The two spheres collide.

Sphere  $A$  has mass  $2\text{ kg}$  and velocity  $\begin{bmatrix} 4 \\ 3 \end{bmatrix} \text{ m s}^{-1}$  before the collision.

Sphere  $B$  has mass  $3\text{ kg}$  and velocity  $\begin{bmatrix} -1 \\ 5 \end{bmatrix} \text{ m s}^{-1}$  before the collision.

After the collision sphere  $A$  has velocity  $\begin{bmatrix} 0.4 \\ 3 \end{bmatrix} \text{ m s}^{-1}$

**6 (a)** Find the magnitude of the impulse exerted on  $A$  during the collision.

**[3 marks]**

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Answer \_\_\_\_\_

**6 (b)** Find the velocity of sphere  $B$  after the collision.

**[3 marks]**

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Answer \_\_\_\_\_

- 6 (c)** Explain why the vector  $\begin{bmatrix} 1 \\ 0 \end{bmatrix}$  is parallel to the line of centres during the collision.

**[2 marks]**

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- 6 (d)** Find the coefficient of restitution between the two spheres.

**[2 marks]**

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Answer \_\_\_\_\_

10

Turn over ►



**7** Two springs are attached to a sphere of mass  $m$  kg which rests on a smooth horizontal surface.

The other end of one spring is attached to the fixed point  $A$  and the other end of the second string is attached to a fixed point  $B$

The points  $A$  and  $B$  are a distance  $3a$  metres apart.

Both springs have natural length  $a$  metres.

The spring attached to  $A$  has stiffness  $k$  N m<sup>-1</sup> and the spring attached to  $B$  has stiffness  $2k$  N m<sup>-1</sup>

The diagram shows the springs and the sphere.



**7 (a)** Show that the extension of the spring attached to  $A$  is  $\frac{2a}{3}$  metres when the system is in equilibrium.

**[3 marks]**

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- 7 (b) (i)** Show that the sphere moves with simple harmonic motion.

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- Express  $k$  in terms of  $m$

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Answer

**Turn over ►**



7 (b) (iii) The point  $C$  is  $\frac{a}{20}$  metres from the equilibrium position.

Hence, find the speed of the sphere at  $C$

Give your answer in an exact form in terms of  $a$

[3 marks]

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Answer \_\_\_\_\_



[illegible]

Answer \_\_\_\_\_

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**17**

8

A smooth hemisphere with centre  $O$  has its base fixed to a horizontal surface.

A particle is released from rest at a point  $A$  on the curved surface of the hemisphere.

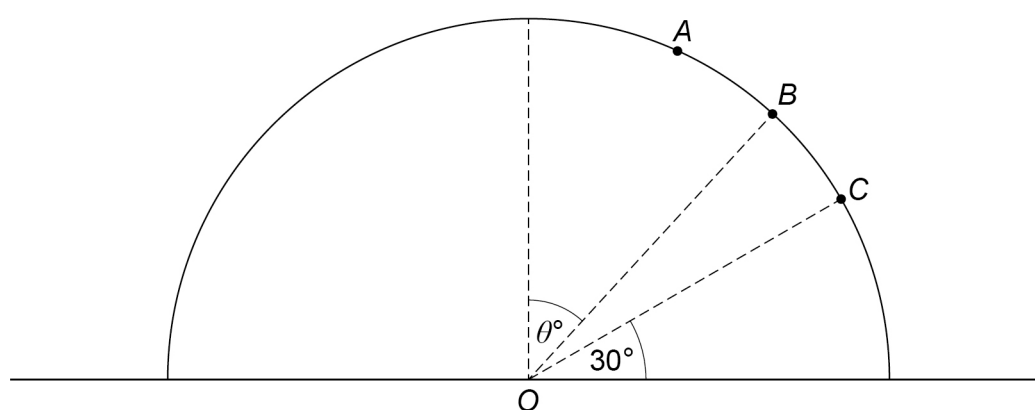
The particle passes through the point  $B$  and leaves the hemisphere at the point  $C$

At  $B$  the angle between the radius  $OB$  and the vertical is  $\theta^\circ$

At  $B$  the magnitude of the normal reaction force exerted on the particle is half of the maximum experienced by the particle as it moves from  $A$  to  $C$

At  $C$  the angle between the radius  $OC$  and the horizontal is  $30^\circ$

The diagram shows the hemisphere and the points  $A$ ,  $B$  and  $C$



Find  $\cos\theta^\circ$

Give your answer as a fraction.

[10 marks]

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[illegible]

Answer \_\_\_\_\_

**10**



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