

General Certificate of Education  
June 2006  
Advanced Level Examination



**MATHEMATICS**  
**Unit Mechanics 2B**

**MM2B**

Tuesday 6 June 2006 1.30 pm to 3.00 pm

**For this paper you must have:**

- an 8-page answer book
  - the **blue** AQA booklet of formulae and statistical tables
- You may use a graphics calculator.

Time allowed: 1 hour 30 minutes

**Instructions**

- Use blue or black ink or ball-point pen. Pencil should only be used for drawing.
- Write the information required on the front of your answer book. The *Examining Body* for this paper is AQA. The *Paper Reference* is MM2B.
- Answer **all** questions.
- Show all necessary working; otherwise marks for method may be lost.
- The **final** answer to questions requiring the use of calculators should be given to three significant figures, unless stated otherwise.
- Take  $g = 9.8 \text{ m s}^{-2}$ , unless stated otherwise.

**Information**

- The maximum mark for this paper is 75.
- The marks for questions are shown in brackets.
- Unit Mechanics 2B has a **written paper only**.

**Advice**

- Unless stated otherwise, you may quote formulae, without proof, from the booklet.

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Answer **all** questions.

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- 1 A particle moves in a horizontal plane, in which the unit vectors **i** and **j** are directed east and north respectively. At time  $t$  seconds, its position vector, **r** metres, is given by

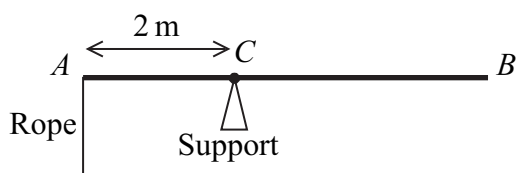
$$\mathbf{r} = (2t^3 - t^2 + 6)\mathbf{i} + (8 - 4t^3 + t)\mathbf{j}$$

- (a) Find an expression for the velocity of the particle at time  $t$ . *(3 marks)*
- (b) (i) Find the velocity of the particle when  $t = \frac{1}{3}$ . *(2 marks)*
- (ii) State the direction in which the particle is travelling at this time. *(1 mark)*
- (c) Find the acceleration of the particle when  $t = 4$ . *(3 marks)*
- (d) The mass of the particle is 6 kg. Find the magnitude of the resultant force on the particle when  $t = 4$ . *(3 marks)*

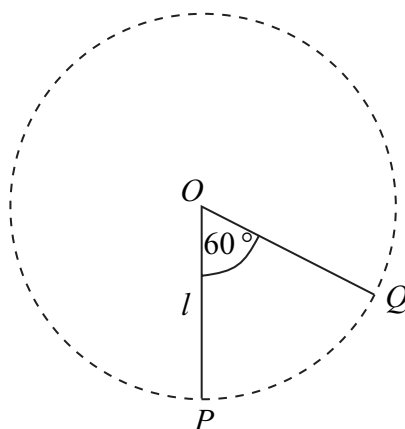
- 2 A ball of mass 0.6 kg is thrown vertically upwards from ground level with an initial speed of  $14 \text{ m s}^{-1}$ .

- (a) Calculate the initial kinetic energy of the ball. *(2 marks)*
- (b) Assuming that no resistance forces act on the ball, use an energy method to find the maximum height reached by the ball. *(3 marks)*
- (c) An experiment is conducted to confirm the maximum height for the ball calculated in part (b). In this experiment the ball rises to a height of only 8 metres.
- (i) Find the work done against the air resistance force that acts on the ball as it moves. *(3 marks)*
- (ii) Assuming that the air resistance force is constant, find its magnitude. *(2 marks)*
- (d) Explain why it is **not** realistic to model the air resistance as a constant force. *(1 mark)*

- 3 The diagram shows a uniform rod,  $AB$ , of mass  $10\text{ kg}$  and length  $5\text{ metres}$ . The rod is held in equilibrium in a horizontal position, by a support at  $C$  and a light vertical rope attached to  $A$ , where  $AC$  is  $2\text{ metres}$ .



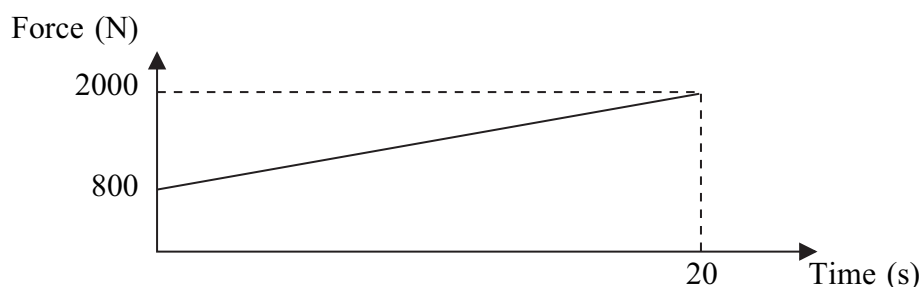
- (a) Draw and label a diagram to show the forces acting on the rod. (1 mark)
- (b) Show that the tension in the rope is  $24.5\text{ N}$ . (3 marks)
- (c) A package of mass  $m\text{ kg}$  is suspended from  $B$ . The tension in the rope has to be doubled to maintain equilibrium.
- (i) Find  $m$ . (4 marks)
- (ii) Find the magnitude of the force exerted on the rod by the support. (3 marks)
- (d) Explain how you have used the fact that the rod is uniform in your solution. (1 mark)
- 4 A particle of mass  $m$  is suspended from a fixed point  $O$  by a light inextensible string of length  $l$ . The particle hangs in equilibrium at the point  $P$  vertically below  $O$ . The particle is then set into motion with a horizontal velocity  $U$  so that it moves in a complete vertical circle with centre  $O$ . The point  $Q$  on the circle is such that  $\angle POQ = 60^\circ$ , as shown in the diagram.



- (a) Find, in terms of  $g$ ,  $l$  and  $U$ , the speed of the particle at  $Q$ . (4 marks)
- (b) Find, in terms of  $g$ ,  $l$ ,  $m$  and  $U$ , the tension in the string when the particle is at  $Q$ . (5 marks)
- (c) Find, in terms of  $g$ ,  $l$ ,  $m$  and  $U$ , the tension in the string when the particle returns to  $P$ . (2 marks)

Turn over ►

- 5 The graph shows a model for the resultant horizontal force on a car, which varies as it accelerates from rest for 20 seconds. The mass of the car is 1200 kg.



- (a) The acceleration of the car at time  $t$  seconds is  $a \text{ m s}^{-2}$ . Show that

$$a = \frac{2}{3} + \frac{t}{20}, \quad \text{for } 0 \leq t \leq 20 \quad (5 \text{ marks})$$

- (b) Find an expression for the velocity of the car at time  $t$ . (3 marks)
- (c) Find the distance travelled by the car in the 20 seconds. (4 marks)
- (d) An alternative model assumes that the resultant force increases uniformly from 900 to 2100 newtons during the 20 seconds. Which term in your expression for the velocity would change as a result of this modification? Explain why. (2 marks)

- 6 A car of mass 1200 kg travels round a roundabout on a horizontal, circular path at a constant speed of  $14 \text{ m s}^{-1}$ . The radius of the circle is 50 metres. Assume that there is no resistance to the motion of the car and that the car can be modelled as a particle.

- (a) A friction force, directed towards the centre of the roundabout, acts on the car as it moves. Show that the magnitude of this friction force is 4704 N. (4 marks)
- (b) The coefficient of friction between the car and the road is  $\mu$ . Show that  $\mu \geq 0.4$ . (3 marks)

- 7 A particle of mass 20 kg moves along a straight horizontal line. At time  $t$  seconds the velocity of the particle is  $v \text{ m s}^{-1}$ . A resistance force of magnitude  $10\sqrt{v}$  newtons acts on the particle while it is moving. At time  $t = 0$  the velocity of the particle is  $25 \text{ m s}^{-1}$ .

- (a) Show that, at time  $t$

$$v = \left( \frac{20 - t}{4} \right)^2 \quad (7 \text{ marks})$$

- (b) State the value of  $t$  when the particle comes to rest. (1 mark)

**END OF QUESTIONS**