

# GCE Examinations

## Mechanics Module M3

Advanced Subsidiary / Advanced Level

Paper E

Time: 1 hour 30 minutes

### *Instructions and Information*

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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*

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



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1. The velocity,  $v \text{ cm s}^{-1}$ , at time  $t$  seconds, of a radio-controlled toy is modelled by the formula

$$\mathbf{v} = e^{2t}\mathbf{i} + 2t\mathbf{j},$$

where  $\mathbf{i}$  and  $\mathbf{j}$  are perpendicular unit vectors.

- (a) Find the acceleration of the toy in terms of  $t$ . (2 marks)
- (b) Find, correct to 2 significant figures, the time at which the acceleration of the toy is parallel to the vector  $(4\mathbf{i} + \mathbf{j})$ . (4 marks)
- (c) Explain why this model is unlikely to be realistic for large values of  $t$ . (1 mark)

2. A particle  $P$  of mass  $0.4 \text{ kg}$  is moving in a straight line through a fixed point  $O$ .

At time  $t$  seconds after it passes through  $O$ , the distance  $OP$  is  $x$  metres and the resultant force acting on  $P$  is of magnitude  $(5 + 4e^{-x}) \text{ N}$  in the direction  $OP$ .

When  $x = 1$ ,  $P$  is at the point  $A$ .

- (a) Find, correct to 3 significant figures, the work done in moving  $P$  from  $O$  to  $A$ . (4 marks)

Given that  $P$  passes through  $O$  with speed  $2 \text{ m s}^{-1}$ ,

- (b) find, correct to 3 significant figures, the speed of  $P$  as it passes through  $A$ . (4 marks)

- 3.

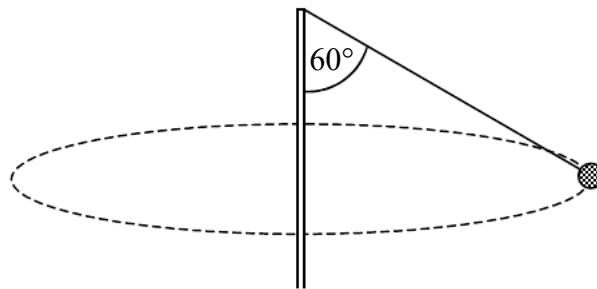


Fig. 1

A popular racket game involves a tennis ball of mass  $0.1 \text{ kg}$  which is attached to one end of a light inextensible string. The other end of the string is attached to the top of a fixed rigid pole.

A boy strikes the ball such that it moves in a horizontal circle with angular speed  $4 \text{ rad s}^{-1}$  and the string makes an angle of  $60^\circ$  with the downward vertical as shown in Figure 1.

- (a) Find the tension in the string. (3 marks)
- (b) Find the length of the string. (5 marks)

4. A particle moves with simple harmonic motion along a straight line.

When the particle is 3 cm from its centre of motion it has a speed of  $8 \text{ cm s}^{-1}$  and an acceleration of magnitude  $12 \text{ cm s}^{-2}$ .

- (a) Show that the period of the motion is  $\pi$  seconds. (4 marks)
- (b) Find the amplitude of the motion. (3 marks)
- (c) Hence, find the greatest speed of the particle. (2 marks)

5. A physics student is set the task of finding the mass of an object without using a set of scales. She decides to use a light elastic string of natural length 2 m and modulus of elasticity 280 N attached to two points  $A$  and  $B$  which are on the same horizontal level and 2.4 m apart.

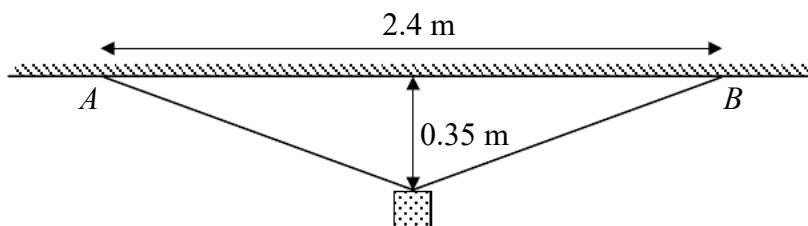


Fig. 2

She attaches the object to the midpoint of the string so that it hangs in equilibrium 0.35 m below  $AB$  as shown in Figure 2.

- (a) Explain why it is reasonable to assume that the tensions in each half of the string are equal. (1 mark)
- (b) Find the mass of the object. (7 marks)
- (c) Find the elastic potential energy of the string when the object is suspended from it. (2 marks)

Turn over

6.

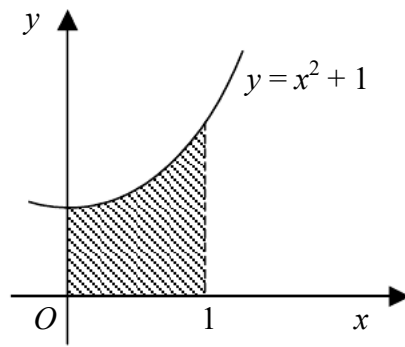


Fig. 3

Figure 3 shows part of the curve  $y = x^2 + 1$ . The shaded region enclosed by the curve, the coordinate axes and the line  $x = 1$  is rotated through  $360^\circ$  about the  $x$ -axis.

- (a) Find the coordinates of the centre of mass of the solid obtained. **(10 marks)**

The solid is suspended from a point on its larger circular rim and hangs in equilibrium.

- (b) Find, correct to the nearest degree, the acute angle which the plane surfaces of the solid make with the vertical. **(3 marks)**

7. A particle of mass 0.5 kg is hanging vertically at one end of a light inextensible string of length 0.6 m. The other end of the string is attached to a fixed point.

The particle is given an initial horizontal speed of  $u \text{ ms}^{-1}$ .

- (a) Show that the particle will perform complete circles if  $u \geq \sqrt{3g}$ . **(8 marks)**

Given that  $u = 5$ ,

- (b) find, correct to the nearest degree, the angle through which the string turns before it becomes slack, **(7 marks)**

- (c) find, correct to the nearest centimetre, the greatest height the particle reaches above its position when the string becomes slack. **(5 marks)**

**END**