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ADVANCED  
General Certificate of Education  
January 2014

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## Mathematics

Assessment Unit M2

*assessing*

Module M2: Mechanics 2

[AMM21]



TUESDAY 28 JANUARY, MORNING

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### TIME

1 hour 30 minutes.

### INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number on the Answer Booklet provided.

Answer **all seven** questions.

Show clearly the full development of your answers.

Answers should be given to three significant figures unless otherwise stated.

You are permitted to use a graphic or a scientific calculator in this paper.

### INFORMATION FOR CANDIDATES

The total mark for this paper is 75

Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

Answers should include diagrams where appropriate and marks may be awarded for them.

Take  $g = 9.8 \text{ m s}^{-2}$ , unless specified otherwise.

A copy of the **Mathematical Formulae and Tables booklet** is provided.

Throughout the paper the logarithmic notation used is  $\ln z$  where it is noted that  $\ln z \equiv \log_e z$

**Answer all seven questions.**

**Show clearly the full development of your answers.**

**Answers should be given to three significant figures unless otherwise stated.**

- 1** At time  $t = 0$  seconds, a particle of mass 2 kg is at rest at the origin.  
A constant force  $\mathbf{F}$  of magnitude 27 N acts on the particle in the direction of the vector  $\mathbf{d} = 4\mathbf{i} + 7\mathbf{j} - 4\mathbf{k}$

**(i)** Find the magnitude of  $\mathbf{d}$  [2]

**(ii)** Find  $\mathbf{F}$  [1]

**(iii)** Find the speed of the particle when  $t = 4$  [6]

- 2** A particle moves in a plane so that its position vector  $\mathbf{r}$  metres at time  $t$  seconds ( $t \geq 0$ ) is given by

$$\mathbf{r} = \begin{pmatrix} 4t^2 - 6t + 1 \\ 3t^2 + 4 \end{pmatrix}$$

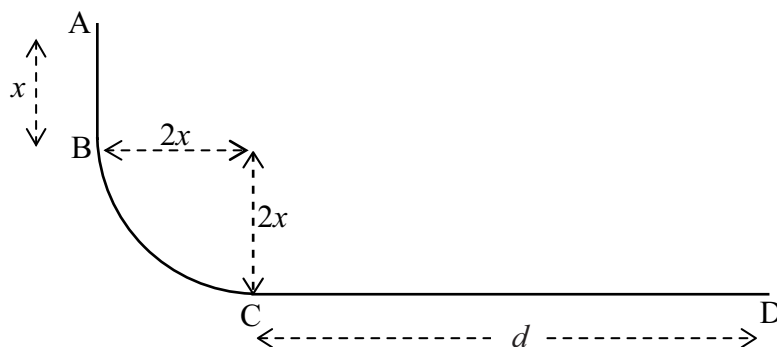
**(i)** Find an expression for the velocity of the particle at any time  $t$ . [3]

**(ii)** Find  $t$  when the particle is moving parallel to the vector  $\begin{pmatrix} 1 \\ 2 \end{pmatrix}$  [4]

**(iii)** Show that the acceleration of the particle is constant, and find its magnitude. [3]

- 3 A car of mass 1800 kg is travelling along a straight horizontal road.  
When the car is travelling at a speed of  $v \text{ m s}^{-1}$ , it experiences a resistance of  $42v$  newtons.
- (i) Find the power produced by the car's engine when the car is travelling at its maximum speed of  $45 \text{ m s}^{-1}$  [4]
- (ii) With the engine working at the same rate, find the acceleration of the car when its speed is  $35 \text{ m s}^{-1}$  [4]

- 4 **Fig. 1** below shows the cross section of a baggage chute composed of three sections, AB, BC and CD.  
AB is vertical and of length  $x$  metres.  
BC is a quarter circle of radius  $2x$  metres.  
CD is horizontal and of length  $d$  metres.  
AB and BC are smooth.  
CD is rough.



**Fig. 1**

A bag of mass  $m$  kg is released from rest at the point A and slides down the chute. Assume gravitational potential energy to be zero at C.

- (i) Find, in terms of  $g$ ,  $m$  and  $x$ , an expression for the potential energy of the bag at A. [2]

The coefficient of friction between the bag and CD is  $\mu$ .  
The bag comes to rest at the point D.

- (ii) Using the work–energy principle, or otherwise, find  $d$  in terms of  $\mu$  and  $x$ . [5]

- (iii) Find, in terms of  $g$  and  $x$ , the speed  $v \text{ m s}^{-1}$  of the bag when it is halfway along CD. [5]

- 5 A racing car of mass 1200 kg moves along a straight horizontal road. The engine of the car develops a constant power of 80 kW. The constant resistances to the motion of the car total 1600 N.

(i) Show that the acceleration of the car can be modelled by

$$\frac{200 - 4v}{3v}$$

where  $v \text{ ms}^{-1}$  is the velocity of the car at time  $t$  seconds. [4]

At  $t = 0$  seconds, the car is travelling at a speed of  $20 \text{ ms}^{-1}$

(ii) Find the time taken for the car to accelerate from  $20 \text{ ms}^{-1}$  to  $30 \text{ ms}^{-1}$  [11]

- 6 At time  $t = 0$  seconds, a missile is fired from a point O on horizontal ground with a velocity of  $u \text{ ms}^{-1}$  at an angle of  $\theta$  above the horizontal. When the missile is at a point P which is 200 m vertically above the ground, it has a velocity of  $50 \text{ ms}^{-1}$  at an angle of  $30^\circ$  above the horizontal, as shown in Fig. 2 below.

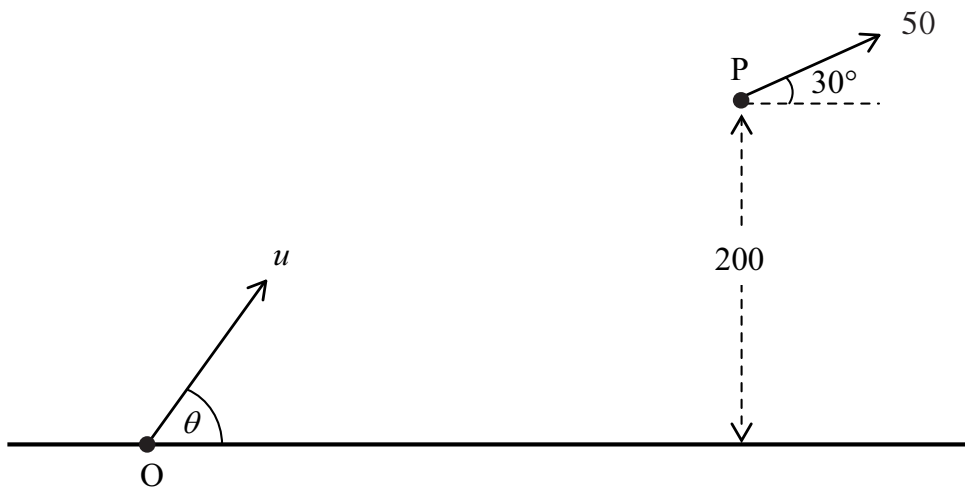


Fig. 2

(i) Find  $u$  and  $\theta$ . [7]

(ii) Hence, find the value of  $t$  at which the missile is 200 m vertically above the ground for the second time. [4]

(iii) State one modelling assumption you have made when answering this question. [1]

7 [Take  $g = 10 \text{ m s}^{-2}$  in this question]

One end of a light inextensible string of length 0.5 m is attached to the vertex, V, of a smooth right circular cone.

A particle P of mass 2 kg is attached to the other end.

P rotates as a conical pendulum in a horizontal circle of diameter 0.6 m on the smooth outer surface of the cone, as shown in Fig. 3 below.

The string remains parallel to the surface of the cone and P remains in contact with the cone at all times.

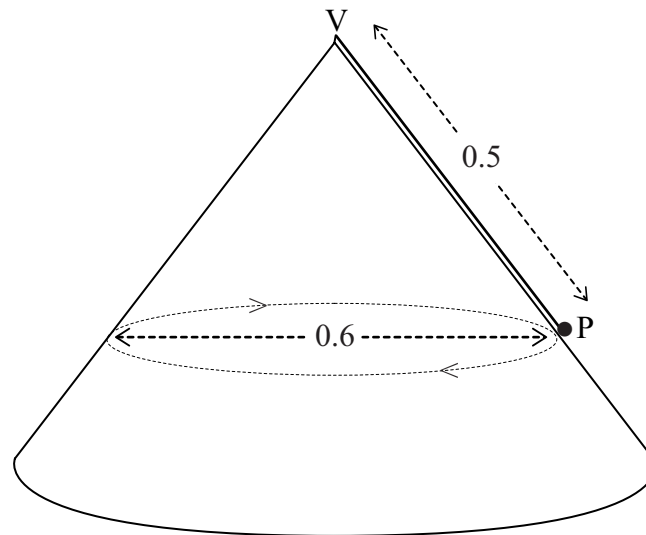


Fig. 3

- (i) Draw a diagram showing the external forces acting on P. [2]

P travels with an angular velocity of  $3 \text{ rad s}^{-1}$

- (ii) Find the tension in the string. [7]

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**THIS IS THE END OF THE QUESTION PAPER**

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