GCE Examinations

Mechanics
Module M1

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.

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1.

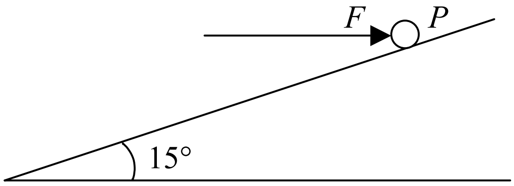

Fig. 1

Figure 1 shows a particle P of mass 4 kg on a smooth plane inclined at 15° to the horizontal. P is held in equilibrium by a horizontal force, F.

(a) Show that the normal reaction exerted by the plane on P is 40.6 N correct to 3 significant figures. **(4 marks)**

(b) Calculate the value of F. **(3 marks)**

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2. During trials of a bullet-proof vest, a shotgun of mass 2 kg is used to fire a bullet of mass 30 g horizontally at the vest. The initial speed of the bullet is 100 m s^{-1}.

(a) Calculate the initial speed of recoil of the gun. **(3 marks)**

The bullet hits the vest horizontally at a speed of 80 m s^{-1} and is brought uniformly to rest in a distance of 2 cm.

(b) Find the magnitude of the force exerted by the vest on the bullet in bringing it to rest. **(4 marks)**

3.

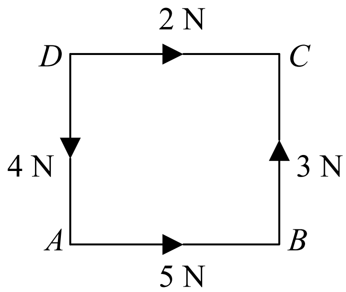

Fig. 2

Figure 2 shows 4 points A, B, C and D arranged such that they form the corners of a square of side 2 m. Forces of 5 N, 3 N, 2 N and 4 N act in the directions $\overrightarrow{AB}$, $\overrightarrow{BC}$, $\overrightarrow{DC}$ and $\overrightarrow{DA}$ respectively.

(a) Calculate the magnitude and sense of the resultant moment about A. **(3 marks)**

An additional force of magnitude X Newtons is added in the direction $\overrightarrow{CA}$. The resultant moment of all the forces about D is now zero.

(b) Find, in the form $k\sqrt{2}$, the value of X. **(4 marks)**

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4. A lift of mass 70 kg is supported by a cable which remains taut at all times. A man of mass 90 kg gets into the lift and it begins to descend vertically from rest with constant acceleration 0.5 m s^{-2}.

Calculate, giving your answers correct to 3 significant figures,

(a) the magnitude of the force which the lift exerts on the man, **(3 marks)**

(b) the tension in the cable. **(4 marks)**

Prior to slowing down, the lift is moving at 2 m s^{-1}. It then uniformly decelerates until it is brought to rest.

(c) Find the impulse exerted by the cable on the lift in bringing the lift to rest. **(2 marks)**

(d) Given that it takes 2 seconds to come to rest, use your answer to part *(c)* to calculate the magnitude of the force exerted by the cable on the lift in bringing the lift to rest.

(2 marks)

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5. The unit vectors **i** and **j** are due east and due north respectively.

At midday a motor boat A is 6 km east of a fixed origin O and is moving with constant velocity $({}^{-}4\mathbf{i} + \mathbf{j}) \text{ km h}^{-1}$. At the same time, another boat B is 3 km north of O and is moving with uniform velocity $(4\mathbf{i} - 3\mathbf{j}) \text{ km h}^{-1}$.

(a) Show that, at time T hours after midday, the position vector of A is $[(6 - 4T)\mathbf{i} + T\mathbf{j}]$ km and find a similar expression for the position vector of B at this time.

(6 marks)

(b) Hence show that, at time T, the position vector of B relative to A is

$$[(8T - 6)\mathbf{i} + (3 - 4T)\mathbf{j}] \text{ km}$$ **(2 marks)**

(c) By using your answer to part *(b)*, or otherwise, show that the boats would collide if they continued at the same velocities and find the time at which the collision would occur.

(3 marks)

Turn over

6. A student attempts to sketch the acceleration-time graph of a parachutist who jumps from a plane at a height of 2200 m above the ground.

The student assumes that the parachutist falls freely from rest under gravity until she is 240 m from the ground at which point she opens her parachute. The student makes the assumption that, at this point, the velocity of the parachutist is immediately reduced to a value which remains constant until she reaches the ground 140 seconds after she left the plane.

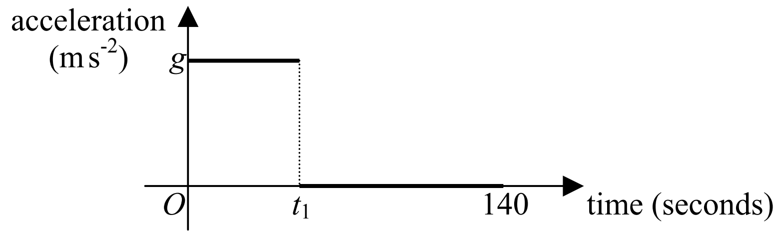

Fig. 3

The student decides to ignore air resistance and his sketch is shown in Figure 3. The value t_1 is used by the student to denote the time at which the parachute is opened.

Using the model proposed by the student, calculate

(a) the speed of the parachutist immediately before she opens her parachute, **(4 marks)**

(b) the value of t_1, **(3 marks)**

(c) the speed of the parachutist after the parachute is opened. **(2 marks)**

(d) Comment on two features of the student's model which are unrealistic and say what effect taking account of these would have had on the values which you calculated in parts *(a)* and *(b)*.

(4 marks)

7. A machine fires ball-bearings up the line of greatest slope of a rough plane inclined at an angle α to the horizontal, where $\sin\alpha = \frac{3}{5}$.

The coefficient of friction between the ball-bearings and the plane is $\frac{1}{4}$.

(a) Show that the magnitude of the acceleration of the ball-bearings is $\frac{4}{5}g$ and state its direction.

(8 marks)

Given that the machine is placed at a point A, 30 m from the top edge of the plane, and the ball-bearings are projected with an initial speed of 20 m s^{-1},

(b) find, giving your answer to the nearest cm, how close the ball-bearings get to the top edge of the plane.

(4 marks)

(c) How long does it take for a ball-bearing to travel from the highest point it reaches back down to the point A again?

(7 marks)

END