GCE Examinations

Mechanics
Module M2

Advanced Subsidiary / Advanced Level

Paper E

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. A ball of mass 0.6 kg bounces against a wall and is given an impulse of $(12\mathbf{i} - 9\mathbf{j})$ N s where **i** and **j** are perpendicular horizontal unit vectors. The velocity of the particle after the impact is $(5\mathbf{i} + 3\mathbf{j})$ m s^{-1}.

Find the velocity of the particle before the impact. **(4 marks)**

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2. A particle P moves along the x-axis such that its displacement, x metres, from the origin O at time t seconds is given by

$$x = 2 + t - \tfrac{1}{10}\mathrm{e}^{t}.$$

(a) Find the distance of P from O when $t = 0$. **(2 marks)**

(b) Find, correct to 1 decimal place, the value of t when the velocity of P is zero. **(4 marks)**

3.

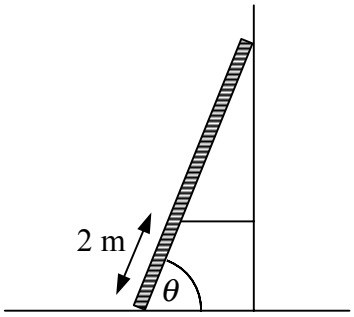


Fig. 1

Figure 1 shows a ladder of mass 20 kg and length 6 m leaning against a rough vertical wall with its lower end on smooth horizontal ground. The ladder is prevented from slipping along the ground by a light rope which is attached to the ladder 2 m from its bottom end and fastened to the wall so that the rope is horizontal and perpendicular to the wall.

The ladder is at an angle θ to the horizontal where $\tan\theta = \frac{5}{2}$ and the coefficient of friction between the ladder and the wall is $\frac{1}{3}$.

(a) Draw a diagram showing all the forces acting on the ladder. **(2 marks)**

(b) Show that the magnitude of the tension in the rope is $5g$. **(7 marks)**

A man wishes to use the ladder but fears the rope will snap as he climbs the ladder.

(c) Suggest, giving a reason for your answer, a more suitable position for the rope.

(2 marks)

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4.

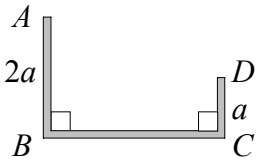


Fig. 2

Figure 2 shows an earring consisting of a uniform wire $ABCD$ of length $6a$ bent to form right angles at B and C such that AB and CD are of length $2a$ and a respectively.

(a) Find, in terms of a, the distance of the centre of mass from

(i) AB,

(ii) BC. **(8 marks)**

The earring is to be worn such that it hangs in equilibrium suspended from the point A.

(b) Find, to the nearest degree, the angle made by AB with the downward vertical. **(4 marks)**

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5. A lorry of mass 40 tonnes moves up a straight road inclined at an angle α to the horizontal where $\sin\alpha = \frac{1}{20}$. The lorry moves at a constant speed of 20 m s^{-1}.

In a model of the motion of the lorry, the non-gravitational resistance to motion is assumed to be constant and of magnitude 4400 N.

(a) Show that the engine of the lorry is working at a rate of 480 kW. **(5 marks)**

The road becomes horizontal. The lorry's engine continues to work at the same rate and the resistance to motion is assumed to remain unchanged.

(b) Find the initial acceleration of the lorry. **(3 marks)**

(c) Find, correct to 3 significant figures, the maximum speed of the lorry. **(3 marks)**

(d) Using your answer to part *(c)*, comment on the suitability of the modelling assumption. **(2 marks)**

Turn over

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6. Particle S of mass $2M$ is moving with speed $U\ \text{m s}^{-1}$ on a smooth horizontal plane when it collides directly with a particle T of mass $5M$ which is lying at rest on the plane. The coefficient of restitution between S and T is $\frac{3}{4}$.

Given that the speed of T after the collision is $4\ \text{m s}^{-1}$,

(a) find U. **(6 marks)**

As a result of the collision, T is projected horizontally from the top of a building of height 19.6 m and falls freely under gravity. T strikes the ground at the point X as shown in Figure 3.

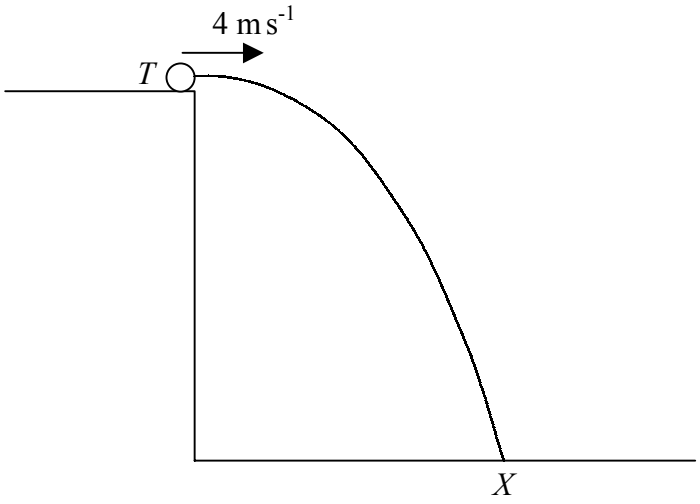


Fig. 3

(b) Find the time taken for T to reach X. **(3 marks)**

(c) Show that the angle between the horizontal and the direction of motion of T, just before it strikes the ground at X, is 78.5° correct to 3 significant figures. **(4 marks)**

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7.

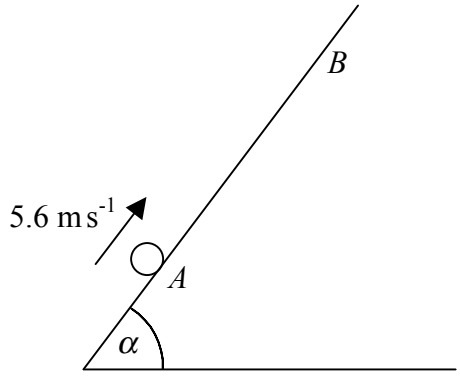


Fig. 4

Figure 4 shows a particle P projected from the point A up the line of greatest slope of a rough plane which is inclined at an angle α to the horizontal where $\sin\alpha = \frac{4}{5}$. P is projected with speed 5.6 m s^{-1} and the coefficient of friction between P and the plane is $\frac{4}{7}$.

Given that P first comes to rest at point B,

(a) use the Work-Energy principle to show that the distance AB is 1.4 m. **(10 marks)**

The particle then slides back down the plane.

(b) Find, correct to 2 significant figures, the speed of P when it returns to A. **(6 marks)**

END

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