GCE Examinations

Mechanics
Module M2

Advanced Subsidiary / Advanced Level

Paper B

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. A bullet of mass 25 g is fired directly at a fixed wooden block of thickness 4 cm and passes through it. When the bullet hits the block, it is travelling horizontally at 200 $\mathrm{m\,s^{-1}}$. The block exerts a constant resistive force of 8000 N on the bullet.

(a) Find the work done by the block on the bullet. **(2 marks)**

By using the Work-Energy principle,

(b) show that the bullet emerges from the block with speed 120 $\mathrm{m\,s^{-1}}$. **(5 marks)**

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2. A car is travelling along a straight horizontal road against resistances to motion which are constant and total 2000 N. When the engine of the car is working at a rate of H kilowatts, the maximum speed of the car is 30 $\mathrm{m\,s^{-1}}$.

(a) Find the value of H. **(3 marks)**

The car driver wishes to overtake another vehicle so she increases the rate of working of the engine by 20% and this results in an initial acceleration of 0.32 $\mathrm{m\,s^{-2}}$. Assuming that the resistances to motion remain constant,

(b) find the mass of the car. **(4 marks)**

3.

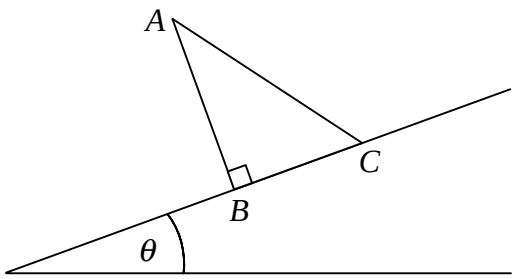

Fig. 1

Figure 1 shows a uniform triangular lamina ABC placed with edge BC along the line of greatest slope of a plane inclined at an angle θ to the horizontal. The lengths AC and BC are 15 cm and 9 cm respectively and $\angle ABC$ is a right angle.

(a) Find the distance of the centre of mass of the lamina from

(i) AB,

(ii) BC. **(6 marks)**

Assuming that the plane is rough enough to prevent the lamina from slipping,

(b) find in degrees, correct to 1 decimal place, the maximum value of θ for which the lamina remains in equilibrium. **(4 marks)**

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4. The velocity $\mathbf{v}$ m s^{-1} of a particle P at time t seconds is given by $\mathbf{v} = 3t\mathbf{i} - t^2\mathbf{j}$.

(a) Find the magnitude of the acceleration of P when $t = 2$. **(4 marks)**

When $t = 0$, the displacement of P from a fixed origin O is $(6\mathbf{i} + 12\mathbf{j})$ m s^{-1}, where $\mathbf{i}$ and $\mathbf{j}$ are perpendicular horizontal unit vectors.

(b) Show that the displacement of P from O when $t = 6$ is given by $k(\mathbf{i} - \mathbf{j})$ m, where k is an integer which you should find.

(6 marks)

5.

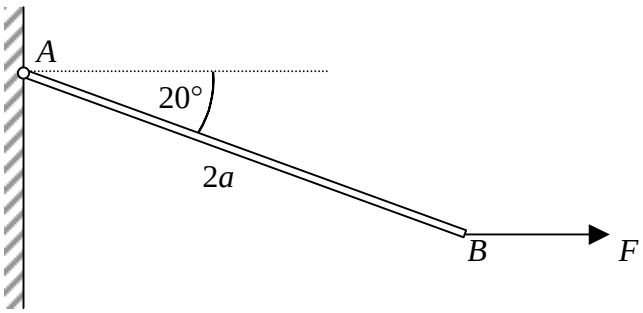

Fig. 2

A uniform rod AB of length $2a$ and mass 8 kg is smoothly hinged to a vertical wall at A.

The rod is held in equilibrium inclined at an angle of 20° to the horizontal by a force of magnitude F newtons acting horizontally at B which is below the level of A as shown in Figure 2.

(a) Find, correct to 3 significant figures, the value of F. **(4 marks)**

(b) Show that the magnitude of the reaction at the hinge is 133 N, correct to 3 significant figures, and find to the nearest degree the acute angle which the reaction makes with the vertical.

(6 marks)

Turn over

6. A particle P is projected from a point A on horizontal ground with speed u at an angle of elevation α and moves freely under gravity. P hits the ground at the point B.

(a) Show that $AB = \frac{u^2}{g}\sin 2\alpha$. **(6 marks)**

An archer fires an arrow with an initial speed of 45 m s^{-1} at a target which is level with the point of projection and at a distance of 80 m.

Given that the arrow hits the target,

(b) find in degrees, correct to 1 decimal place, the two possible angles of projection.

(5 marks)

(c) Write down, with a reason, which of the two possible angles of projection would give the shortest time of flight.

(2 marks)

(d) Show that the minimum time of flight is 1.8 seconds, correct to 1 decimal place.

(2 marks)

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7. A smooth sphere A of mass $4m$ is moving on a smooth horizontal plane with speed u. It collides directly with a stationary smooth sphere B of mass $5m$ and with the same radius as A.

The coefficient of restitution between A and B is $\frac{1}{2}$.

(a) Show that after the collision the speed of B is 4 times greater than the speed of A.

(7 marks)

Sphere B subsequently hits a smooth vertical wall at right angles. After rebounding from the wall, B collides with A again and as a result of this collision, B comes to rest.

Given that the coefficient of restitution between B and the wall is e,

(b) find e. **(9 marks)**

END