

General Certificate of Education
June 2004
Advanced Level Examination



MATHEMATICS (SPECIFICATION A)
Unit Mechanics 2

MAM2/W

Monday 21 June 2004 Morning Session

In addition to this paper you will require:

- an 8-page answer book;
- the AQA booklet of formulae and statistical tables.

You may use a graphics calculator.

Time allowed: 1 hour 20 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 MAM2/W.
- Answer **all** questions.
- Take $g = 9.8 \text{ m s}^{-2}$ unless otherwise stated.
- All necessary working should be shown; otherwise marks for method may be lost.
- The **final** answer to questions requiring the use of tables or calculators should normally be given to three significant figures.
- Tie loosely any additional sheets you have used to the back of your answer book before handing it to the invigilator.

Information

- The maximum mark for this paper is 60.
- Mark allocations are shown in brackets.

Advice

- Unless stated otherwise, formulae may be quoted, without proof, from the booklet.

Answer **all** questions.

- 1 Two particles, of masses 2 kilograms and m kilograms, are placed at the points $(1, 8)$ and $(7, 11)$, respectively, in the x - y plane. The unit of distance is the metre.

The centre of mass of this system of particles lies on the line $x = 5$.

- (a) Show that $m = 4$. (3 marks)
- (b) Determine the y -coordinate of the centre of mass of this system. (3 marks)

- 2 Two cars, A and B , are travelling in the same direction on a straight horizontal road. Car A is travelling at 12 m s^{-1} when it collides with car B which is travelling at 8 m s^{-1} , as shown in the diagram.



Car A has mass 800 kg and car B has mass 1000 kg. To model this collision, the cars can be considered as particles. The coefficient of restitution between these particles is $\frac{1}{8}$.

Show that the speed of car B immediately after the collision is 10 m s^{-1} and find the speed of car A . (7 marks)

- 3 A car of mass 760 kg is travelling down a straight road inclined at an angle of $\sin^{-1}\left(\frac{1}{10}\right)$ to the horizontal. At the point A on the road, the car is travelling with speed 10 m s^{-1} , as shown in **Figure 1**. The point B is 200 m along the road from A . When the car reaches B , its speed is 25 m s^{-1} , as shown in **Figure 2**.

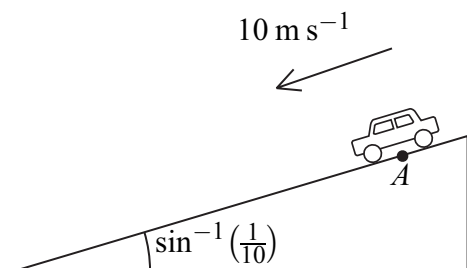


Figure 1

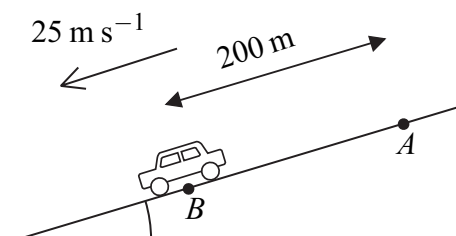
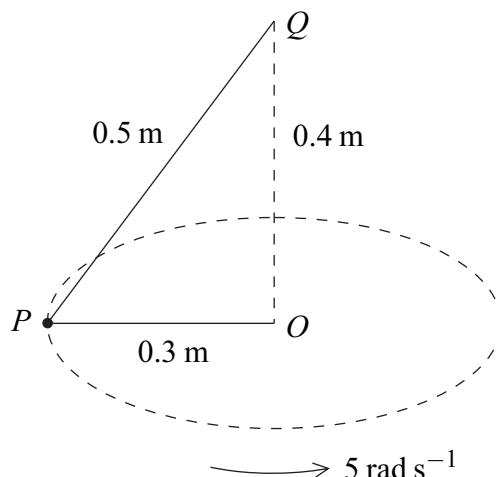


Figure 2

- (a) Using a simple model, resistance forces are neglected and the driving force of the car is assumed to be constant.
- Find the gain in mechanical energy of the car when it travels from A to B . (4 marks)
 - Deduce that the driving force of the car is approximately 253 N. (2 marks)
- (b) Using a different model, the resistance force on the car is assumed to be 1000 N and the driving force is **not** assumed to be constant. The car reaches its maximum speed of 25 m s^{-1} at B .
- Draw a diagram to show all the forces acting on the car at B . (1 mark)
 - Determine the driving force of the car at B using this model. (4 marks)

TURN OVER FOR THE NEXT QUESTION

- 4 A particle of mass 0.4 kg is attached at the point P to two light strings, QP and OP . The points O and Q are fixed with Q at a distance of 0.4 m vertically above O . The string QP is inextensible and of length 0.5 m . The string OP is elastic and of natural length 0.2 m and stiffness $k \text{ N m}^{-1}$. The particle moves in a horizontal circle, centre O and radius 0.3 m , at a constant angular speed of 5 rad s^{-1} .

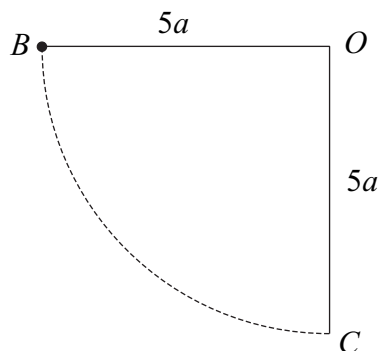


- (a) Draw a diagram showing the forces acting on the particle. (1 mark)
- (b) Show that the tension in the string QP is 4.9 N . (3 marks)
- (c) Write down, in terms of k , the tension in the string OP . (1 mark)
- (d) Show that $k = 0.6$. (5 marks)
- (e) Find the elastic potential energy stored in the string OP . (2 marks)
- 5 A body of mass 1.5 kg is moving under the action of a single force, \mathbf{F} newtons. At time t seconds, the velocity of the body is \mathbf{v} metres per second, where

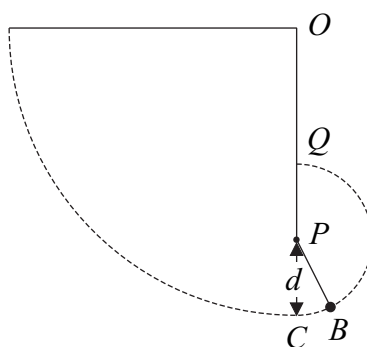
$$\mathbf{v} = \begin{bmatrix} 1 + 4 \sin 2t \\ 4 \cos 2t \end{bmatrix}.$$

- (a) (i) Find an expression for \mathbf{F} in terms of t . (3 marks)
- (ii) Show that, for all values of t , $|\mathbf{F}| = 12$. (2 marks)
- (b) Determine the work done by \mathbf{F} over the interval $0 \leq t \leq \frac{\pi}{4}$ seconds. (6 marks)

- 6 Adam has set up an experiment for his Mechanics coursework. He has attached a small ball, B , of mass m , to one end of a light inextensible string of length $5a$. The other end of the string is attached to a fixed point O . The ball is released from rest with the string taut and horizontal, as shown in the diagram. The ball subsequently passes through the point C , which is a vertical distance $5a$ below O .



- (a) Find an expression, in terms of a and g , for the speed of B when it reaches C .
(2 marks)
- (b) A small smooth peg, P , is fixed at a distance d vertically above C . When the string reaches the vertical position, B begins to move in a vertical circle with centre P and radius d , as shown in the diagram.



The ball reaches Q , the point at a distance d vertically above P , with speed v . At Q , the string is taut.

- (i) Show that $v^2 = 2g(5a - 2d)$.
(4 marks)
- (ii) Find, in terms of a , d , g and m , the tension in the string when the ball is at Q .
(4 marks)
- (iii) Hence show that $d < 2a$.
(2 marks)
- (c) State **one** modelling assumption used in this question.
(1 mark)

END OF QUESTIONS

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