OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE **4762/01**

MATHEMATICS (MEI)

Mechanics 2

THURSDAY 17 JANUARY 2008 Afternoon

Time: 1 hour 30 minutes

Additional materials: Answer Booklet (8 pages)
Graph paper
MEI Examination Formulae and Tables (MF2)

INSTRUCTIONS TO CANDIDATES

- Write your name in capital letters, your Centre Number and Candidate Number in the spaces provided on the Answer Booklet.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Answer **all** the questions.
- You are permitted to use a graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by $g\,\mathrm{m\,s^{-2}}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is 72.
- 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.

This document consists of **6** printed pages and **2** blank pages.

1 **(a)** A battering-ram consists of a wooden beam fixed to a trolley. The battering-ram runs along horizontal ground and collides directly with a vertical wall, as shown in Fig. 1.1. The battering-ram has a mass of 4000 kg.

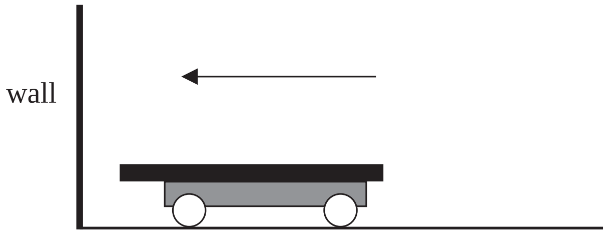

Fig. 1.1

Initially the battering-ram is at rest. Some men push it for 8 seconds and let go just as it is about to hit the wall. While the battering-ram is being pushed, the constant overall force on it in the direction of its motion is 1500 N.

(i) At what speed does the battering-ram hit the wall? [3]

The battering-ram hits a loose stone block of mass 500 kg in the wall. Linear momentum is conserved and the coefficient of restitution in the impact is 0.2.

(ii) Calculate the speeds of the stone block and of the battering-ram immediately after the impact. [6]

(iii) Calculate the energy lost in the impact. [3]

(b) Small objects A and B are sliding on smooth, horizontal ice. Object A has mass 4 kg and speed 18 m s^{-1} in the **i** direction. B has mass 8 kg and speed 9 m s^{-1} in the direction shown in Fig. 1.2, where **i** and **j** are the standard unit vectors.

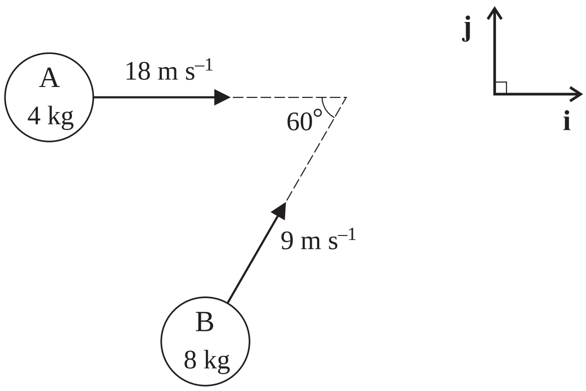

Fig. 1.2

(i) Write down the linear momentum of A and show that the linear momentum of B is $(36\mathbf{i} + 36\sqrt{3}\,\mathbf{j})$ N s. [2]

After the objects meet they stick together (coalesce) and move with a common velocity of $(u\mathbf{i} + v\mathbf{j})\text{ m s}^{-1}$.

(ii) Calculate u and v. [3]

(iii) Find the angle between the direction of motion of the combined object and the **i** direction. Make your method clear. [2]

2 A cyclist and her bicycle have a combined mass of 80 kg.

(i) Initially, the cyclist accelerates from rest to $3\,\mathrm{m\,s^{-1}}$ against negligible resistances along a horizontal road.

(A) How much energy is gained by the cyclist and bicycle? [2]

(B) The cyclist travels 12 m during this acceleration. What is the average driving force on the bicycle? [2]

(ii) While exerting no driving force, the cyclist free-wheels down a hill. Her speed increases from $4\,\mathrm{m\,s^{-1}}$ to $10\,\mathrm{m\,s^{-1}}$. During this motion, the total work done against friction is 1600 J and the drop in vertical height is h m.

Without assuming that the hill is uniform in either its angle or roughness, calculate h. [5]

(iii) The cyclist reaches another horizontal stretch of road and there is now a constant resistance to motion of 40 N.

(A) When the power of the driving force on the bicycle is a constant 200 W, what constant speed can the cyclist maintain? [3]

(B) Find the power of the driving force on the bicycle when travelling at a speed of $0.5\,\mathrm{m\,s^{-1}}$ with an acceleration of $2\,\mathrm{m\,s^{-2}}$. [5]

3

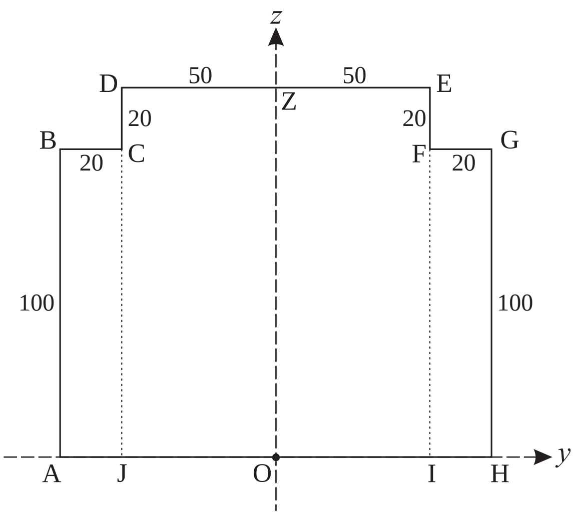

Fig. 3.1

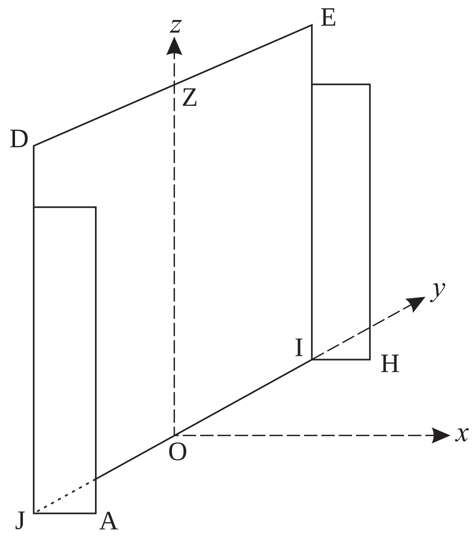

Fig. 3.2

A lamina is made from uniform material in the shape shown in Fig. 3.1. BCJA, DZOJ, ZEIO and FGHI are all rectangles. The lengths of the sides are shown in centimetres.

(i) Find the coordinates of the centre of mass of the lamina, referred to the axes shown in Fig. 3.1. [5]

The rectangles BCJA and FGHI are folded through 90° about the lines CJ and FI respectively to give the fire-screen shown in Fig. 3.2.

(ii) Show that the coordinates of the centre of mass of the fire-screen, referred to the axes shown in Fig. 3.2, are (2.5, 0, 57.5). [4]

The x- and y-axes are in a horizontal floor. The fire-screen has a weight of 72 N. A horizontal force P N is applied to the fire-screen at the point Z. This force is perpendicular to the line DE in the **positive** x direction. The fire-screen is on the point of tipping about the line AH.

(iii) Calculate the value of P. [5]

The coefficient of friction between the fire-screen and the floor is μ.

(iv) For what values of μ does the fire-screen slide before it tips? [4]

4 Fig. 4.1 shows a uniform beam, CE, of weight 2200 N and length 4.5 m. The beam is freely pivoted on a fixed support at D and is supported at C. The distance CD is 2.75 m.

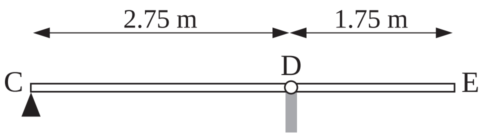

Fig. 4.1

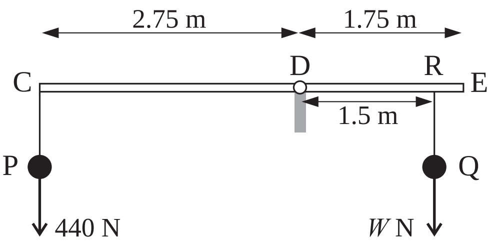

Fig. 4.2

The beam is horizontal and in equilibrium.

(i) Show that the anticlockwise moment of the weight of the beam about D is 1100 N m.

Find the value of the normal reaction on the beam of the support at C. [6]

The support at C is removed and spheres at P and Q are suspended from the beam by light strings attached to the points C and R. The sphere at P has weight 440 N and the sphere at Q has weight W N. The point R of the beam is 1.5 m from D. This situation is shown in Fig. 4.2.

(ii) The beam is horizontal and in equilibrium. Show that $W = 1540$. [3]

The sphere at P is changed for a lighter one with weight 400 N. The sphere at Q is unchanged. The beam is now held in equilibrium at an angle of 20° to the horizontal by means of a light rope attached to the beam at E. This situation (but without the rope at E) is shown in Fig. 4.3.

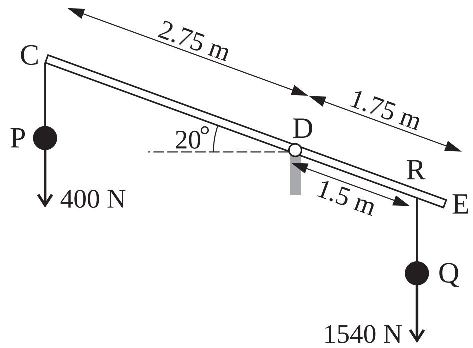

Fig. 4.3

(iii) Calculate the tension in the rope when it is

(A) at 90° to the beam, [6]

(B) horizontal. [3]

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