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FURTHER MATHEMATICS

9231/31

Paper 3 Further Mechanics

May/June 2026

1 hour 30 minutes

You must answer on the question paper.

You will need: List of formulae (MF19)

INSTRUCTIONS

- 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. Do **not** use correction fluid or tape.
- 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 m s^{-2} .

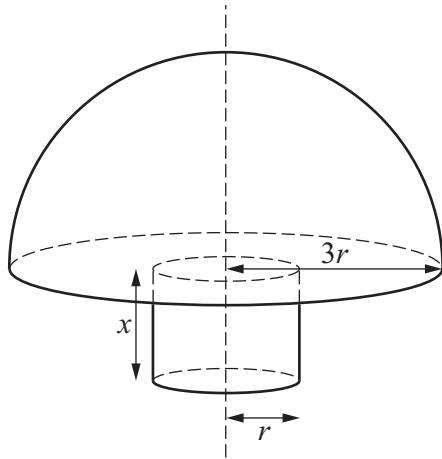
INFORMATION

- 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.



1



An object consists of a uniform solid hemisphere of radius $3r$ attached to a uniform solid cylinder of radius r and height x . The hemisphere and the cylinder are made of the same material. The axes of symmetry of the hemisphere and the cylinder coincide (see diagram).

- (a) Find, in terms of r and x , the distance of the centre of mass of the object from the base of the cylinder.

[4]

[illegible]



- (b) The point A lies on the circumference of the base of the hemisphere. When the object is freely suspended from point A , the base of the hemisphere makes an angle θ with the downward vertical through A .

It is given that $x = r$.

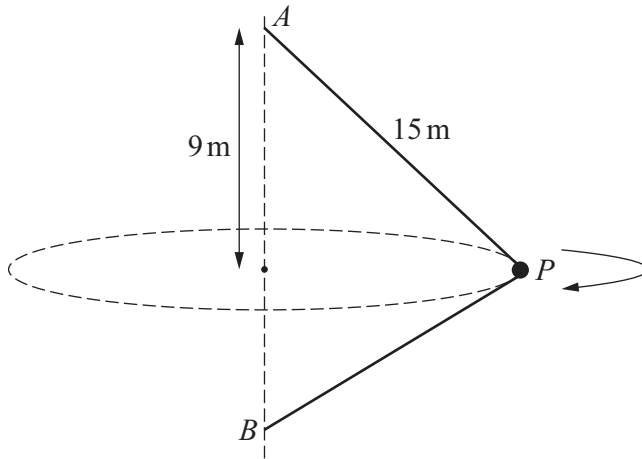
Find the value of θ .

[3]

[illegible]



2



The point B is vertically below the point A . One end of a light inextensible string is attached to A , and the other end is attached to B . A particle P of mass 7 kg is attached to the string so that the length AP is 15 m . The particle P moves at a constant angular speed of 4 radians per second in a horizontal circle with centre between A and B at a distance 9 m vertically below A (see diagram). The string has length 28 m , and both sections of the string are taut.

The tensions in the sections of the string AP and BP are T_A and T_B respectively.

Find the value of T_A and the value of T_B .

[5]

[illegible]



[Turn over



- 3** A particle P of mass 6.4 kg moves along a straight horizontal line. At time $t\text{ s}$, the speed of P is $v\text{ m s}^{-1}$ and the distance of P from its starting position is $x\text{ m}$. The forces acting on P are a constant driving force of magnitude 8 N and a resistive force of magnitude $0.5v^2\text{ N}$. Initially, P is at rest.

(a) Find the speed of P when it has travelled 0.8 m. [5]

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

[4]

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- 4 A particle P is moving on a fixed smooth horizontal surface with speed u . The particle collides with a fixed smooth vertical barrier. Immediately before the collision, the direction of motion of P makes an angle α with the barrier, where $\tan \alpha = \frac{12}{5}$.

The kinetic energy of P after the collision is $\frac{4}{13}$ times its kinetic energy before the collision.

- (a) Find the coefficient of restitution between P and the barrier. [4]

[illegible]



- (b) A second smooth vertical barrier is fixed to the surface and to the first barrier. The angle between the two barriers is 120° . Particle P subsequently collides with the second barrier and rebounds immediately after with speed w at an angle θ with the second barrier. The coefficient of restitution is the same as in the first collision.

Find the value of θ correct to 3 significant figures.

[4]

[illegible]



- 5** A particle of mass m is attached to a fixed point O by a light inextensible string of length a . The particle initially hangs directly below O at the point A . The particle is then projected horizontally with speed $2\sqrt{ag}$, and begins to move in a vertical circle.
- (a)** Find an expression for the tension in the string when it has turned through an angle θ . Give your answer in terms of m , g and θ . [4]

[illegible]



- (b)** Find, in terms of a , the maximum height above the horizontal through A that is reached by the particle.

[5]

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- 6 A light elastic string has natural length 2.5 m and modulus of elasticity 15 N. One end of the string is attached to the fixed point O , and the other end is attached to a particle P of mass 1.5 kg. The particle P is held at O and then released from rest so that it begins to fall vertically. In its subsequent motion, P moves with velocity $v \text{ m s}^{-1}$ when the extension of the string is $x \text{ m}$. The maximum extension of the string during this motion is $E \text{ m}$.

(a) Show that, for $0 < x < E$,

$$v^2 = -4(x^2 - 5x - 12.5). \quad [3]$$

[illegible]



(b) Find the value of E .

[1]

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(c) Find the maximum speed of P .

[2]

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- 7 The points O and A lie on a horizontal plane 10 m apart. The point A lies at the foot of another plane which is inclined at an angle of α above the horizontal such that $\tan \alpha = \frac{4}{3}$. The point B is on the inclined plane at a distance of 5 m from A measured along a line of greatest slope. The points O , A and B are in the same vertical plane and angle OAB is obtuse.

A particle is projected from O at an angle θ to the horizontal with initial speed $u \text{ m s}^{-1}$ towards the inclined plane. The particle moves freely under gravity. The particle strikes the inclined plane at the point B when its direction of motion is perpendicular to the inclined plane.

Find, in either order, the value of u and the value of θ .

[6]

[illegible]



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Additional page

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