GCE Examinations

Mechanics
Module M1

Advanced Subsidiary / Advanced Level

Paper K

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.

Solomon Press

Written by Shaun Armstrong & Chris Huffer

1. In a safety test, a car of mass 800 kg is driven directly at a wall at a constant speed of 15 m s^{-1}. The constant force exerted by the wall on the car in bringing it to rest is 60 kN.

(a) Calculate the magnitude of the impulse exerted by the wall on the car. **(2 marks)**

(b) Find the time it takes for the car to come to rest. **(2 marks)**

(c) Show that the deceleration of the car is 75 m s^{-2}. **(3 marks)**

2.

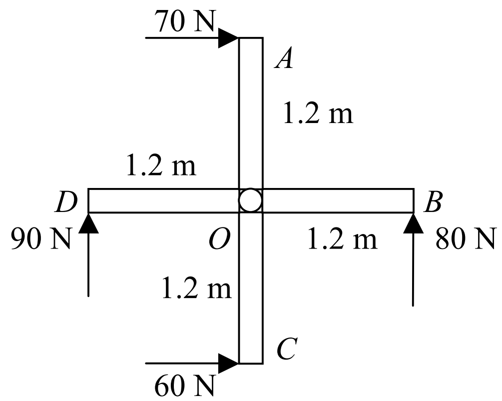

Fig. 1

Figure 1 shows an aerial view of a revolving door consisting of 4 panels, each of width 1.2 m and set at 90° intervals, which are free to rotate about a fixed central column, *O*.

The revolving door is situated outside a lecture theatre and four students are trying to push the door. Two of the students are pushing panels *OA* and *OD* clockwise (as viewed from above) with horizontal forces of 70 N and 90 N respectively, whilst the other two are pushing panels *OB* and *OC* anti-clockwise with horizontal forces of 80 N and 60 N respectively.

(a) Calculate the total moment about *O* when the four students are pushing the panels at their outer edge, 1.2 m from *O*.

(3 marks)

The student at *C* moves her hand 0.2 m closer to *O* and the student at *D* moves his hand *x* m closer to *O*. Given that the students all push in the same directions and with the same forces as in part *(a)*, and that the door is in equilibrium,

(b) find the value of *x*. **(5 marks)**

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3. During a cricket match, the batsman hits the ball and begins running with constant velocity $4\mathbf{i}$ m s^{-1} to try and score a run. When the batsman is at the fixed origin O, the ball is thrown by a member of the opposing team with velocity $(^{-}8\mathbf{i} + 24\mathbf{j})$ m s^{-1} from the point with position vector $(30\mathbf{i} - 60\mathbf{j})$ m, where $\mathbf{i}$ and $\mathbf{j}$ are horizontal perpendicular unit vectors. At time t seconds after the ball is thrown, the position vectors of the batsman and the ball are $\mathbf{r}$ metres and $\mathbf{s}$ metres respectively.

In a model of the situation, the ball is assumed to travel horizontally and air resistance is considered to be negligible.

(a) Find expressions for $\mathbf{r}$ and $\mathbf{s}$ in terms of t. **(3 marks)**

(b) Show that the ball hits the batsman and find the position vector of the batsman when this occurs. **(5 marks)**

(c) Write down two reasons why the assumptions used in these calculations are unlikely to provide a realistic model. **(2 marks)**

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4. In a physics experiment, two balls A and B, of mass $4m$ and $3m$ respectively, are travelling towards one another on a straight horizontal track. Both balls are travelling with speed 2 m s^{-1} immediately before they collide.

As a result of the impact, A is brought to rest and the direction of motion of B is reversed.

Modelling the track as smooth and the balls as particles,

(a) find the speed of B immediately after the collision. **(3 marks)**

A student notices that after the collision, B comes to rest 0.2 m from A.

(b) Show that the coefficient of friction between B and the track is 0.113, correct to 3 decimal places. **(7 marks)**

Turn over

5. A cyclist is riding up a hill inclined at an angle of 5° to the horizontal. She produces a driving force of 50 N and experiences resistive forces which total 20 N.

Given that the combined mass of the cyclist and her bicycle is 70 kg,

(a) find, correct to 2 decimal places, the magnitude of the deceleration of the cyclist.

(4 marks)

When the cyclist reaches the top of the hill, her speed is 3 m s^{-1}. She subsequently accelerates uniformly so that in the fifth second after she has reached the top of the hill, she travels 12 m.

(b) Find her speed at the end of the fifth second. **(8 marks)**

6.

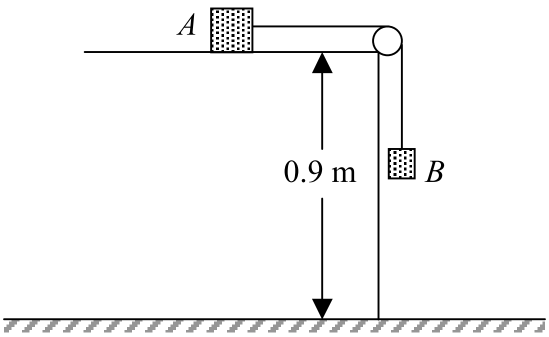

Fig. 2

Figure 2 shows a particle *A* of mass 5 kg, lying on a smooth horizontal table which is 0.9 m above the floor. A light inextensible string of length 0.7 m connects *A* to a particle *B* of mass 2 kg. The string passes over a smooth pulley which is fixed to the edge of the table and *B* hangs vertically 0.4 m below the pulley.

When the system is released from rest,

(a) show that the magnitude of the force exerted on the pulley is $\frac{10\sqrt{2}}{7}g$ N, **(7 marks)**

(b) find the speed with which *A* hits the pulley. **(3 marks)**

When *A* hits the pulley, the string breaks and *B* subsequently falls freely under gravity.

(c) Find the speed with which *B* hits the ground. **(4 marks)**

7.

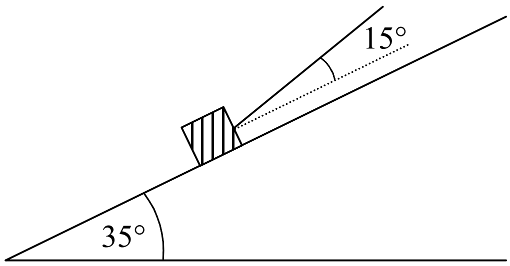

Fig. 3

Figure 3 shows a block of mass 25 kg held in equilibrium on a plane inclined at an angle of 35° to the horizontal by means of a string which is at an angle of 15° to the line of greatest slope of the plane.

In an initial model of the situation, the plane is assumed to be smooth. Giving your answers correct to 3 significant figures,

(a) show that the tension in the string is 145 N, **(3 marks)**

(b) find the magnitude of the reaction between the plane and the block. **(4 marks)**

In a more refined model, the plane is assumed to be rough.

Given that the tension in the string can be increased to 200 N before the block begins to move up the slope,

(c) find, correct to 3 significant figures, the magnitude of the frictional force and state the direction in which it acts.

(4 marks)

(d) Without performing any further calculations, state whether the reaction calculated in part *(b)* will increase, decrease or remain the same in the refined model. Give a reason for your answer.

(3 marks)

END