

GCE Examinations

Mechanics Module M3

Advanced Subsidiary / Advanced Level

Paper A

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.



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1.

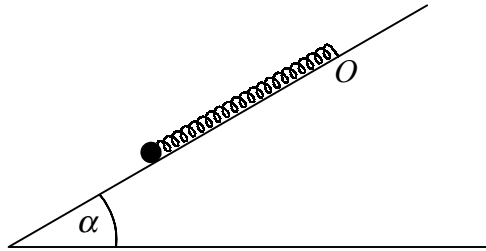


Fig. 1

A particle of mass 0.6 kg is attached to one end of a light elastic spring of natural length 1 m and modulus of elasticity 30 N. The other end of the spring is fixed to a point O which lies on a smooth plane inclined at an angle α to the horizontal where $\tan \alpha = \frac{3}{4}$ as shown in Figure 1.

The particle is held at rest on the slope at a point 1.2 m from O down the line of greatest slope of the plane.

(a) Find the tension in the spring. **(2 marks)**

(b) Find the initial acceleration of the particle. **(5 marks)**

2. A particle P of mass 0.5 kg moves along the positive x -axis under the action of a single force directed away from the origin O . When P is x metres from O , the magnitude of the force is $3x^{\frac{1}{2}}$ N and P has a speed of v m s^{-1} .

Given that when $x = 1$, P is moving away from O with speed 2 m s^{-1} ,

(a) find an expression for v^2 in terms of x , **(5 marks)**

(b) show that when $x = 4$, P has a speed of 7.7 m s^{-1} , correct to 1 decimal place. **(2 marks)**

3. A particle is performing simple harmonic motion along a straight line between the points A and B where $AB = 8$ m. The period of the motion is 12 seconds.

(a) Find the maximum speed of the particle in terms of π . **(4 marks)**

The points P and Q are on the line AB at distances of 3m and 6m respectively from A .

(b) Find, correct to 3 significant figures, the time it takes for the particle to travel directly from P to Q .

(6 marks)

4. Whilst in free-fall a parachutist falls vertically such that his velocity, $v \text{ m s}^{-1}$, when he is x metres below his initial position is given by

$$v^2 = kg(1 - e^{-\frac{2x}{k}}),$$

where k is a constant.

Given that he experiences an acceleration of $f \text{ m s}^{-2}$,

- (a) show that $f = ge^{-\frac{2x}{k}}$. (4 marks)

After falling a large distance, his velocity is constant at 49 m s^{-1} .

- (b) Find the value of k . (3 marks)

- (c) Hence, express f in the form $(\lambda - \mu v^2)$ where λ and μ are constants which you should find. (4 marks)

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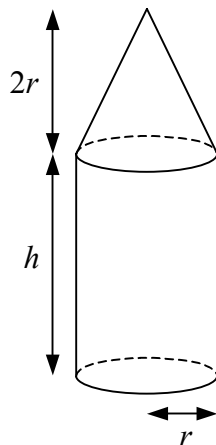


Fig. 2

A firework is modelled as a uniform solid formed by joining the plane surface of a right circular cone of height $2r$ and base radius r , to one of the plane surfaces of a cylinder of height h and base radius r as shown in Figure 2.

Using this model,

- (a) show that the distance of the centre of mass of the firework from its plane base is

$$\frac{3h^2 + 4hr + 2r^2}{2(3h + 2r)}. \quad (9 \text{ marks})$$

The firework is to be launched from rough ground inclined at an angle α to the horizontal. Given that the firework does not slip or topple and that $h = 4r$,

- (b) Find, correct to the nearest degree, the maximum value of α . (4 marks)

Turn over

6.

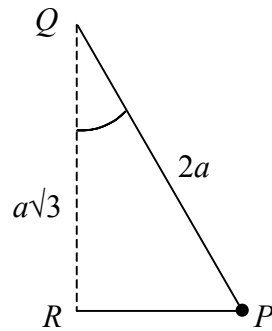


Fig. 3

The two ends of a light inextensible string of length $3a$ are attached to fixed points Q and R which are a distance of $a\sqrt{3}$ apart with R vertically below Q . A particle P of mass m is attached to the string at a distance of $2a$ from Q .

P is given a horizontal speed, u , such that it moves in a horizontal circle with both sections of the string taut as shown in Figure 3.

- (a) Show that $\angle PRQ$ is a right angle. (2 marks)
- (b) Find $\angle PQR$ in degrees. (1 mark)
- (c) Find, in terms of a , g , m and u , the tension in the section of string
- (i) PQ ,
- (ii) PR . (7 marks)
- (d) Show that $u^2 \geq \frac{ga}{\sqrt{3}}$. (3 marks)

7. A particle of mass 2 kg is attached to one end of a light elastic string of natural length 1 m and modulus of elasticity 50 N. The other end of the string is attached to a fixed point O on a rough horizontal plane and the coefficient of friction between the particle and the plane is $\frac{10}{49}$.

The particle is projected from O along the plane with an initial speed of 5 m s^{-1} .

- (a) Show that the greatest distance from O which the particle reaches is 1.84 m. (9 marks)
- (b) Find, correct to 2 significant figures, the speed at which the particle returns to O . (5 marks)

END