GCE Examinations

Mechanics
Module M3

Advanced Subsidiary / Advanced Level

Paper C

Time: 1 hour 30 minutes

Instructions and Information

Candidates may use any calculator except those with a facility for symbolic algebra and / or calculus.

Full marks may be obtained for answers to ALL questions.

Mathematical and statistical formulae and tables are available.

This paper has 7 questions.

When a numerical value of g is required, use $g = 9.8 \text{ m s}^{-2}$.

Advice to Candidates

You must show sufficient working to make your methods clear to an examiner. Answers without working will gain no credit.

Solomon Press

Written by Shaun Armstrong & Chris Huffer

1. A light elastic string has natural length a and modulus of elasticity $4mg$. One end of the string is attached to a fixed point A and a particle of mass m is attached to the other end.

The particle is released from rest at A and falls vertically until it comes to rest instantaneously at the point B.

Find the distance AB in terms of a. **(7 marks)**

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2. A particle P of mass 0.25 kg is moving on a horizontal plane.

At time t seconds the velocity, $\mathbf{v}$ m s^{-1}, of P relative to a fixed origin O is given by

$$\mathbf{v} = \ln(t+1)\mathbf{i} - \mathrm{e}^{-2t}\mathbf{j}, \quad t \leq 0,$$

where $\mathbf{i}$ and $\mathbf{j}$ are perpendicular unit vectors in the horizontal plane.

(a) Find the acceleration of P in terms of t. **(3 marks)**

(b) Find, correct to 3 significant figures, the magnitude of the resultant force acting on P when $t = 1$.

(4 marks)

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3. A coin of mass 5 grams is placed on a vinyl disc rotating on a record player. The distance between the centre of the coin and the centre of the disc is 0.1 m and the coefficient of friction between the coin and the disc is μ. The disc rotates at 45 revolutions per minute around a vertical axis at its centre and the coin moves with it and does not slide.

By modelling the coin as a particle and giving your answers correct to an appropriate degree of accuracy, find

(a) the speed of the coin, **(2 marks)**

(b) the horizontal and vertical components of the force exerted on the coin by the disc.

(4 marks)

Given that the coin is on the point of moving,

(c) show that, correct to 2 significant figures, $\mu = 0.23$. **(3 marks)**

4.

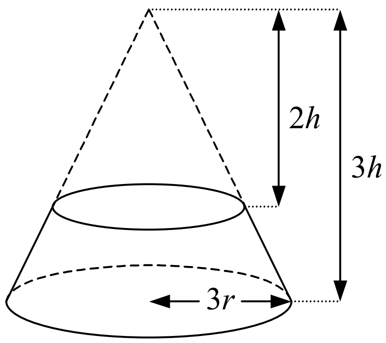

Fig. 1

A stand used to reach high shelves in a storeroom is in the shape of a frustum of a cone. It is modelled as a uniform solid formed by removing a right circular cone of height $2h$ from a similar cone of height $3h$ and base radius $3r$ as shown in Figure 1.

(a) Show that the centre of mass of the stand is a distance of $\frac{33}{76}h$ from its larger plane face.

(7 marks)

The stand is stored hanging in equilibrium from a point on the circumference of the larger plane face. Given that $h = 2r$,

(b) find, correct to the nearest degree, the acute angle which the plane faces of the stand make with the vertical.

(4 marks)

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5. A particle of mass 0.8 kg is moving along the positive x-axis at a speed of 5 m s^{-1} away from the origin O. When the particle is 2 metres from O it becomes subject to a single force directed towards O. The magnitude of the force is $\frac{k}{x^2}$ N when the particle is x metres from O.

Given that when the particle is 4 m from O its speed has been reduced to 3 m s^{-1},

(a) show that $k = \frac{128}{5}$, **(8 marks)**

(b) find the distance of the particle from O when it comes to instantaneous rest. **(4 marks)**

Turn over

6.

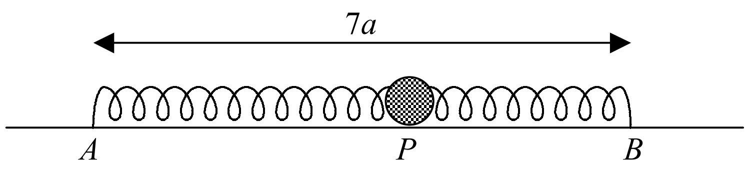

Fig. 2

Figure 2 shows a particle P of mass m which lies on a smooth horizontal table. It is attached to a point A on the table by a light elastic spring of natural length $3a$ and modulus of elasticity λ, and to a point B on the table by a light elastic spring of natural length $2a$ and modulus of elasticity 2λ. The distance between the points A and B is $7a$.

(a) Show that in equilibrium $AP = \frac{9}{2}a$. **(5 marks)**

The particle is released from rest at a point Q where Q lies on the line AB and $AQ = 5a$.

(b) Prove that the subsequent motion of the particle is simple harmonic with a period of $\pi\sqrt{\frac{3ma}{\lambda}}$. **(9 marks)**

7.

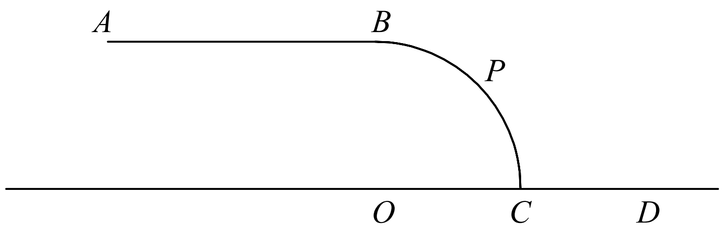

Fig. 3

Figure 3 shows a vertical cross-section through part of a ski slope consisting of a horizontal section AB followed by a downhill section BC. The point O is on the same horizontal level as C and BC is a circular arc of radius 30 m and centre O, such that $\angle BOC = 90°$.

A skier of mass 60 kg is skiing at 12m s^{-1} along AB.

(a) Assuming that friction and air resistance may be neglected, find the magnitude of the loss in reaction between the skier and the surface at B.

(4 marks)

The skier subsequently leaves the slope at the point P.

(b) Find, correct to 3 significant figures, the speed at which the skier leaves the slope.

(8 marks)

(c) Find, correct to 3 significant figures, the speed of the skier immediately before hitting the ground again at the point D which is on the same horizontal level as C.

(3 marks)

END