

# GCE Examinations

## Mechanics

### Module M3

Advanced Subsidiary / Advanced Level

Paper B

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.



*Written by Shaun Armstrong & Chris Huffer*

© Solomon Press

*These sheets may be copied for use solely by the purchaser's institute.*

1. A student is attempting to model the expansion of an airbag in a car following a collision.

The student considers the displacement from the steering column,  $s$  metres, of a point  $P$  on the airbag  $t$  seconds after a collision and uses the formula

$$s = e^{3t} - 1, \quad 0 \leq t \leq 0.1$$

Using this model,

- (a) find, correct to the nearest centimetre, the maximum displacement of  $P$ , **(2 marks)**
- (b) find the initial velocity of  $P$ , **(3 marks)**
- (c) find the acceleration of  $P$  in terms of  $t$ . **(1 mark)**
- (d) Explain why this model is unlikely to be realistic. **(1 mark)**
- 

2. A particle  $P$  is attached to one end of a light elastic string of modulus of elasticity 80 N. The other end of the string is attached to a fixed point  $A$ .

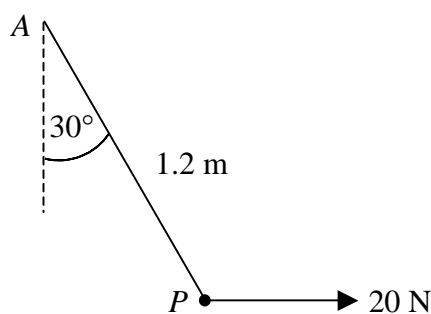


Fig. 1

When a horizontal force of magnitude 20 N is applied to  $P$ , it rests in equilibrium with the string making an angle of  $30^\circ$  with the vertical and  $AP = 1.2$  m as shown in Figure 1.

- (a) Find the tension in the string. **(3 marks)**
- (b) Find the elastic potential energy stored in the string. **(5 marks)**
-

3.

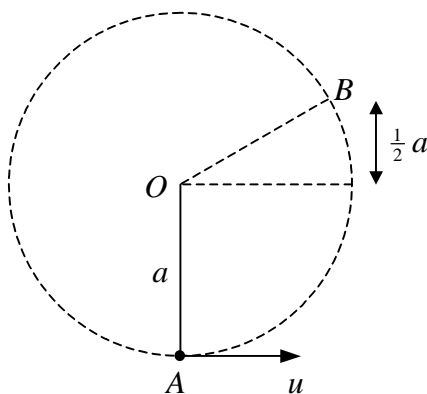


Fig. 2

A particle of mass  $m$  is suspended at a point  $A$  vertically below a fixed point  $O$  by a light inextensible string of length  $a$  as shown in Figure 2. The particle is given a horizontal velocity  $u$  and subsequently moves along a circular arc until it reaches the point  $B$  where the string becomes slack.

Given that the point  $B$  is at a height  $\frac{1}{2}a$  above the level of  $O$ ,

(a) show that  $\angle BOA = 120^\circ$ , **(2 marks)**

(b) show that  $u^2 = \frac{7}{2}ga$ . **(6 marks)**

4. On a particular day, high tide at the entrance to a harbour occurs at 11 a.m. and the water depth is 14 m. Low tide occurs  $6\frac{1}{4}$  hours later at which time the water depth is 6 m.

In a model of the situation, the water level is assumed to perform simple harmonic motion.

Using this model,

(a) write down the amplitude and period of the motion. **(2 marks)**

A ship needs a depth of 9 m before it can enter or leave the harbour.

(b) Show that on this day a ship must enter the harbour by 2.38 p.m., correct to the nearest minute, or wait for low tide to pass.

**(6 marks)**

Given that a ship is not ready to enter the harbour until 5 p.m.,

(c) find, to the nearest minute, how long the ship must wait before it can enter the harbour.

**(4 marks)**

*Turn over*

5. (a) Use integration to show that the centre of mass of a uniform solid right circular cone of height  $h$  is  $\frac{3}{4}h$  from the vertex of the cone.

**(6 marks)**

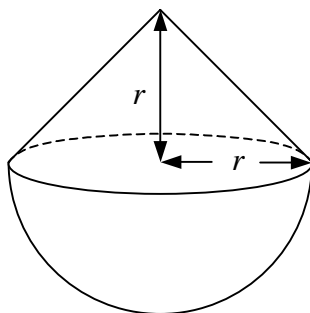


Fig. 3

A paperweight is made by removing material from the top half of a solid sphere of radius  $r$  so that the remaining solid consists of a hemisphere of radius  $r$  and a cone of height  $r$  and base radius  $r$  as shown in Figure 3.

- (b) Find the distance of the centre of mass of the paperweight from its vertex. **(7 marks)**

6. A car is travelling on a horizontal racetrack round a circular bend of radius 40 m. The coefficient of friction between the car and the road is  $\frac{2}{5}$ .

- (a) Find the maximum speed at which the car can travel round the bend without slipping, giving your answer correct to 3 significant figures.

**(5 marks)**

The owner of the track decides to bank the corner at an angle of  $25^\circ$  in order to enable the cars to travel more quickly.

- (b) Show that this increases the maximum speed at which the car can travel round the bend without slipping by 63%, correct to the nearest whole number.

**(8 marks)**

7. A particle is travelling along the  $x$ -axis. At time  $t = 0$ , the particle is at  $O$  and it travels such that its velocity,  $v \text{ m s}^{-1}$ , at a distance  $x$  metres from  $O$  is given by

$$v = \frac{2}{x+1}.$$

The acceleration of the particle is  $a \text{ m s}^{-2}$ .

- (a) Show that  $a = \frac{-4}{(x+1)^3}$ . **(4 marks)**

The points  $A$  and  $B$  lie on the  $x$ -axis. Given that the particle travels  $d$  metres from  $O$  to  $A$  in  $T$  seconds and 4 metres from  $A$  to  $B$  in 9 seconds,

- (b) show that  $d = 1.5$ , **(8 marks)**

- (c) find  $T$ . **(2 marks)**

---

**END**