



CANDIDATE
NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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9231/31

October/November 2020

1 hour 30 minutes

You will need: List of formulae (MF19)

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- If additional space is needed, you should use the lined page at the end of this booklet; the question number or numbers must be clearly shown.
- You should use a calculator where appropriate.
- You must show all necessary working clearly; no marks will be given for unsupported answers from a calculator.
- Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place for angles in degrees, unless a different level of accuracy is specified in the question.
- Where a numerical value for the acceleration due to gravity (g) is needed, use 10 ms^{-2} .

- The total mark for this paper is 50.
- The number of marks for each question or part question is shown in brackets [].

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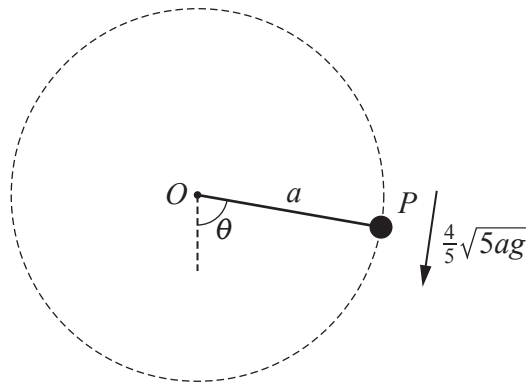
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- 1 A particle P of mass m is placed on a fixed smooth plane which is inclined at an angle θ to the horizontal. A light spring, of natural length a and modulus of elasticity $3mg$, has one end attached to P and the other end attached to a fixed point O at the top of the plane. The spring lies along a line of greatest slope of the plane. The system is released from rest with the spring at its natural length.

Find, in terms of a and θ , an expression for the greatest extension of the spring in the subsequent motion. [3]

[illegible]



Find the value of $\cos \theta$. [5]

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.

- 3 One end of a light elastic string, of natural length a and modulus of elasticity $4mg$, is attached to a fixed point O . The other end of the string is attached to a particle of mass m . The particle moves in a horizontal circle with a constant angular speed $\sqrt{\frac{g}{a}}$ with the string inclined at an angle θ to the downward vertical through O . The length of the string during this motion is $(k+1)a$.

(a) Find the value of k . [4]

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(b) Find the value of $\cos \theta$. [2]

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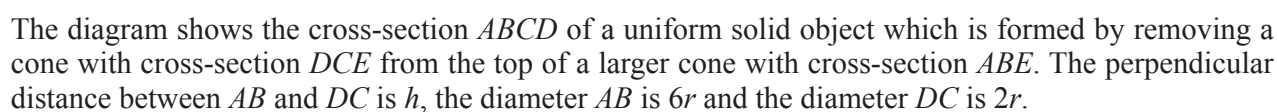
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- [4]

[illegible]

The object is freely suspended from the point B and hangs in equilibrium. The angle between AB and the downward vertical through B is θ .

- (b)** Given that $h = \frac{13}{4}r$, find the value of $\tan \theta$. [2]

[illegible]

- 5 A particle P is projected with speed u at an angle α above the horizontal from a point O on a horizontal plane and moves freely under gravity. The horizontal and vertical displacements of P from O at a subsequent time t are denoted by x and y respectively.

- (a) Derive the equation of the trajectory of P in the form

$$y = x \tan \alpha - \frac{gx^2}{2u^2} \sec^2 \alpha. \quad [3]$$

[illegible]

The point Q is the highest point on the trajectory of P in the case where $\alpha = 45^\circ$.

- (b)** Show that the x -coordinate of Q is $\frac{u^2}{2g}$. [3]

[illegible]

- (c) Find the other value of α for which P would pass through the point Q . [4]

- 6 Two smooth spheres A and B have equal radii and masses m and $2m$ respectively. Sphere B is at rest on a smooth horizontal floor. Sphere A is moving on the floor with velocity u and collides directly with B . The coefficient of restitution between the spheres is e .

(a) Find, in terms of u and e , the velocities of A and B after the collision. [3]

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Subsequently, B collides with a fixed vertical wall which makes an angle θ with the direction of motion of B , where $\tan \theta = \frac{3}{4}$.

The coefficient of restitution between B and the wall is $\frac{2}{3}$. Immediately after B collides with the wall, the kinetic energy of A is $\frac{5}{32}$ of the kinetic energy of B .

(b) Find the possible values of e . [7]

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- 7 A particle P moving in a straight line has displacement x m from a fixed point O on the line at time t s. The acceleration of P , in m s^{-2} , is given by $\frac{200}{x^2} - \frac{100}{x^3}$ for $x > 0$. When $t = 0$, $x = 1$ and P has velocity 10 m s^{-1} directed towards O .

(a) Show that the velocity $v \text{ m s}^{-1}$ of P is given by $v = \frac{10(1-2x)}{x}$. [5]

This image shows a full page of a worksheet designed for handwriting practice. It consists of approximately 20 horizontal rows. Each row is defined by two parallel dotted lines, creating a series of uniform gaps for writing. The entire page is otherwise blank, with no text or other markings.

- (b)** Show that x and t are related by the equation $e^{-40t} = (2x-1)e^{2x-2}$ and deduce what happens to x as t becomes large. [5]

[illegible]

[illegible]

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