GCE Examinations

Mechanics
Module M2

Advanced Subsidiary / Advanced Level

Paper F

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

1. An ice hockey puck of mass 0.5 kg is moving with velocity $(5\mathbf{i} - 8\mathbf{j})\ \mathrm{m\,s^{-1}}$, where **i** and **j** are perpendicular horizontal unit vectors, when it is struck by a stick. After the impact, the puck travels with velocity $(13\mathbf{i} + 7\mathbf{j})\ \mathrm{m\,s^{-1}}$.

Find the magnitude of the impulse exerted by the stick on the puck. **(5 marks)**

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2. A car of mass 1 tonne is climbing a hill inclined at an angle θ to the horizontal where $\sin\theta = \frac{1}{7}$. When the car passes a point *X* on the hill, it is travelling at $20\ \mathrm{m\,s^{-1}}$. When the car passes the point *Y*, 200 m further up the hill, it has speed $10\ \mathrm{m\,s^{-1}}$.

In a preliminary model of the situation, the car engine is assumed only to be doing work against gravity. Using this model,

(a) find the change in the total mechanical energy of the car as it moves from *X* to *Y*.

(6 marks)

In a more sophisticated model, the car engine is also assumed to work against other forces.

(b) Write down two other forces which this model might include. **(2 marks)**

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3. A particle moves along a straight horizontal track such that its displacement, *s* metres, from a fixed point *O* on the line after *t* seconds is given by

$$s = 2t^3 - 13t^2 + 20t.$$

(a) Find the values of *t* for which the particle is at *O*. **(4 marks)**

(b) Find the values of *t* at which the particle comes instantaneously to rest. **(4 marks)**

Turn over

4.

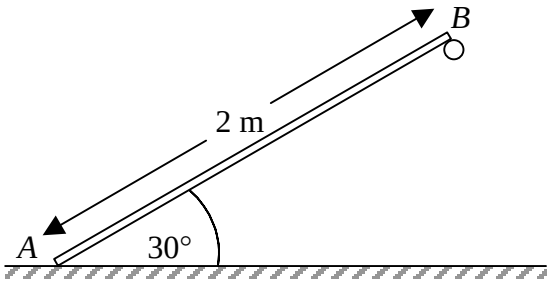

Fig. 1

Figure 1 shows a uniform rod AB of length 2 m and mass 6 kg inclined at an angle of 30° to the horizontal with A on smooth horizontal ground and B supported by a rough peg. The rod is in limiting equilibrium and the coefficient of friction between B and the peg is μ.

(a) Find, in terms of g, the magnitude of the reactions at A and B. **(6 marks)**

(b) Show that $\mu = \frac{1}{\sqrt{3}}$. **(3 marks)**

5.

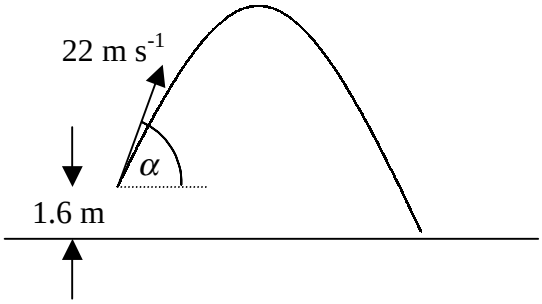

Fig. 2

During a cricket match, a batsman hits the ball giving it an initial velocity of 22 m s^{-1} at an angle α to the horizontal where $\sin\alpha = \frac{7}{8}$. When the batsman strikes the ball it is 1.6 metres above the ground, as shown in Figure 2, and it subsequently moves freely under gravity.

(a) Find, correct to 3 significant figures, the maximum height above the ground reached by the ball.

(4 marks)

The ball is caught by a fielder when it is 0.2 metres above the ground.

(b) Find the length of time for which the ball is in the air. **(4 marks)**

Assuming that the fielder who caught the ball ran at a constant speed of 6 m s^{-1},

(c) find, correct to 3 significant figures, the maximum distance that the fielder could have been from the ball when it was struck.

(4 marks)

Turn over

6.

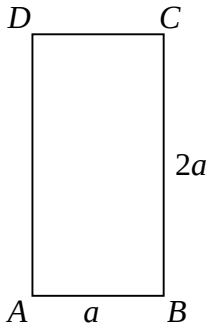

Fig. 3

Figure 3 shows a uniform rectangular lamina $ABCD$ of mass $8m$ in which the sides AB and BC are of length a and $2a$ respectively. Particles of mass $2m$, $6m$ and $4m$ are fixed to the lamina at the points A, B and D respectively.

(a) Write down the distance of the centre of mass from AD. **(1 mark)**

(b) Show that the distance of the centre of mass from AB is $\frac{4}{5}a$. **(5 marks)**

Another particle of mass km is attached to the lamina at the point B.

(c) Show that the distance of the centre of mass from AD is now given by $\frac{(10+k)a}{20+k}$. **(4 marks)**

Given that when the lamina is suspended freely from the point A the side AB makes an angle of 45° with the vertical,

(d) find the value of k. **(6 marks)**

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7. Particle A of mass 7 kg is moving with speed u_1 on a smooth horizontal surface when it collides directly with particle B of mass 4 kg moving in the same direction as A with speed u_2.

After the impact, A continues to move in the same direction but its speed has been halved. Given that the coefficient of restitution between the particles is e,

(a) show that $8u_2(e + 1) = u_1(8e - 3)$. **(7 marks)**

Given also that $u_1 = 14\ \text{m s}^{-1}$ and $u_2 = 3\ \text{m s}^{-1}$,

(b) find e, **(3 marks)**

(c) show that the percentage of the kinetic energy of the particles lost as a result of the impact is 9.6%, correct to 2 significant figures. **(7 marks)**

END