

# GCE Examinations

# Mechanics

# Module M2

Advanced Subsidiary / Advanced Level

Paper C

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. A particle  $P$  of mass 2 kg is subjected to a force  $\mathbf{F}$  such that its displacement,  $\mathbf{r}$  metres, from a fixed origin,  $O$ , at time  $t$  seconds is given by

$$\mathbf{r} = (3t^2 - 4)\mathbf{i} + (3 - 4t^2)\mathbf{j}.$$

(a) Show that the acceleration of  $P$  is constant. **(4 marks)**

(b) Find the magnitude of  $\mathbf{F}$ . **(3 marks)**

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2. A pump raises water from a well 12 metres below the ground and ejects the water through a pipe of diameter 10 cm at a speed of  $6 \text{ m s}^{-1}$ .

Given that the mass of  $1 \text{ m}^3$  of water is 1000 kg,

(a) find, in terms of  $\pi$ , the mass of water discharged by the pipe every second, **(4 marks)**

(b) find in kJ, correct to 3 significant figures, the total mechanical energy gained by the water per second.

**(4 marks)**

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3. A particle moves in a straight horizontal line such that its velocity,  $v \text{ m s}^{-1}$ , at time  $t$  seconds is given by  $v = 2t^2 - 9t + 4$ . Initially, the particle has displacement 9 m from a fixed point  $O$  on the line.

(a) Find the initial velocity of the particle. **(1 mark)**

(b) Show that the particle is at rest when  $t = 4$  and find the other value of  $t$  when it is at rest.

**(3 marks)**

(c) Find the displacement of the particle from  $O$  when  $t = 6$ .

**(5 marks)**

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4.

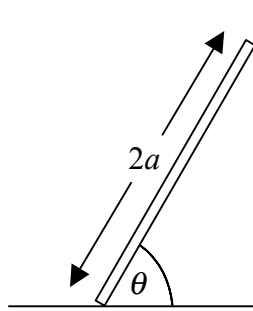


Fig. 1

Figure 1 shows a uniform ladder of mass  $m$  and length  $2a$  resting against a rough vertical wall with its lower end on rough horizontal ground. The coefficient of friction between the ladder and the wall is  $\frac{1}{2}$  and the coefficient of friction between the ladder and the ground is  $\frac{1}{3}$ .

Given that the ladder is in limiting equilibrium when it is inclined at an angle  $\theta$  to the horizontal, show that  $\tan \theta = \frac{5}{4}$ .

**(9 marks)**

5. A firework company is testing its new brand of firework, the *Sputnik Special*. One of the company's employees lights a *Sputnik Special* on a large area of horizontal ground and it takes off at a small angle to the vertical. After a flight lasting 8 seconds it lands at a distance of 24 metres from the point where it was launched.

The employee models the firework as a particle and ignores air resistance and any loss of mass which the *Sputnik Special* experiences.

Using this model, find for this flight of the *Sputnik Special*,

- (a) the horizontal and vertical components of the initial velocity, **(5 marks)**
- (b) the initial speed, correct to 3 significant figures, **(2 marks)**
- (c) the maximum height attained. **(3 marks)**
- (d) Comment on the suitability of the modelling assumptions made by the employee.

**(3 marks)***Turn over*

6. Three uniform spheres  $A$ ,  $B$  and  $C$  of equal radius have masses  $3m$ ,  $2m$  and  $2m$  respectively. Initially, the spheres are at rest on a smooth horizontal table with their centres in a straight line and with  $B$  between  $A$  and  $C$ . Sphere  $A$  is projected directly towards  $B$  with speed  $u$ .

Given that the coefficient of restitution between  $A$  and  $B$  is  $\frac{2}{3}$ ,

- (a) show that the speeds of  $A$  and  $B$  after the collision are  $\frac{1}{3}u$  and  $u$  respectively.

**(6 marks)**

The coefficient of restitution between  $B$  and  $C$  is  $e$ . Given that  $A$  and  $B$  collide again,

- (b) show that  $e > \frac{1}{3}$ .

**(8 marks)**

7.

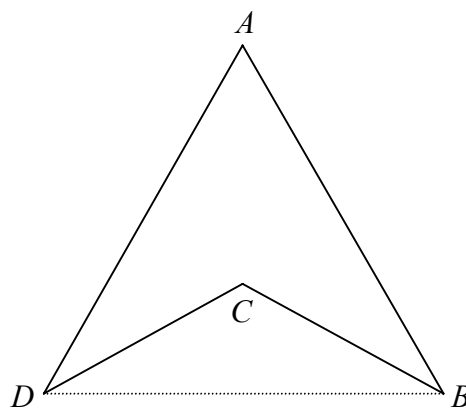


Fig. 2

Figure 2 shows a uniform lamina  $ABCD$  formed by removing an isosceles triangle  $BCD$  from an equilateral triangle  $ABD$  of side  $2d$ . The point  $C$  is the centroid of triangle  $ABD$ .

- (a) Find the area of triangle  $BCD$  in terms of  $d$ .

**(3 marks)**

- (b) Show that the distance of the centre of mass of the lamina from  $BD$  is  $\frac{4}{9}\sqrt{3}d$ .

**(8 marks)**

The lamina is freely suspended from the point  $B$  and hangs at rest.

- (c) Find in degrees, correct to 1 decimal place, the acute angle that the side  $AB$  makes with the vertical.

**(4 marks)**

**END**