

CANDIDATE
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MATHEMATICS

9709/51

Paper 5 Mechanics 2 **(M2)**

May/June 2017

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name in the spaces at the top of this page.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

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Answer **all** the questions.

Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place in the case of angles in degrees, unless a different level of accuracy is specified in the question.

Where a numerical value for the acceleration due to gravity is needed, use 10 m s^{-2} .

The use of an electronic calculator is expected, where appropriate.

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This document consists of **14** printed pages and **2** blank pages.



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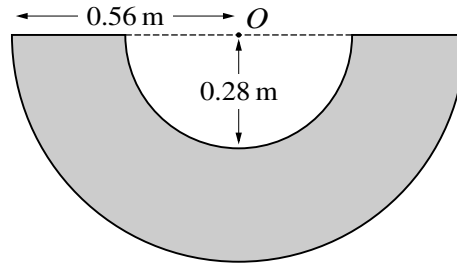
- 1** A particle is projected with speed 20 m s^{-1} at an angle of 60° above the horizontal. Calculate the time after projection when the particle is descending at an angle of 40° below the horizontal. [4]

[illegible]

P is released from rest by removing the 7 N force. In its subsequent motion P first comes to instantaneous rest at a point where $BP = 0.3$ m and the elastic string makes an angle of 30° with the horizontal (see Fig. 2).

[4]

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.



An object is made from a uniform solid hemisphere of radius 0.56 m and centre O by removing a hemisphere of radius 0.28 m and centre O . The diagram shows a cross-section through O of the object.

- (i) Calculate the distance of the centre of mass of the object from O . [4]

[The volume of a hemisphere is $\frac{2}{3}\pi r^3$.]

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The object has weight 24 N. A uniform hemisphere H of radius 0.28 m is placed in the hollow part of the object to create a non-uniform hemisphere with centre O . The centre of mass of the non-uniform hemisphere is 0.15 m from O .

(ii) Calculate the weight of H .

[3]

[illegible]

- 4 A particle is projected from a point O on horizontal ground. The initial components of the velocity of the particle are 10 m s^{-1} horizontally and 15 m s^{-1} vertically. At time $t \text{ s}$ after projection, the horizontal and vertically upwards displacements of the particle from O are $x \text{ m}$ and $y \text{ m}$ respectively.

(i) Express x and y in terms of t , and hence find the equation of the trajectory of the particle. [4]

[illegible]

The horizontal ground is at the top of a vertical cliff. The point O is at a distance d m from the edge of the cliff. The particle is projected towards the edge of the cliff and does not strike the ground before it passes over the edge of the cliff.

(ii) Show that d is less than 30.

[2]

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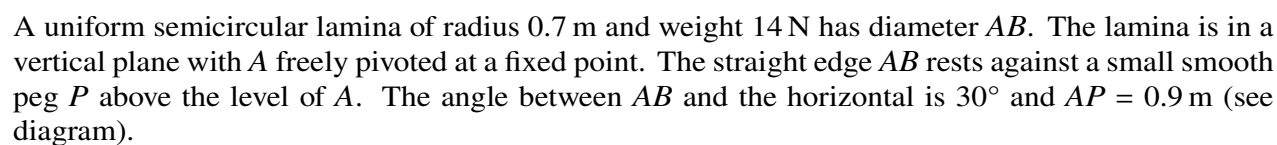
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- [illegible]

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- 6** A particle P of mass 0.15 kg is attached to one end of a light elastic string of natural length 0.4 m and modulus of elasticity 12 N . The other end of the string is attached to a fixed point A . The particle P moves in a horizontal circle which has its centre vertically below A , with the string inclined at θ° to the vertical and $AP = 0.5\text{ m}$.

(i) Find the angular speed of P and the value of θ . [5]

[illegible]

- (ii) Calculate the difference between the elastic potential energy stored in the string and the kinetic energy of P . [4]

[illegible]

- 7 A particle P of mass 0.5 kg is at rest at a point O on a rough horizontal surface. At time $t = 0$, where t is in seconds, a horizontal force acting in a fixed direction is applied to P . At time $t \text{ s}$ the magnitude of the force is $0.6t^2 \text{ N}$ and the velocity of P away from O is $v \text{ m s}^{-1}$. It is given that P remains at rest at O until $t = 0.5$.

(i) Calculate the coefficient of friction between P and the surface, and show that

$$\frac{dv}{dt} = 1.2t^2 - 0.3 \quad \text{for } t > 0.5. \quad [3]$$

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(ii) Express v in terms of t for $t > 0.5$. [3]

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(iii) Find the displacement of P from O when $t = 1.2$. [3]

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- 1 A particle P of mass 0.2 kg moves with speed 4 m s^{-1} and angular speed 5 rad s^{-1} in a horizontal circle on a smooth surface. P is attached to one end of a light elastic string of natural length 0.6 m . The other end of the string is attached to the point on the surface which is the centre of the circular motion of P .

(i) Find the radius of this circle.

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(ii) Find the modulus of elasticity of the string.

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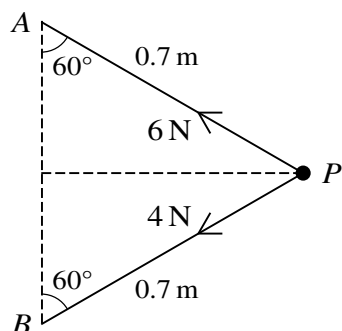
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(i) Find the mass of P .

[2]

[illegible]

(ii) Calculate the speed of P .

[3]

[illegible]

- 3** An open box in the shape of a cube with edges of length 0.2 m is placed with its base horizontal and its four sides vertical. The four sides and base are uniform laminas, each with weight 3 N.

(i) Calculate the height of the centre of mass of the box above its base. [3]

This image shows a full page of white paper with horizontal ruling lines. The lines are evenly spaced and extend across the width of the page, providing a template for handwriting practice or general writing. There are no margins, text, or other markings on the page.

The box is now fitted with a thin uniform square lid of weight 3 N and with edges of length 0.2 m. The lid is attached to the box by a hinge of length 0.2 m and weight 2 N. The lid of the box is held partly open.

- (ii)** Find the angle which the lid makes with the horizontal when the centre of mass of the box (including the lid and hinge) is 0.12 m above the base of the box. [4]

This image shows a full page of white paper with horizontal dotted lines. The lines are evenly spaced and run across the width of the page, providing a guide for handwriting practice. There are no margins, text, or other markings on the page.

- 4 A small object of mass 0.4 kg is released from rest at a point 8 m above the ground. The object descends vertically and when its downwards displacement from its initial position is x m the object has velocity v m s⁻¹. While the object is moving, a force of magnitude $0.2v^2$ N opposes the motion.

(i) Show that $v \frac{dv}{dx} = 10 - 0.5v^2$. [2]

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(ii) Express v in terms of x . [4]

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- (iii) Find the increase in the value of v during the final 4 m of the descent of the object. [2]

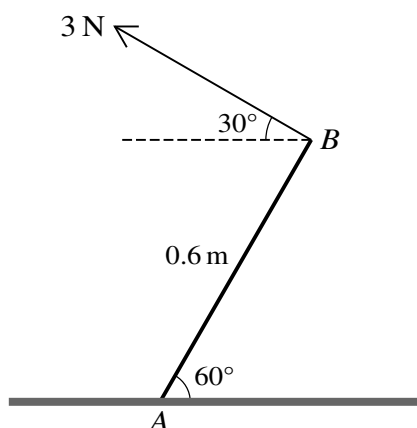
- 5** A particle of mass 0.3 kg is attached to one end of a light elastic string of natural length 0.8 m and modulus of elasticity 6 N . The other end of the string is attached to a fixed point O . The particle is projected vertically downwards from O with initial speed 2 m s^{-1} .

(i) Calculate the greatest speed of the particle during its descent.

[5]

This image shows a full page of white paper with horizontal dashed lines, typical of primary-ruled notebook paper. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

[illegible]



The end A of a non-uniform rod AB of length 0.6 m and weight 8 N rests on a rough horizontal plane, with AB inclined at 60° to the horizontal. Equilibrium is maintained by a force of magnitude 3 N applied to the rod at B . This force acts at 30° above the horizontal in the vertical plane containing the rod (see diagram).

- (i) Find the distance of the centre of mass of the rod from A. [2]

[illegible]

The 3 N force is removed, and the rod is held in equilibrium by a force of magnitude P N applied at B , acting in the vertical plane containing the rod, at an angle of 30° below the horizontal.

(ii) Calculate P .

[2]

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In one of the two situations described, the rod AB is in limiting equilibrium.

(iii) Find the coefficient of friction at A .

[4]

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- 7 A particle P is projected from a point O with speed $V \text{ m s}^{-1}$. At time $t \text{ s}$ after projection the horizontal and vertically upwards displacements of P from O are $x \text{ m}$ and $y \text{ m}$ respectively. The equation of the trajectory of P is $y = 2x - \frac{25x^2}{V^2}$.

(i) Write down the value of $\tan \theta$, where θ is the angle of projection of P . [1]

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When $t = 4$, P passes through the point A where $x = y = a$.

(ii) Calculate V and a . [5]

This image shows a full page of a handwriting practice worksheet. It consists of multiple horizontal rows, each defined by two parallel dashed lines. The lines are evenly spaced across the entire page, providing a guide for letter height and placement. There is no text or other markings on the page.

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(iii) Find the direction of motion of P when it passes through A .

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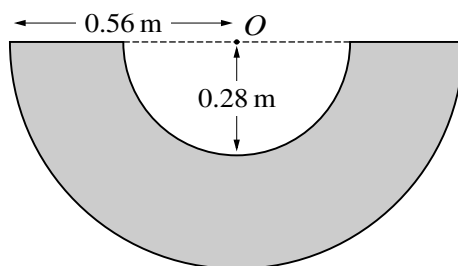
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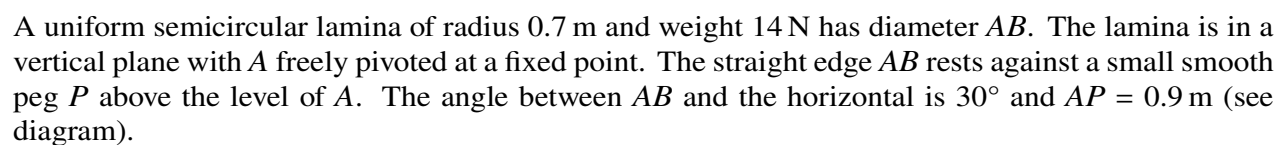
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