GCE Examinations

Mechanics
Module M1

Advanced Subsidiary / Advanced Level

Paper D

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 8 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. A particle, P, of mass 5 kg moves with speed 3 m s^{-1} along a smooth horizontal track. It strikes a particle Q of mass 2 kg which is at rest on the track. Immediately after the collision, P and Q move in the same direction with speeds v and $2v$ m s^{-1} respectively.

(a) Calculate the value of v. **(3 marks)**

(b) Calculate the magnitude of the impulse received by Q on impact. **(2 marks)**

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2. A particle P moves with a constant velocity $(3\mathbf{i} + 2\mathbf{j})$ m s^{-1} with respect to a fixed origin O. It passes through the point A whose position vector is $(2\mathbf{i} + 11\mathbf{j})$ m at $t = 0$.

(a) Find the angle in degrees that the velocity vector of P makes with the vector $\mathbf{i}$.

(2 marks)

(b) Calculate the distance of P from O when $t = 2$. **(4 marks)**

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3. A car of mass 1250 kg is moving at constant speed up a hill, inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{10}$. The driving force produced by the engine is 1800 N.

(a) Calculate the resistance to motion which the car experiences. **(4 marks)**

At the top of the hill, the road becomes horizontal.

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

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4. A non-uniform plank AB of mass 20 kg and length 6 m is supported at both ends so that it is horizontal. When a woman of mass 60 kg stands on the plank at a distance of 2 m from B, the magnitude of the reaction at A is $35g$ N.

(a) Suggest a suitable model for

(i) the plank,

(ii) the woman. **(2 marks)**

(b) Calculate the magnitude of the reaction at B, giving your answer in terms of g.

(2 marks)

(c) Explain briefly, in the context of the problem, the term 'non-uniform'. **(2 marks)**

(d) Find the distance of the centre of mass of the plank from A. **(4 marks)**

5.

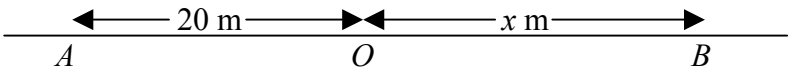

Fig. 1

The points A, O and B lie on a straight horizontal track as shown in Figure 1. A is 20 m from O and B is on the other side of O at a distance x m from O.

At time $t = 0$, a particle P starts from rest at O and moves towards B with uniform acceleration of 3 $\mathrm{m\,s^{-2}}$. At the same instant, another particle Q, which is at the point A, is moving with a velocity of 3 $\mathrm{m\,s^{-1}}$ in the direction of O with uniform acceleration of 4 $\mathrm{m\,s^{-2}}$ in the same direction.

Given that the Q collides with P at B, find the value of x. **(10 marks)**

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6. A sledge of mass 4 kg rests in limiting equilibrium on a rough slope inclined at an angle 10° to the horizontal. By modelling the sledge as a particle,

(a) show that the coefficient of friction, μ, between the sledge and the ground is 0.176 correct to 3 significant figures.

(6 marks)

The sledge is placed on a steeper part of the slope which is inclined at an angle 30° to the horizontal. The value of μ remains unchanged.

(b) Find the minimum extra force required along the line of greatest slope to prevent the sledge from slipping down the hill.

(5 marks)

Turn over

7. Whilst looking over the edge of a vertical cliff, 122.5 metres in height, Jim dislodges a stone. The stone falls freely from rest towards the sea below.

Ignoring the effect of air resistance,

(a) calculate the time it would take for the stone to reach the sea, **(3 marks)**

(b) find the speed with which the stone would hit the water. **(2 marks)**

Two seconds after the stone begins to fall, Jim throws a tennis ball downwards at the stone. The tennis ball's initial speed is u m s^{-1} and it hits the stone before they both reach the water.

(c) Find the minimum value of u. **(5 marks)**

(d) If you had taken air resistance into account in your calculations, what effect would this have had on your answer to part *(c)*? Explain your answer. **(2 marks)**

8.

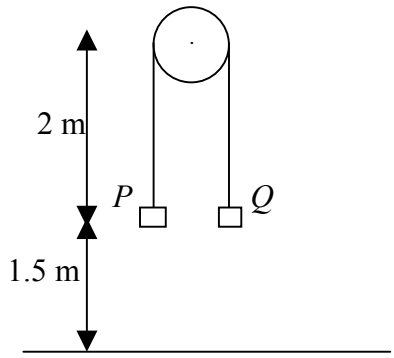

Fig. 2

Figure 2 shows two particles P and Q, of mass 3 kg and 2 kg respectively, attached to the ends of a light, inextensible string which passes over a smooth, fixed pulley. The system is released from rest with P and Q at the same level 1.5 metres above the ground and 2 metres below the pulley.

(a) Show that the initial acceleration of the system is $\frac{g}{5}$ m s^{-2}. **(4 marks)**

(b) Find the tension in the string. **(2 marks)**

(c) Find the speed with which P hits the ground. **(3 marks)**

When P hits the ground, it does not rebound.

(d) What is the closest that Q gets to the pulley. **(5 marks)**

END