OXFORD CAMBRIDGE AND RSA EXAMINATIONS

A2 GCE

4762

MATHEMATICS (MEI)

Mechanics 2

QUESTION PAPER

FRIDAY 13 JANUARY 2012: Morning
DURATION: 1 hour 30 minutes

SUITABLE FOR VISUALLY IMPAIRED CANDIDATES

Candidates answer on the Printed Answer Book or any suitable paper provided by the centre. The Printed Answer Book may be enlarged by the centre.

OCR SUPPLIED MATERIALS:

Printed Answer Book 4762
MEI Examination Formulae and Tables (MF2)

OTHER MATERIALS REQUIRED:

Scientific or graphical calculator
Model for use in question 2

READ INSTRUCTIONS OVERLEAF

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INSTRUCTIONS TO CANDIDATES

These instructions are the same on the Printed Answer Book and the Question Paper.

- **The Question Paper will be found in the centre of the Printed Answer Book.**
- **Candidates answer on the Printed Answer Book or any suitable paper provided by the centre. The Printed Answer Book may be enlarged by the centre.**
- **Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).**
- **Use black ink. HB pencil may be used for graphs and diagrams only.**
- **Answer ALL the questions.**
- **Read each question carefully. Make sure you know what you have to do before starting your answer.**
- **You are permitted to use a scientific or 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

This information is the same on the Printed Answer Book and the Question Paper.

- **The number of marks is given in brackets [ ] at the end of each question or part question on the Question Paper.**
- **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.**

1 **A bus of mass 8 tonnes is driven up a hill on a straight road. On one part of the hill, the power of the driving force on the bus is constant at 20 kW for one minute.**

(i) Calculate how much work is done by the driving force in this time. [2]

During this minute the speed of the bus increases from $8\,\mathrm{m\,s^{-1}}$ to $12\,\mathrm{m\,s^{-1}}$ and, in addition to the work done against gravity, 125 000 J of work is done against the resistance to motion of the bus parallel to the slope.

(ii) Calculate the change in the kinetic energy of the bus. [3]

(iii) Calculate the vertical displacement of the bus. [4]

On another stretch of the road, a driving force of power 26 kW is required to propel the bus up a slope of angle θ to the horizontal at a constant speed of $6.5\,\mathrm{m\,s^{-1}}$, against a resistance to motion of 225 N parallel to the slope.

(iv) Calculate the angle θ. [6]

The bus later travels up the same slope of angle θ to the horizontal at the same constant speed of $6.5\,\mathrm{m\,s^{-1}}$ but now against a resistance to motion of 155 N parallel to the slope.

(v) Calculate the power of the driving force on the bus. [2]

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2 **The shape shown in Fig. 2.1 is cut from a sheet of thin rigid uniform metal; LBCK and EFHI are rectangles; EF is perpendicular to CK. The dimensions shown in the figure are in centimetres. The O*y* and O*z* axes are also shown.**

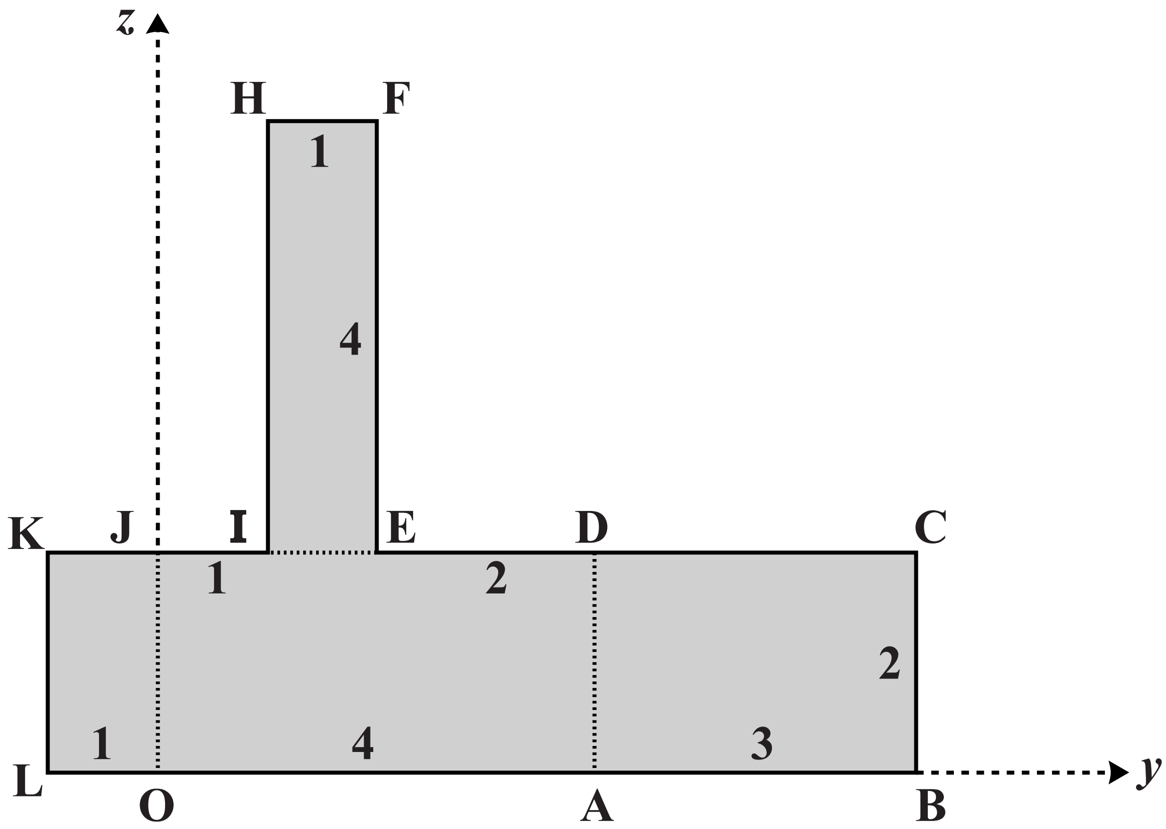

Fig. 2.1

(i) **Calculate the coordinates of the centre of mass of the metal shape referred to the axes shown in Fig. 2.1. [4]**

The metal shape is freely suspended from the point H and hangs in equilibrium.

(ii) **Calculate the angle that HI makes with the vertical. [4]**

The metal shape is now folded along OJ, AD and EI to give the object shown in Fig. 2.2 below, a model of this folded shape is also provided; LOJK, ABCD and IEFH are all perpendicular to OADJ; LOJK and ABCD are on one side of OADJ and IEFH is on the other side of it.

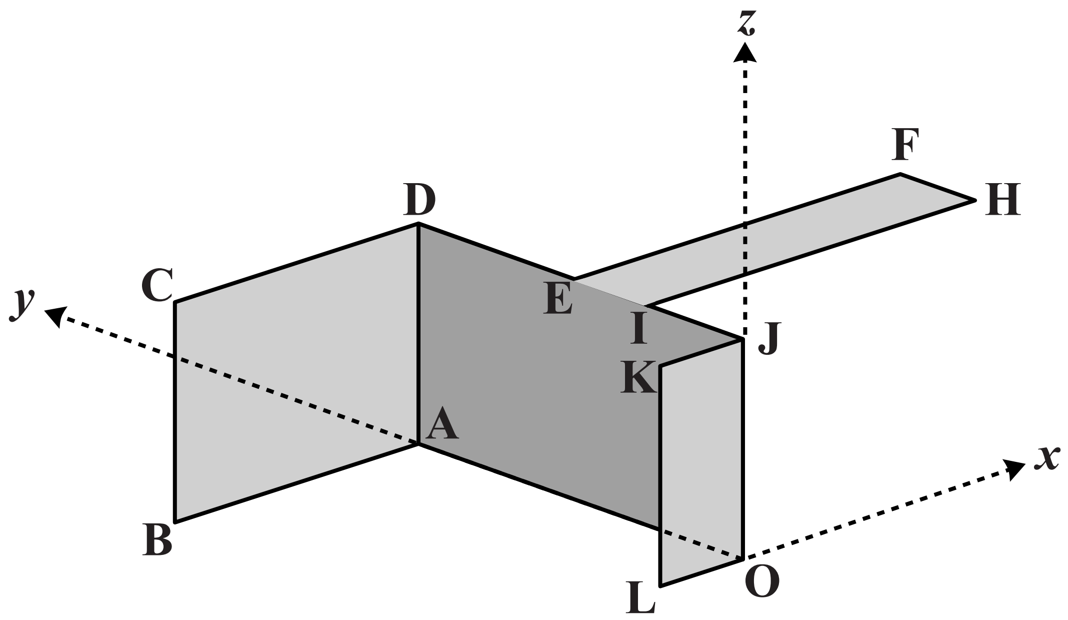

Fig. 2.2

(iii) Referred to the axes shown in Fig. 2.2, show that the *x*-coordinate of the centre of mass of the object is –0.1 and find the other two coordinates of the centre of mass. [6]

The object is placed on a rough inclined plane with LOAB in contact with the plane. OL is parallel to a line of greatest slope of the plane with L higher than O. The object does not slip but is on the point of tipping about the edge OA.

(iv) Calculate the angle of OL to the horizontal. [4]

3 **A thin rigid non-uniform beam AB of length 6 m has weight 800 N. Its centre of mass, G, is 2 m from B.**

Initially the beam is horizontal and in equilibrium when supported by a small round peg at C, 1 m from A, and a light vertical wire at B. This situation is shown in Fig. 3.1 below where the lengths are in metres.

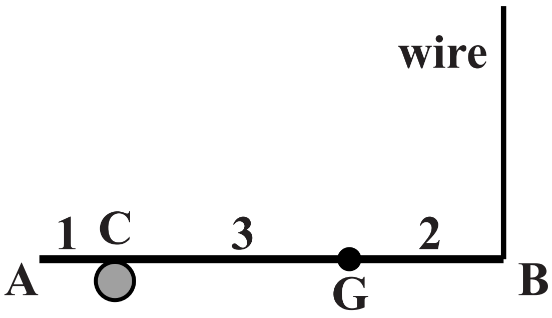

Fig. 3.1

(i) Calculate the tension in the wire and the normal reaction of the peg on the beam. [4]

The beam is now held horizontal and in equilibrium with the wire at 70° to the horizontal, as shown in Fig. 3.2 below. The peg at C is rough and still supports the beam 1 m from A. The beam is on the point of slipping.

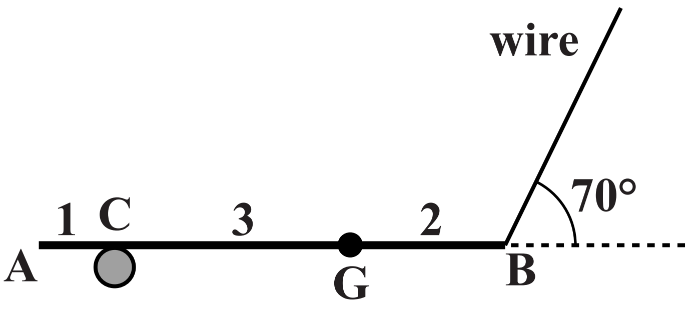

Fig. 3.2

(ii) Calculate the new tension in the wire.

Calculate also the coefficient of friction between the peg and the beam. [7]

The beam is now held in equilibrium at 30° to the vertical with the wire at θ° to the beam, as shown in Fig. 3.3 below. A new small SMOOTH peg now makes contact with the beam at C, still 1 m from A. The tension in the wire is now T N.

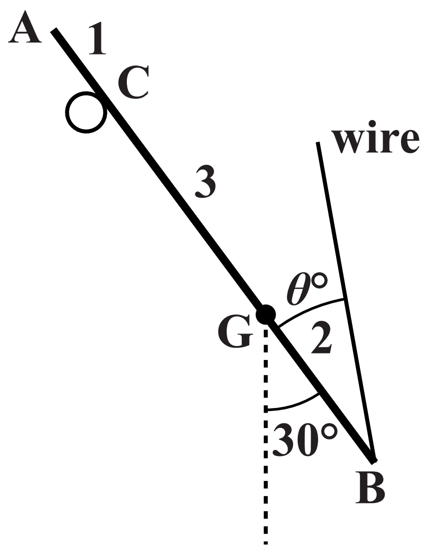

Fig. 3.3

(iii) By taking moments about C, resolving in a suitable direction and obtaining two equations in terms of θ and T, or otherwise, calculate θ and T. [7]

4 (a) A large nail of mass 0.02 kg has been driven a short distance horizontally into a fixed block of wood, as shown in Fig. 4.1 below, and is to be driven horizontally further into the block. The wood produces a constant resistance of 2.43 N to the motion of the nail. The situation is modelled by assuming that linear momentum is conserved when the nail is struck, that all the impacts with the nail are direct and that the head of the nail never reaches the wood.

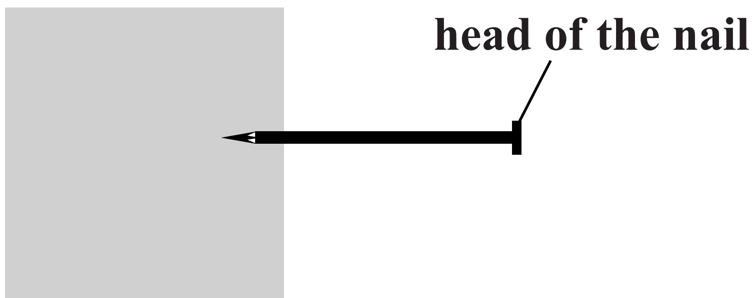

Fig. 4.1

The nail is first struck by an object of mass 0.1 kg that is moving parallel to the nail with linear momentum of magnitude 0.108 N s. The object becomes firmly attached to the nail.

(i) Calculate the speed of the nail and object immediately after the impact. [2]

(ii) Calculate the time for which the nail and object move, and the distance they travel in that time. [4]

On a second attempt to drive in the nail, it is struck by the same object of mass 0.1 kg moving parallel to the nail with the same linear momentum of magnitude 0.108 N s. This time the object does not become attached to the nail and after the contact is still moving parallel to the nail. The coefficient of restitution in the impact is $\frac{1}{3}$.

(iii) Calculate the speed of the nail immediately after this impact. [6]

(b) A small ball slides on a smooth horizontal plane and bounces off a smooth straight vertical wall. The speed of the ball is *u* before the impact and, as shown in Fig. 4.2 below, the impact turns the path of the ball through 90°. The coefficient of restitution in the collision between the ball and the wall is *e*. Before the collision, the path is inclined at *α* to the wall.

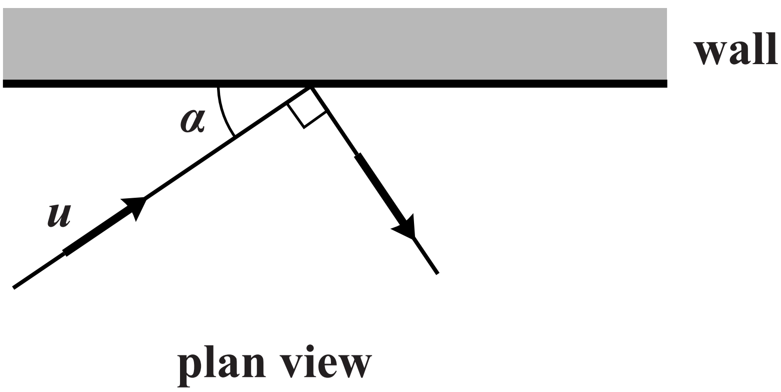

Fig. 4.2

(i) Write down, in terms of *u*, *e* and *α*, the components of the velocity of the ball parallel and perpendicular to the wall before and after the impact. [3]

(ii) Show that $\tan \alpha = \frac{1}{\sqrt{e}}$**. [3]**

(iii) Hence show that $\alpha \geqslant 45°$**. [1]**