

**OXFORD CAMBRIDGE AND RSA EXAMINATIONS**

**Advanced Subsidiary General Certificate of Education  
Advanced General Certificate of Education**

**MEI STRUCTURED MATHEMATICS**

**4761**

**Mechanics 1**

Tuesday

**7 JUNE 2005**

Afternoon

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.**

## Section A (36 marks)

- 1 A particle travels along a straight line. Its *acceleration* during the time interval  $0 \leq t \leq 8$  is given by the acceleration–time graph in Fig. 1.

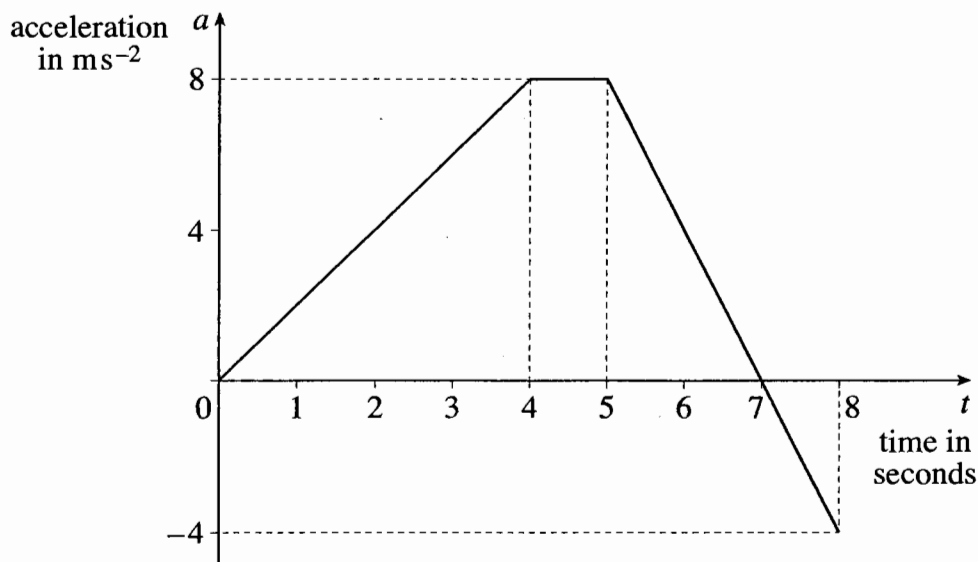


Fig. 1

- (i) Write down the acceleration of the particle when  $t = 4$ . Given that the particle starts from rest, find its speed when  $t = 4$ . [2]
- (ii) Write down an expression in terms of  $t$  for the acceleration,  $a \text{ ms}^{-2}$ , of the particle in the time interval  $0 \leq t \leq 4$ . [1]
- (iii) Without calculation, state the time at which the *speed* of the particle is greatest. Give a reason for your answer. [2]
- (iv) Calculate the change in speed of the particle from  $t = 5$  to  $t = 8$ , indicating whether this is an increase or a decrease. [3]
- 2 A particle moves along the  $x$ -axis with velocity,  $v \text{ m s}^{-1}$ , at time  $t$  given by

$$v = 24t - 6t^2.$$

The positive direction is in the sense of  $x$  increasing.

- (i) Find an expression for the acceleration of the particle at time  $t$ . [2]
- (ii) Find the times,  $t_1$  and  $t_2$ , at which the particle has zero speed. [2]
- (iii) Find the distance travelled between the times  $t_1$  and  $t_2$ . [4]

- 3 A particle rests on a smooth, horizontal plane. Horizontal unit vectors  $\mathbf{i}$  and  $\mathbf{j}$  lie in this plane. The particle is in equilibrium under the action of the three forces  $(-3\mathbf{i} + 4\mathbf{j})\text{ N}$  and  $(21\mathbf{i} - 7\mathbf{j})\text{ N}$  and  $\mathbf{R}\text{ N}$ .

(i) Write down an expression for  $\mathbf{R}$  in terms of  $\mathbf{i}$  and  $\mathbf{j}$ . [2]

(ii) Find the magnitude of  $\mathbf{R}$  and the angle between  $\mathbf{R}$  and the  $\mathbf{i}$  direction. [4]

- 4 A block of mass 4 kg is in equilibrium on a rough plane inclined at  $60^\circ$  to the horizontal, as shown in Fig. 4. A frictional force of 10 N acts up the plane and a vertical string AB attached to the block is in tension.

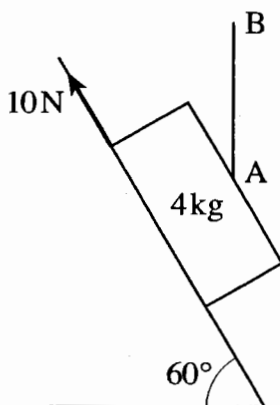


Fig. 4

(i) Draw a diagram showing the four forces acting on the block. [1]

(ii) By considering the components of the forces parallel to the slope, calculate the tension in the string. [3]

(iii) Calculate the normal reaction of the plane on the block. [3]

- 5 The position vector of a particle at time  $t$  is given by

$$\mathbf{r} = \frac{1}{2}t\mathbf{i} + (t^2 - 1)\mathbf{j},$$

referred to an origin  $O$  where  $\mathbf{i}$  and  $\mathbf{j}$  are the standard unit vectors in the directions of the cartesian axes  $Ox$  and  $Oy$  respectively.

(i) Write down the value of  $t$  for which the  $x$ -coordinate of the position of the particle is 2. Find the  $y$ -coordinate at this time. [2]

(ii) Show that the cartesian equation of the path of the particle is  $y = 4x^2 - 1$ . [2]

(iii) Find the coordinates of the point where the particle is moving at  $45^\circ$  to both  $Ox$  and  $Oy$ . [3]

## Section B (36 marks)

- 6 A car of mass 1000 kg is travelling along a straight, level road.

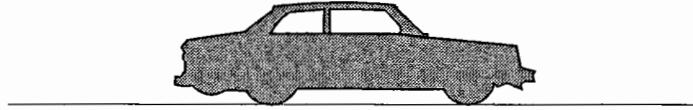


Fig. 6.1

- (i) Calculate the acceleration of the car when a resultant force of 2000 N acts on it in the direction of its motion.

How long does it take the car to increase its speed from  $5 \text{ ms}^{-1}$  to  $12.5 \text{ ms}^{-1}$ ? [3]

The car has an acceleration of  $1.4 \text{ ms}^{-2}$  when there is a driving force of 2000 N.

- (ii) Show that the resistance to motion of the car is 600 N. [2]

A trailer is now attached to the car, as shown in Fig. 6.2. The car still has a driving force of 2000 N and resistance to motion of 600 N. The trailer has a mass of 800 kg. The tow-bar connecting the car and the trailer is light and horizontal. The car and trailer are accelerating at  $0.7 \text{ ms}^{-2}$ .

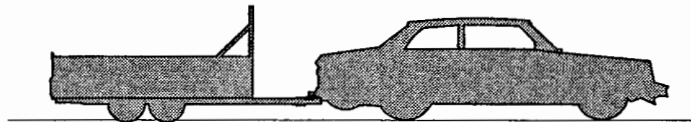


Fig. 6.2

- (iii) Show that the resistance to the motion of the trailer is 140 N. [3]

- (iv) Calculate the force in the tow-bar. [3]

The driving force is now removed and a braking force of 610 N is applied to the car. All the resistances to motion remain as before. The trailer has no brakes.

- (v) Calculate the new acceleration. Calculate also the force in the tow-bar, stating whether it is a tension or a thrust (compression). [6]

7 In this question take the value of  $g$  to be  $10 \text{ m s}^{-2}$ .

A particle A is projected over horizontal ground from a point P which is 9 m above a point O on the ground. The initial velocity has horizontal and vertical components of  $10 \text{ m s}^{-1}$  and  $12 \text{ m s}^{-1}$  respectively, as shown in Fig. 7. The trajectory of the particle meets the ground at X. Air resistance may be neglected.

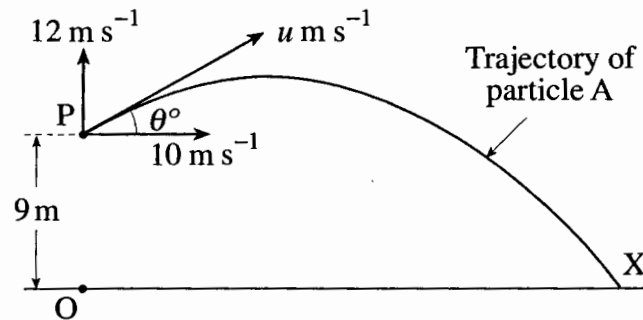


Fig. 7

- (i) Calculate the speed of projection  $u \text{ m s}^{-1}$  and the angle of projection  $\theta^\circ$ . [3]
- (ii) Show that,  $t$  seconds after projection, the height of particle A above the ground is  $9 + 12t - 5t^2$ . Write down an expression in terms of  $t$  for the horizontal distance of the particle from O at this time. [4]
- (iii) Calculate the maximum height of particle A above the point of projection. [2]
- (iv) Calculate the distance OX. [4]

A second particle, B, is projected from O with speed  $20 \text{ m s}^{-1}$  at  $60^\circ$  to the horizontal. The trajectories of A and B are in the same vertical plane. Particles A and B are projected at the same time.

- (v) Show that the horizontal displacements of A and B are always equal. [2]
- (vi) Show that,  $t$  seconds after projection, the height of particle B above the ground is  $10\sqrt{3}t - 5t^2$ . [1]
- (vii) Show that the particles collide 1.7 seconds after projection (correct to two significant figures). [3]