



CANDIDATE
NAME

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9231/31

May/June 2024

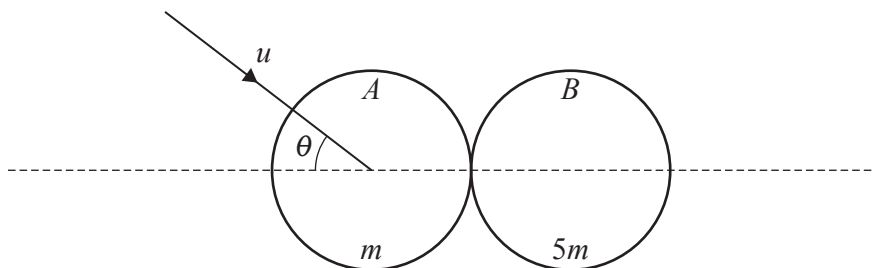
1 hour 30 minutes

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 [].

This document has **16** pages.



Two smooth uniform spheres A and B of equal radii have masses m and $5m$ respectively. Sphere A is moving on a smooth horizontal surface with speed u when it collides with sphere B which is at rest on the surface. Immediately before the collision, A 's direction of motion makes an angle of θ with the line of centres. After the collision, the kinetic energies of A and B are equal. The coefficient of restitution between the spheres is $\frac{1}{2}$.

Find the value of $\tan \theta$.

[6]

This image shows a full page of a handwriting practice worksheet. It consists of multiple rows of horizontal dashed lines spaced evenly apart, providing a guide for letter height and placement. The background is plain white, and there are no margins or additional markings.

- 2 The points A and B are at the same horizontal level a distance $4a$ apart. The ends of a light elastic string, of natural length $4a$ and modulus of elasticity λ , are attached to A and B . A particle P of mass m is attached to the midpoint of the string. The system is in equilibrium with P at a distance $\frac{3}{2}a$ below M , the midpoint of AB .

(a) Find λ in terms of m and g .

[3]

[illegible]

The particle P is pulled down vertically and released from rest at a distance $\frac{8}{3}a$ below M .

- (b)** Find, in terms of a and g , the speed of P as it passes through M in the subsequent motion. [4]

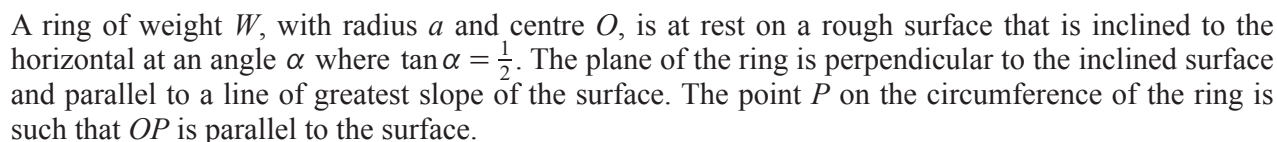
This image shows a full page of a handwriting practice worksheet. It consists of multiple rows of horizontal dotted lines spaced evenly down the page, providing a guide for letter height and placement. The background is plain white, and there are no other markings or text present.

- 3** At time $t = 0$ seconds, a particle P is projected with speed $u \text{ m s}^{-1}$ at an angle 60° above the horizontal from a point O . In the subsequent motion P moves freely under gravity. The direction of motion of P when $t = 5$ is perpendicular to its direction of motion when $t = 15$.

Find the value of u .

[5]

[illegible]



A light inextensible string is attached to P and to the point Q , which is on the surface, such that PQ is horizontal (see diagram). The points O, P and Q are in the same vertical plane. The system is in limiting equilibrium and the coefficient of friction between the ring and the surface is μ .

- (a) Find, in terms of W , the tension in the string PQ . [4]

This image shows a blank 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.

[Turn over

- 5 Two particles A and B of masses m and km respectively are connected by a light inextensible string of length a . The particles are placed on a rough horizontal circular turntable with the string taut and lying along a radius of the turntable. Particle A is at a distance a from the centre of the turntable and particle B is at a distance $2a$ from the centre of the turntable. The coefficient of friction between each particle and the turntable is $\frac{1}{5}$.

When the turntable is made to rotate with angular speed $\frac{2}{5}\sqrt{\frac{g}{a}}$, the system is in limiting equilibrium.

- (a) Find the tension in the string, in terms of m and g . [4]

[illegible]

[Turn over

- 6** A particle P of mass 2 kg moving on a horizontal straight line has displacement $x\text{ m}$ from a fixed point O on the line and velocity $v\text{ m s}^{-1}$ at time $t\text{ s}$. The only horizontal force acting on P has magnitude $\frac{1}{10}(2v-1)^2\text{ e}^{-t}\text{ N}$ and acts towards O . When $t = 0$, $x = 1$ and $v = 3$.

(a) Find an expression for v in terms of t .

[5]

This image shows a full page of a handwriting practice worksheet. It consists of approximately 20 horizontal rows. Each row is defined by two parallel dashed lines, creating a series of uniform gaps for letter height. The lines are evenly spaced across the entire page, providing a guide for consistent letter formation. There is no text or other markings on the page.

(b) Find an expression for x in terms of t .

[4]

[illegible]

- 7 A smooth sphere with centre O and of radius a is fixed to a horizontal plane. A particle P of mass m is projected horizontally from the highest point of the sphere with speed u , so that it begins to move along the surface of the sphere. The particle P loses contact with the sphere at the point Q on the sphere, where OQ makes an angle θ with the upward vertical through O .

(a) Show that $\cos \theta = \frac{u^2 + 2ag}{3ag}$. [4]

[illegible]

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- 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.

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- This image shows a single sheet of white paper with ten horizontal dashed lines, typical of primary school handwriting practice paper. The lines are evenly spaced and extend across the width of the page. There is no text or other markings on the paper.

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.

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