GCE Examinations

Mechanics
Module M1

Advanced Subsidiary / Advanced Level

Paper I

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. The resultant of two forces $\mathbf{F_1}$ and $\mathbf{F_2}$ is $(^{-}2\mathbf{i} + 9\mathbf{j})$ N.

Given that $\mathbf{F_1} = (2p\mathbf{i} - 3q\mathbf{j})$ N and $\mathbf{F_2} = (5q\mathbf{i} + 4p\mathbf{j})$ N, calculate the values of p and q.

(5 marks)

2.

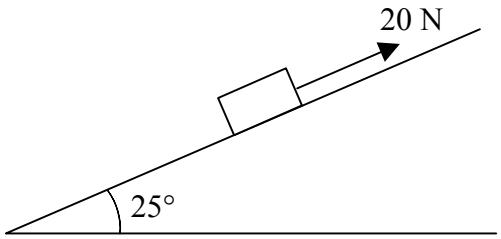


Fig. 1

Figure 1 shows a toy lorry being pulled by a piece of string, up a ramp inclined at an angle of 25° to the horizontal. When the string is pulled with a force of 20 N parallel to the line of greatest slope of the ramp, the lorry is on the point of moving up the ramp.

In a simple model of the situation, the ramp is considered to be smooth.

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

(b) Find the weight of the lorry and the magnitude of the reaction between the lorry and the ramp, giving your answers to an appropriate degree of accuracy.

(4 marks)

(c) Write down any modelling assumptions that you have made about

(i) the lorry,

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

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

(d) State the effect that this would have on your answers to part *(b)*. **(2 marks)**

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3. A cannon of mass 600 kg lies on a rough horizontal surface and is used to fire a 3 kg shell horizontally at 200 $\mathrm{m\,s^{-1}}$.

(a) Find the impulse which the shell exerts on the cannon. **(3 marks)**

(b) Find the speed with which the cannon recoils. **(2 marks)**

Given that the coefficient of friction between the cannon and the surface is 0.75,

(c) calculate, to the nearest centimetre, the distance that the cannon travels before coming to rest.

(6 marks)

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4. The position of an aeroplane flying in a straight horizontal line at constant speed is plotted on a radar screen. At 2 p.m. the position vector of the aeroplane is $(80\mathbf{i} + 5\mathbf{j})$, where **i** and **j** are unit vectors directed east and north respectively relative to a fixed origin, *O*, on the screen. Ten minutes later the position of the aeroplane on the screen is $(32\mathbf{i} + 19\mathbf{j})$.

Each unit on the screen represents 1 km.

(a) Find the position vector of the aeroplane at 2:30 p.m. **(4 marks)**

(b) Find the speed of the aeroplane in $\mathrm{km\,h^{-1}}$. **(4 marks)**

(c) Find, correct to the nearest degree, the bearing on which the aeroplane is flying.

(3 marks)

Turn over

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5. A car on a straight test track starts from rest and accelerates to a speed of V m s^{-1} in 6 seconds. The car maintains this speed for a further 50 seconds before decelerating to rest.

In a simple model of this motion, the acceleration and deceleration are assumed to be uniform and the magnitude of the deceleration to be 1.5 times that of the acceleration.

(a) Show that the total time for which the car is moving is 60 seconds. **(3 marks)**

(b) Sketch a velocity-time graph for this journey. **(3 marks)**

Given that the total distance travelled is 1320 metres,

(c) find V. **(3 marks)**

In a more sophisticated model, the acceleration is assumed to be inversely proportional to the velocity of the car.

(d) Explain how the acceleration would vary during the first six seconds under this model.

(2 marks)

6.

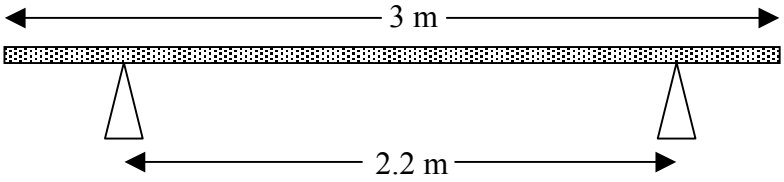


Fig. 2

Figure 2 shows a bench of length 3 m being used in a gymnasium.

The bench rests horizontally on two identical supports which are 2.2 m apart and equidistant from the middle of the bench.

(a) Explain why it is reasonable to model the bench as a uniform rod. **(2 marks)**

When a gymnast of mass 55 kg stands on the bench 0.1 m from one end, the bench is on the point of tilting.

(b) Find the mass of the bench. **(4 marks)**

The first gymnast dismounts and a second gymnast of mass 33 kg steps onto the bench at a distance of 0.4 m from its centre.

(c) Show that the magnitudes of the reaction forces on the two supports are in the ratio 5 : 3. **(6 marks)**

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7. A car of mass 1250 kg tows a caravan of mass 850 kg up a hill inclined at an angle α to the horizontal where $\sin\alpha = \frac{1}{14}$. The total resistance to motion experienced by the car is 400 N, and by the caravan is 500 N.

Given that the driving force of the engine is 3 kN,

(a) show that the acceleration of the system is 0.3 m s^{-2}, **(5 marks)**

(b) find the tension in the towbar linking the car and the caravan. **(3 marks)**

Starting from rest, the car accelerates uniformly for 540 m until it reaches a speed of v m s^{-1} at the top of the hill.

(c) Find v. **(3 marks)**

At the top of the hill the road becomes level and the driver maintains the speed at which the car and caravan reached the top of the hill.

(d) Assuming that the resistance to motion on each part of the system is unchanged, find the percentage reduction in the driving force of the engine required to achieve this.

(4 marks)

END

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