



General Certificate of Education  
Advanced Level Examination  
June 2013

## Mathematics

## MM2B

### Unit Mechanics 2B

Thursday 13 June 2013 9.00 am to 10.30 am

**For this paper you must have:**

- the blue AQA booklet of formulae and statistical tables.
- You may use a graphics calculator.

**Time allowed**

- 1 hour 30 minutes

**Instructions**

- Use black ink or black ball-point pen. Pencil should only be used for drawing.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- Write the question part reference (eg (a), (b)(i) etc) in the left-hand margin.
- You must answer each question in the space provided for that question. If you require extra space, use an AQA supplementary answer book; do **not** use the space provided for a different question.
- Do not write outside the box around each page.
- Show all necessary working; otherwise marks for method may be lost.
- Do all rough work in this book. Cross through any work that you do not want to be marked.
- 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 marks for questions are shown in brackets.
- The maximum mark for this paper is 75.

**Advice**

- Unless stated otherwise, you may quote formulae, without proof, from the booklet.
- You do not necessarily need to use all the space provided.

## 2

- 1 A particle, of mass 3 kg, moves along a straight line. At time  $t$  seconds, the displacement,  $s$  metres, of the particle from the origin is given by

$$s = 8t^3 + 15$$

- (a) Find the velocity of the particle at time  $t$ . (2 marks)
- (b) Find the magnitude of the resultant force acting on the particle when  $t = 2$ . (4 marks)

- 2 Carol, a circus performer, is on a swing. She jumps off the swing and lands in a safety net. When Carol leaves the swing, she has a speed of  $7 \text{ m s}^{-1}$  and she is at a height of 8 metres above the safety net.

Carol is to be modelled as a particle of mass 52 kg being acted upon only by gravity.

- (a) Find the kinetic energy of Carol when she leaves the swing. (2 marks)
- (b) Show that the kinetic energy of Carol when she hits the net is 5350 J, correct to three significant figures. (3 marks)
- (c) Find the speed of Carol when she hits the net. (3 marks)

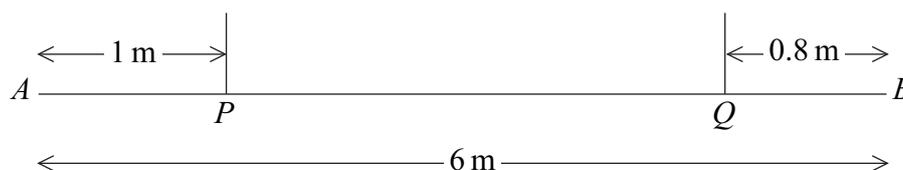
- 3 A particle, of mass 10 kg, moves on a smooth horizontal plane. At time  $t$  seconds, the acceleration of the particle is given by

$$\{(40t + 3t^2) \mathbf{i} + 20e^{-4t} \mathbf{j}\} \text{ m s}^{-2}$$

where the vectors  $\mathbf{i}$  and  $\mathbf{j}$  are perpendicular unit vectors.

- (a) At time  $t = 1$ , the velocity of the particle is  $(6\mathbf{i} - 5e^{-4}\mathbf{j}) \text{ m s}^{-1}$ .  
Find the velocity of the particle at time  $t$ . (5 marks)
- (b) Calculate the initial speed of the particle. (3 marks)

- 4 A uniform plank  $AB$ , of length 6 m, has mass 25 kg. It is supported in equilibrium in a horizontal position by two vertical inextensible ropes. One of the ropes is attached to the plank at the point  $P$  and the other rope is attached to the plank at the point  $Q$ , where  $AP = 1 \text{ m}$  and  $QB = 0.8 \text{ m}$ , as shown in the diagram.



- (a) (i) Find the tension in each rope. (5 marks)
- (ii) State how you have used the fact that the plank is uniform in your solution. (1 mark)



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- (b) A particle of mass  $m$  kg is attached to the plank at point  $B$ , and the tension in each rope is now the same.

Find  $m$ .

(6 marks)

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- 5 Tom is travelling on a train which is moving at a constant speed of  $15 \text{ m s}^{-1}$  on a horizontal track. Tom has placed his mobile phone on a rough horizontal table. The coefficient of friction between the phone and the table is 0.2.

The train moves round a bend of constant radius. The phone does not slide as the train travels round the bend.

Model the phone as a particle moving round part of a circle, with centre  $O$  and radius  $r$  metres.

Find the least possible value of  $r$ .

(4 marks)

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- 6 A car accelerates from rest along a straight horizontal road.

The car's engine produces a constant horizontal force of magnitude 4000 N.

At time  $t$  seconds, the speed of the car is  $v \text{ m s}^{-1}$ , and a resistance force of magnitude  $40v$  newtons acts upon the car.

The mass of the car is 1600 kg.

- (a) Show that  $\frac{dv}{dt} = \frac{100 - v}{40}$ . (2 marks)

- (b) Find the velocity of the car at time  $t$ . (6 marks)

- 7 A train, of mass 22 tonnes, moves along a straight horizontal track. A constant resistance force of 5000 N acts on the train. The power output of the engine of the train is 240 kW.

Find the acceleration of the train when its speed is  $20 \text{ m s}^{-1}$ .

(6 marks)

Turn over ►

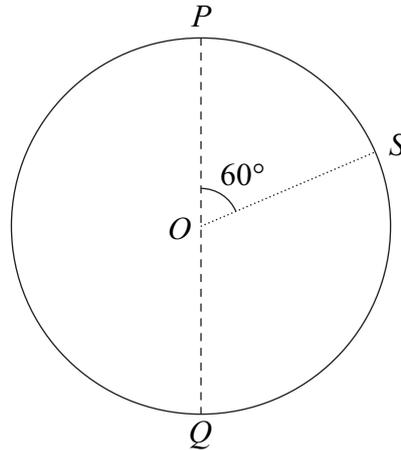


4

- 8 A bead, of mass  $m$ , moves on a smooth circular ring, of radius  $a$  and centre  $O$ , which is fixed in a vertical plane. At  $P$ , the highest point on the ring, the speed of the bead is  $2u$ ; at  $Q$ , the lowest point on the ring, the speed of the bead is  $5u$ .

(a) Show that  $u = \sqrt{\frac{4ag}{21}}$ . (4 marks)

- (b)  $S$  is a point on the ring so that angle  $POS$  is  $60^\circ$ , as shown in the diagram.



Find, in terms of  $m$  and  $g$ , the magnitude of the reaction of the ring on the bead when the bead is at  $S$ . (5 marks)

- 9 Two particles,  $A$  and  $B$ , are connected by a light elastic string that passes through a hole at a point  $O$  in a rough horizontal table. The edges of the hole are smooth. Particle  $A$  has a mass of 8 kg and particle  $B$  has a mass of 3 kg.

The elastic string has natural length 3 metres and modulus of elasticity 60 newtons.

Initially, particle  $A$  is held 3.5 metres from the point  $O$  on the surface of the table and particle  $B$  is held at a point 2 metres vertically below  $O$ .

The coefficient of friction between the table and particle  $A$  is 0.4.

The two particles are released from rest.

- (a) (i) Show that initially particle  $A$  moves towards the hole in the table. (3 marks)

- (ii) Show that initially particle  $B$  also moves towards the hole in the table. (2 marks)

- (b) Calculate the **initial** elastic potential energy in the string. (2 marks)

- (c) Particle  $A$  comes permanently to rest when it has moved 0.46 metres, at which time particle  $B$  is still moving upwards.

Calculate the distance that particle  $B$  has moved when it is at rest for the first time. (7 marks)

