

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced Subsidiary General Certificate of Education  
Advanced General Certificate of Education

MEI STRUCTURED MATHEMATICS

4761

Mechanics 1

Friday

14 JANUARY 2005

Morning

1 hour 30 minutes

Additional materials:

Answer booklet

Graph paper

MEI Examination Formulae and Tables (MF2)

**TIME** 1 hour 30 minutes

**INSTRUCTIONS TO CANDIDATES**

- Write your name, centre number and candidate number in the spaces provided on the answer booklet.
- Answer **all** the questions.
- You are permitted to use a graphical calculator in this paper.

**INFORMATION FOR CANDIDATES**

- The number of marks is given in brackets [ ] at the end of each question or part question.
- You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used.
- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by  $g \text{ m s}^{-2}$ . Unless otherwise instructed, when a numerical value is needed, use  $g = 9.8$ .
- The total number of marks for this paper is 72.

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**This question paper consists of 5 printed pages and 3 blank pages.**

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## Section A (36 marks)

- 1 The position vector,  $\mathbf{r}$ , of a particle of mass 4 kg at time  $t$  is given by

$$\mathbf{r} = t^2 \mathbf{i} + (5t - 2t^2) \mathbf{j},$$

where  $\mathbf{i}$  and  $\mathbf{j}$  are the standard unit vectors, lengths are in metres and time is in seconds.

- (i) Find an expression for the acceleration of the particle. [4]

The particle is subject to a force  $\mathbf{F}$  and a force  $12\mathbf{j}$  N.

- (ii) Find  $\mathbf{F}$ . [3]

- 2 Particles of mass 2 kg and 4 kg are attached to the ends X and Y of a light, inextensible string. The string passes round fixed, smooth pulleys at P, Q and R, as shown in Fig. 2. The system is released from rest with the string taut.

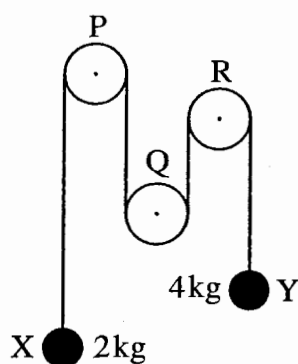


Fig. 2

- (i) State what information in the question tells you that
- (A) the tension is the same throughout the string,
- (B) the magnitudes of the accelerations of the particles at X and Y are the same. [2]

The tension in the string is  $T$  N and the magnitude of the acceleration of the particles is  $a$  m s<sup>-2</sup>.

- (ii) Draw a diagram showing the forces acting at X and a diagram showing the forces acting at Y. [1]
- (iii) Write down equations of motion for the particles at X and at Y. Hence calculate the values of  $T$  and  $a$ . [5]

3

- 3 A particle is in equilibrium when acted on by the forces  $\begin{pmatrix} x \\ -7 \\ z \end{pmatrix}$ ,  $\begin{pmatrix} 4 \\ y \\ -5 \end{pmatrix}$  and  $\begin{pmatrix} 5 \\ 4 \\ -7 \end{pmatrix}$ , where the units are newtons.

(i) Find the values of  $x$ ,  $y$  and  $z$ . [4]

(ii) Calculate the magnitude of  $\begin{pmatrix} 5 \\ 4 \\ -7 \end{pmatrix}$ . [2]

- 4 A particle is projected vertically upwards from a point O at  $21 \text{ ms}^{-1}$ .

(i) Calculate the greatest height reached by the particle. [2]

When this particle is at its highest point, a second particle is projected vertically upwards from O at  $15 \text{ ms}^{-1}$ .

(ii) Show that the particles collide 1.5 seconds later and determine the height above O at which the collision takes place. [6]

- 5 A small box B of weight  $400 \text{ N}$  is held in equilibrium by two light strings AB and BC. The string BC is fixed at C. The end A of string AB is fixed so that AB is at an angle  $\alpha$  to the vertical where  $\alpha < 60^\circ$ . String BC is at  $60^\circ$  to the vertical. This information is shown in Fig. 5.

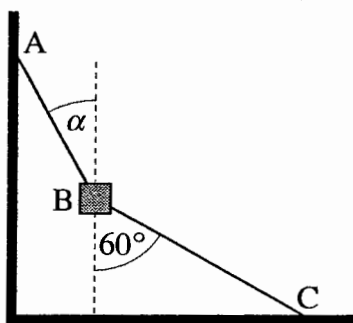


Fig. 5

(i) Draw a labelled diagram showing all the forces acting on the box. [1]

(ii) In one situation string AB is fixed so that  $\alpha = 30^\circ$ .

By drawing a triangle of forces, or otherwise, calculate the tension in the string BC and the tension in the string AB. [4]

(iii) Show carefully, but briefly, that the box cannot be in equilibrium if  $\alpha = 60^\circ$  and BC remains at  $60^\circ$  to the vertical. [2]

5

- 7 The trajectory ABCD of a small stone moving with negligible air resistance is shown in Fig. 7. AD is horizontal and BC is parallel to AD.

The stone is projected from A with speed  $40 \text{ m s}^{-1}$  at  $50^\circ$  to the horizontal.

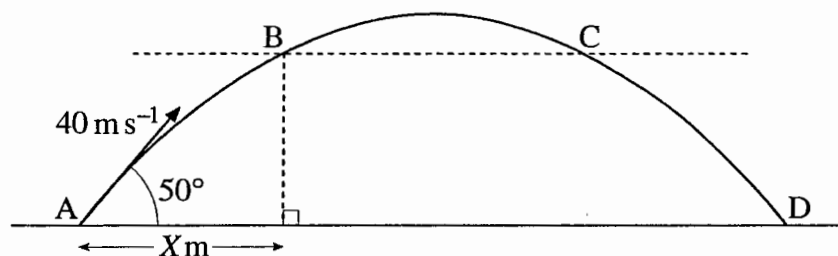


Fig. 7

- (i) Write down an expression for the horizontal displacement from A of the stone  $t$  seconds after projection. Write down also an expression for the vertical displacement at time  $t$ . [3]
- (ii) Show that the stone takes 6.253 seconds (to three decimal places) to travel from A to D. Calculate the range of the stone. [5]

You are given that  $X = 30$ .

- (iii) Calculate the time it takes the stone to reach B. Hence determine the time for it to travel from A to C. [4]
- (iv) Calculate the direction of the motion of the stone at C. [5]

## Section B (36 marks)

6 In this question take  $g$  as  $10 \text{ m s}^{-2}$ .

A small ball is released from rest. It falls for 2 seconds and is then brought to rest over the next 5 seconds. This motion is modelled in the speed-time graph Fig. 6.

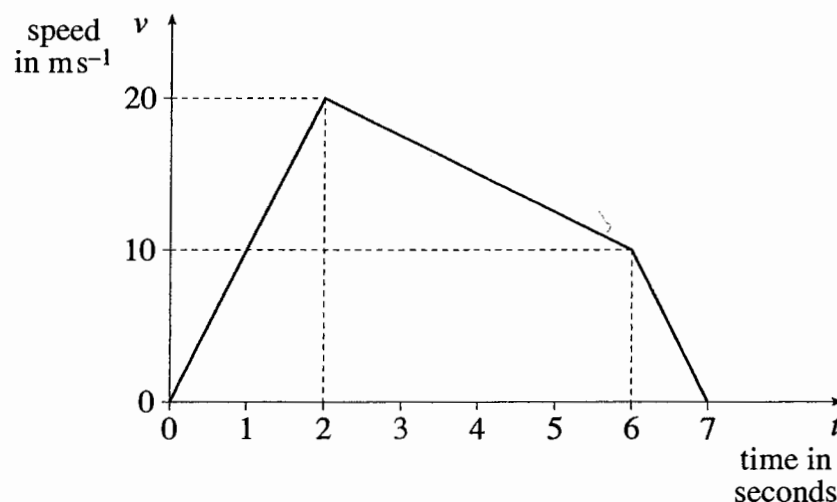


Fig. 6

For this model,

- (i) calculate the distance fallen from  $t = 0$  to  $t = 7$ , [3]
- (ii) find the acceleration of the ball from  $t = 2$  to  $t = 6$ , specifying the direction, [3]
- (iii) obtain an expression in terms of  $t$  for the downward speed of the ball from  $t = 2$  to  $t = 6$ , [3]
- (iv) state the assumption that has been made about the resistance to motion from  $t = 0$  to  $t = 2$ . [1]

The part of the motion from  $t = 2$  to  $t = 7$  is now modelled by  $v = -\frac{3}{2}t^2 + \frac{19}{2}t + 7$ .

- (v) Verify that  $v$  agrees with the values given in Fig. 6 at  $t = 2$ ,  $t = 6$  and  $t = 7$ . [2]
- (vi) Calculate the distance fallen from  $t = 2$  to  $t = 7$  according to this model. [7]