

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

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

MEI STRUCTURED MATHEMATICS

4762

Mechanics 2

Friday **27 JANUARY 2006** Afternoon 1 hour 30 minutes

Additional materials:
8 page 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.
- 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 $g = 9.8$.

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.
- The total number of marks for this paper is 72.

This question paper consists of 6 printed pages and 2 blank pages.

- 1 When a stationary firework P of mass 0.4 kg is set off, the explosion gives it an instantaneous impulse of 16 N s vertically upwards.

(i) Calculate the speed of projection of P. [2]

While travelling vertically upwards at 32 m s^{-1} , P collides directly with another firework Q, of mass 0.6 kg, that is moving directly downwards with speed $u \text{ m s}^{-1}$, as shown in Fig. 1. The coefficient of restitution in the collision is 0.1 and Q has a speed of 4 m s^{-1} vertically *upwards* immediately after the collision.

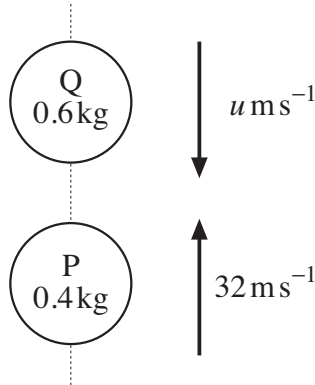


Fig. 1

- (ii) Show that $u = 18$ and calculate the speed and direction of motion of P immediately after the collision. [7]

Another firework of mass 0.5 kg has a velocity of $(-3.6\mathbf{i} + 5.2\mathbf{j}) \text{ m s}^{-1}$, where \mathbf{i} and \mathbf{j} are horizontal and vertical unit vectors, respectively. This firework explodes into two parts, C and D. Part C has mass 0.2 kg and velocity $(3\mathbf{i} + 4\mathbf{j}) \text{ m s}^{-1}$ immediately after the explosion.

- (iii) Calculate the velocity of D immediately after the explosion in the form $a\mathbf{i} + b\mathbf{j}$. Show that C and D move off at 90° to one another. [8]

- 2 A uniform beam, AB, is 6 m long and has a weight of 240 N.

Initially, the beam is in equilibrium on two supports at C and D, as shown in Fig. 2.1. The beam is horizontal.

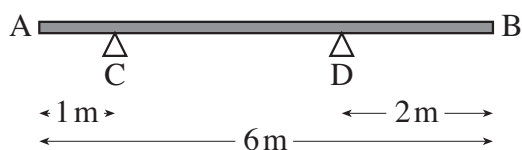


Fig. 2.1

- (i) Calculate the forces acting on the beam from the supports at C and D. [4]

A workman tries to move the beam by applying a force T N at A at 40° to the beam, as shown in Fig. 2.2. The beam remains in horizontal equilibrium but the reaction of support C on the beam is zero.

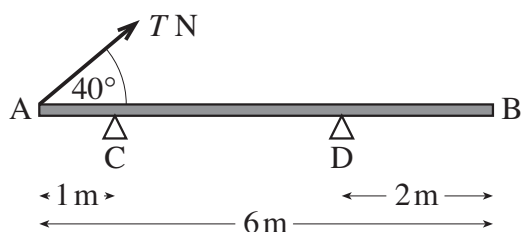


Fig. 2.2

- (ii) (A) Calculate the value of T . [4]
 (B) Explain why the support at D cannot be smooth. [1]

The beam is now supported by a light rope attached to the beam at A, with B on rough, horizontal ground. The rope is at 90° to the beam and the beam is at 30° to the horizontal, as shown in Fig. 2.3. The tension in the rope is P N. The beam is in equilibrium on the point of sliding.

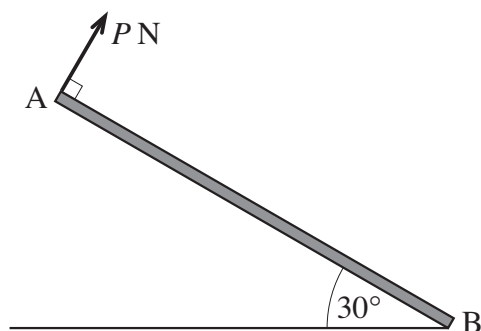


Fig. 2.3

- (iii) (A) Show that $P = 60\sqrt{3}$ and hence, or otherwise, find the frictional force between the beam and the ground. [5]
 (B) Calculate the coefficient of friction between the beam and the ground. [5]

- 3 (a) A uniform lamina made from rectangular parts is shown in Fig. 3.1. All the dimensions are centimetres. All coordinates are referred to the axes shown in Fig. 3.1.

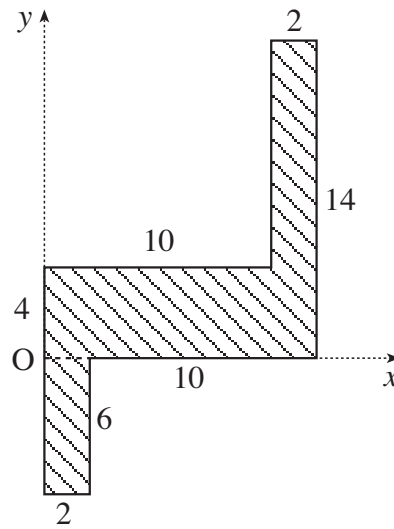


Fig. 3.1

- (i) Show that the x -coordinate of the centre of mass of the lamina is 6.5 and find the y -coordinate. [5]

A square of side 2 cm is to be cut from the lamina. The sides of the square are to be parallel to the coordinate axes and the centre of the square is to be chosen so that the x -coordinate of the centre of mass of the new shape is 6.4.

- (ii) Calculate the x -coordinate of the centre of the square to be removed. [3]

The y -coordinate of the centre of the square to be removed is now chosen so that the y -coordinate of the centre of mass of the final shape is as large as possible.

- (iii) Calculate the y -coordinate of the centre of mass of the lamina with the square removed, giving your answer correct to three significant figures. [3]

- (b) Fig. 3.2 shows a framework made from light rods of length 2m freely pin-jointed at A, B, C, D and E. The framework is in a vertical plane and is supported at A and C. There are loads of 120 N at B and at E. The force on the framework due to the support at A is R N.

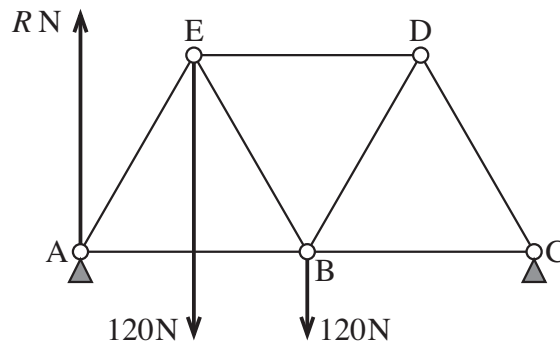


Fig. 3.2

- (i) Show that $R = 150$. [2]
- (ii) Draw a diagram showing all the forces acting at the points A, B, D and E, including the forces internal to the rods. Calculate the internal forces in rods AE and EB, and determine whether each is a tension or a thrust. [You may leave your answers in surd form.] [6]
- (iii) Without any further calculation of the forces in the rods, explain briefly how you can tell that rod ED is in thrust. [1]

[Question 4 is printed overleaf.]

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- 4 A block of mass 20 kg is pulled by a light, horizontal string over a rough, horizontal plane. During 6 seconds, the work done against resistances is 510 J and the speed of the block increases from 5 m s^{-1} to 8 m s^{-1} .

(i) Calculate the power of the pulling force. [4]

The block is now put on a rough plane that is at an angle α to the horizontal, where $\sin \alpha = \frac{3}{5}$. The frictional resistance to sliding is $11g \text{ N}$. A light string parallel to the plane is connected to the block. The string passes over a smooth pulley and is connected to a freely hanging sphere of mass $m \text{ kg}$, as shown in Fig. 4.

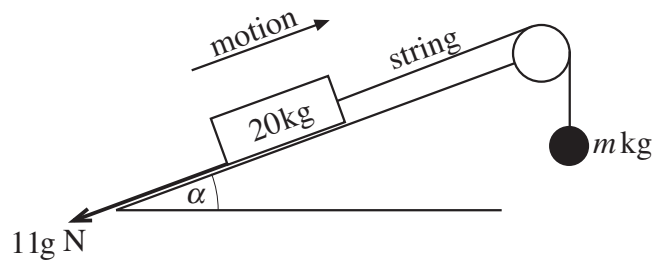


Fig. 4

In parts (ii) and (iii), the sphere is pulled downwards and then released when travelling at a speed of 4 m s^{-1} vertically downwards. The block never reaches the pulley.

- (ii) Suppose that $m = 5$ and that after the sphere is released the block moves $x \text{ m}$ up the plane before coming to rest.
- (A) Find an expression in terms of x for the change in gravitational potential energy of the system, stating whether this is a gain or a loss. [4]
- (B) Find an expression in terms of x for the work done against friction. [1]
- (C) Making use of your answers to parts (A) and (B), find the value of x . [3]
- (iii) Suppose instead that $m = 15$. Calculate the speed of the sphere when it has fallen a distance 0.5 m from its point of release. [4]